Process, Substance and Irreversibility

— some problems involved in metaphysical interpretations of thermodynamics

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Niels Viggo Hansen, Dept. of Information and Media Science, Univ. of Aarhus, Denmark.

... like every gambler looking for a card that was so
high and wild
he'd never need another game of poker.
Leonard Cohen: Stranger.

Scientific and technological developments have provided a rich source of inspiration for the inventive production of speculative metaphysics and made possible important shifts and metamorphoses in the most general features of the way things are grasped and handled and the way experiences are organized. One of the most amazing and implication-rich structures to emerge is the idea of "time's arrow".

It has become easy to think of time as pure and independent of the particularities of specific events, rhythms or clocks. This idea, now part of what is frequently stated as common sense, was once something that it took quite an effort to produce. A justly famous meditative exercise designed to bring about this imaginative stunt is Chapter 11 of St. Augustine's *Confessions*. Talking to God in his heart, Augustine imagines first the halting of all celestial movements, then the halting of all earthly movements such as that of the potter's wheel, then the silencing of voices — and by analogy, just as he can imagine the halting of any specific process, he finally arrives at the imagination of the halting of them all, proving that time does not necessarily imply movement or change. Of course, in Augustine's version of the exercise there is still the implicit ongoing dialogue between worldly and divine, the stream of consciousness, to keep a sort of transcendental movement running: "What are we doing when we measure silence, and say that this silence has lasted as long as that voice lasts"? This could be criticized as a kind of fault or cheating, inasmuch as the task was to imagine time without any process going on whatsoever, including "measuring the silence", but it is more interesting to see it in an affirmative light, as Mircea Eliade[1] did: as expressing an intensification of mental powers made possible by the extreme

[1]) M. Eliade: *Myth of the Eternal Return*, Princeton U.P. 1971

tension of Christian religious faith. According to Eliade, without this tension probably noone would ever have found the courage to begin thinking of time as something different from omnipresent processes incarnating the Holy in cycles of myth and ritual. Something *out of joint*[2] in Prince Hamlet's words.

A short story by Borges[3] shows how much easier this metaphysical excercise has become. The hero is an author imprisoned and convicted to death while in the process of writing a masterpiece novel. We meet him in the seconds just before his execution, praying to be allowed to finish the novel. Then, the entire furniture of the world freezes in an instant, the bullet hovering mid-air half way through the trajectory from gun to head. No gradual grinding to a halt of one thing after the other is relied upon here, to produce the idea; it is sufficient for Borges to refer to one abstract act of suspending the passage of all-pervading time, with simultaneous and perfectly abrupt effect — as if everything was already wired up to one central power supply, or "movement supply" perhaps. Furthermore, obviously noone will notice the difference when the transcendental start button is pressed and the entire mechanism set in motion again, just as abruptly. Noone except our hero, of course, who was granted the boon of just the sufficient amount of working time — in a compartment of pure thought, generating and memorizing the greatest of novels — and who will be dead a split second later, a split second of "real time" of course, to keep records clean. As so often in Borges, the resulting vision is one of enormous potentials of beauty, insight and power existing millimetres beside the track of ordinary life — out of reach except by violent ruptures or chance stumblings.

I take it to be an uncontroversial observation that the more or less joint developments of mechanics and clocks have helped tremendously in making pure time so much more readily conceivable. The well distributed network of well tuned and well adjusted clocks has made a virtually tangible everyday object out of the idea of the perfect time, the objective truth of what time it is, according to which clocks ought to be set. Of course time has acquired an object-like character also in the important sense that clock time has become a commodity: working hours bought and sold, usually on more profane accounts than the exchange described by Borges, at least as far as you and I would know. Theoretical mechanics, then, with its ever more generalized tools for calculating predictions and coordinating control in all kinds of local particular cases and projects, provides with truly cosmic greatness, ranging from elementary particles to galaxy

[2]) Shakespeare: *Hamlet*, Act 1, scene 4: "The time is out of joint". Clearly Hamlet is not referring to abstract pure time but to a historical state of affairs. However, Hamlet captures very well the kind of tragedy and tension that violently breaks open the old cycles of homeliness.

[3]) J.L. Borges: "The Secret Miracle", *Labyrinths: Selected Stories and other Writings*, 1988

superclusters, the speculative vision of the standardized and universally applicable parameter *t* as just the kind of singular handle of world mechanism that Borges refers to. For now, let us not blur this glory with discussions of the technical problems of unifying and extending parameters of time, although they are of great metaphysical import too — we will discuss some of them later.

Now, if we are capable of meditating time as let loose from the bodily grip of worldly processes to such an extent that the passage of time could be stopped — or that the world could be stopped while true time continues passing — it takes but a small additional effort of spiritual exercise to imagine the passage of time reversed, or the entire world tracing its history backwards. Beckett has played with the idea in one of his plays, and so has Philip K. Dick in his novel *Counter-clock world*. Their reversal is “incomplete” in the sense that the characters possess an order of mental events that allows them to think and talk of the passage from grave to cradle as the natural order of things and even allows one particularly adventurous character to speculate what it would be like to live upside down, from cradle to grave. In other words, the playwright did not conserve, under the transformation, the alignment of the order of memory, anticipation and even conversation, with the order of birth, aging and death. However, this “fault” of reversal is of course what makes the story interesting. If the imaginary transformation was so complete that every difference within the horizon of the plot cancelled out, there would be no story — just as in Borges’ and Augustine’s constructions, the interesting points are made through a kind of “slip” in the halting of everything, a slip internally related to the suggestive power of the exercise.

Once there is the idea of a more or less logically perfect reversal of time, or of the sequence of things happening in time, the problem of “time’s arrow” is born: why do things happen in one particular sequence rather than the reverse? What kind of difference would it make if all things or some things happened in the reverse order, and what kind of cause could be responsible for the orientation of the order of time, if two “choices” of such an orientation are equally conceivable?

The development of the metaphysical structure of “time’s arrow”, powered at least partly by developments in the sciences and technologies and inspiring imaginative expressions in other fields of culture, assumes central importance in discussions within and on the edge of thermodynamics, concerning the nature of irreversible processes, the distinction between reversible and irreversible processes, and the role of these concepts in delimiting the subject of thermodynamics. I am going to look at a contemporary discussion where the power of completing an imaginary time reversal assumes central importance, and where a particular kind of symmetry argument to display and criticize faults of

completeness is relied upon with great assurance as a criterion of mental penetration of the matter. The instances of symmetry criticism we shall look at contain a sad moment of disinterest in the points made or even the problems treated in that which is criticized, and maybe closely related to this there is an interesting "slip" in the application of the symmetry argument, as I shall try to show. However, the philosophically interesting thing to do here is not so much the debunking of the criticism, I think, as it is the taking of a chance of new and even wilder metaphysical exercise which can sprout in the cracks and fault lines of "time's arrow": the idea of "process", which is, I suggest, becoming conceivable in a much more complete and explicit way by virtue the metaphysical attempts at assimilating the (relatively) new sciences of dynamic systems, such as thermodynamics and evolutionary biology, into a coherent general framework of ideas.

The instances of the symmetry criticism we shall look at are raised by the philosopher Huw Price and the physicist Jean Bricmont against what they describe as a fashionable trend of hailing chaos theory as an answer to the problem of time’s arrow. They both launch this criticism at the trend of “chaos” in general and, in particular, at the joint work of Ilya Prigogine the physicist and Isabelle Stengers the philosopher — a work devoted to the implications of the ongoing extension of thermodynamics towards the handling of physical systems further from thermodynamic equilibrium. It is significant that the critics both express great veneration for Prigogine’s innovative work “within” the scientific discipline of thermodynamics — where the brackets signify that Prigogine’s accomplishments are contributions to a large-scale redefinition of the universe of systems available for study within the scope of thermodynamics — but that they find that Prigogine, Stengers and others associate with this work an extradisciplinary and inappropriate general interpretation of thermodynamics, and particularly of that central structure, time’s arrow. It is to set this straight that Bricmont and Price insist on sharp and complete meditations on temporal symmetry.

Thermodynamics, entropy and irreversibility

The problem of time’s arrow, and of the general temporal symmetry or asymmetry of processes, has a very sharp point of focus within theoretical physics: the second law of thermodynamics. I shall be referring to this second law or principle of thermodynamics so often in the following that it is expedient to introduce an acronym: let us call it 2lt. In systematic expositions of thermodynamics it is from the simple general principle of 2lt that every irreversible feature of more complex descriptions of particular systems derives, and in systematic expositions of the natural sciences as a coherent system, thermodynamics is traditionally seen as the layer of transition between reversible basic “levels” of physics and irreversile phenomena on higher “levels” of chemistry, astrophysics, physiology, etc.

There are several ways of stating 2lt, and many discussions of the degree to which they are exactly equivalent or merely analogous. Some of the forms of statement refer to classical *macroscopic* thermodynamic quantities such as temperature and work, others refer via statistical summaries to *microscopic* state descriptions such as the phase state points of sets of particles. In any case the second law requires or predicts that a quantity called *entropy* does not decrease. Entropy either stays where it is — the defining characteristic of reversible thermodynamic processes — or it increases so that we have irreversible processes. Hence, the change of entropy provides an arrow of time wherever it is defined: entropy must increase. Depending on the way of stating the principle and defining the quantity of entropy, this can be either expressed in terms of degradation of energy to an increasingly low-grade and useless form, or in terms of a passage from highly ordered and improbable states to disordered state of high probability — like the famous image of the man who leaves his new Rolls Royce in the street and should not be as surprised to find it turned into a pile of rust when he returns years later as the man who leaves a pile of rust and finds it sponaneously organized into even a Wartburg. The word entropy is constructed from greek roots to mean propensity for change, implying that spontaneous change can happen as long as some of this propensity is left, then grinds to a halt. Entropy definitions happen to be signed in such a way that it is negative entropy which plays the role of the general resource for change — a resource which “runs out” when the entropy maximum is reached at thermodynamic equilibrium.

In classical thermodynamics 2lt is not formulated in terms of statistics, so that spontaneous entropy decrease (the thermodynamic analogue of the spontaneous Wartburg happening — e.g. the cold coffee in my cup spontaneously heating up from room temperature to the boiling point by refigerating the table underneath it) is not just very improbable but plainly impossible. Furthermore, it is acknowledged that completely entropy conserving (i.e. perfectly reversible) processes do not really happen. [This may seem problematic at first, because classical thermodynamics constructs the definition of entropy by means of ideal reversible processes. The trouble is that a system for which only reversible paths are open will not start moving or changing by itself — it must be “stirred” out of equilibrium or “motivated” by an entropy increase. However, as it can be shown that entropy is a “state function”, e.g. that the change of entropy does not depend on the (in practice irreversible) path taken, entropy is well defined at least when thermodynamic equilibrium is (re)established. Hence, a constructed generalized measuring rod of entropy can be extended to a broad range of suitable sections of real world systems, by comparing them with something which might have been

brought about reversibly.] Fully reversible processes, in other words, are confined to mechanics, to systems in which the laws of mechanics apply while thermodynamics can be ignored. Such systems exist, of course. The great classical example is celestial mechanics. Within ordinary timespans, of seconds and centuries for example, the planetary system’s movements can be treated as an instance of pure mechanics, with the famous norm-setting precision of this paradigmatic application. However, over longer timespans, there is indeed a grinding towards thermodynamic equilibrium (if not an Augustine-style halt) whose effects build up to become significant in the long run: the celestial bodies exercise tidal forces on each other, resulting in a gradual leakage of energy from orbital movement into (low grade, i.e. high entropy) radiated heat. Thus, within the frameworks of classical mechanics and classical thermodynamics, there is a general understanding that there is no absolute exception to the second law — rather, there are limiting cases of *practically* pure mechanics.

Textbooks give two basic formulations defining entropy. First, the classical one in terms of the difference

$$dS = dQ/T \qquad (1)$$

where S denotes entropy, Q denotes heat and T absolute temperature, under adequate qualifications of reversibility and the possibility of reconstructing differences over irreversible changes by means of differences over equivalent reversible changes of open subsystems. (1) has its paradigmatic case in a contained gas where heat, temperature, volume and pressure can be modified under various constraints — generalized heat engines (Carnot cycles). Entropy in this sense, and hence 2lt in a classical form, can be extended to all kinds of systems in the world of classical physics involving solids, liquids, forces, etc. An interesting aspect of this kind of definition is that it is a measure of a difference between the beginning and the end of a *process*, not an absolute measure of a state. Therefore, in classical thermodynamics, the quantity of entropy is an integral containing a choice of origin, an arbitrary choice at least until one adds to the definitions what is sometimes called “the zeroth law of thermodynamics” to set S=0 for a perfect crystal at the absolute zero point of temperature.

The second basic textbook definition of entropy is the statistical-mechanical one in terms of the volume of a generalized space of possible configurations of the system

$$S=k \log W \qquad (2)$$

where k is Boltzmann's constant and W is a measure of the (microscopic) configurations corresponding to the state in question. The paradigmatic situation for representation by (2) is the configurations of microparticles corresponding to the contained gas, and the configuration space measured is the "phase space" with six dimensions (position and impulse) for each particle. The idea is that the exact microstate of a system is never known or observed, while any macroscopic state of a system — that is, any combination of observable properties — corresponds to a very large number of possible microstates.The great success of statistical mechanics is Boltzmann's demonstrations that the behaviour of paradigmatic classical thermodynamic systems can be modelled very accurately by means of statistical operations on a generalized system of possible states of such microparticles — each one behaving according to the laws of mechanics, while the behaviour of the real world system corresponds to statistical summaries. A central accomplishment in this intellectual triumph is the formulation of a statistical function completely analogous to classical entropy under a few assumptions which seem immediately unquestionable, notably the assumption of "molecular chaos" we shall discuss later.

It is interesting to note that definition (2) does attribute entropy to *states* rather than entropy differences to processes and, correspondingly, that it assigns an *absolute* quantity of entropy to each state without depending on a more or less arbitrary choice of origin. This difference reflects the question whether something is fixed as the "bottom level" micro-components of the system. If each micro-component was a subsystem with its own mutable configurations, this would contribute extra dimensions to the space of states measured and an additional amount of entropy. Just like the choice of origin in the first definition, this would be without any practical consequence wherever such extra pools of entropy stay out of the way of the proces in interest — say, if the atoms of the gas in the steam engine we look at have a capacity for nuclear processes which stays virtually "frozen" in the timespans or at the temperatures relevant.

Therefore, this characteristic of the second type of entropy definition does not mean that the use of statistical mechanical methods itself commits anyone to a particular answer to the metaphysical question whether there is a fundamental level of constituents which are ultimately solid and beyond change — that is, a level which is ultimately and not just practically *mechanical*. However, to one metaphysical interpretation of the relation between thermodynamics and statistical mechanics such an assumption is unquestionable: the fundamental level which is not just practically and temporarily frozen but absolutely solid is there, somewhere, even if perhaps several levels deeper down than anything we know about at the moment. With other interpretations we can go on just as well with thermodynamics and statistical mechanics without excluding the possibility of

semistable levels "all the way down". However, even if such interpretations are a relaxation of a pragmatically unnecessary metaphysical claim, this may be the kind of metaphysical question in which the more relaxed metaphysics appears more speculative and "metaphysical" to many, because certain implicit assumptions are so dominant as to make alternatives more or less impossible to meditate.

A closely related metaphysical question concerns the exact sense in which the second kind of entropy definition is "statistical". The probabilities involved can either be taken to refer solely to deficiencies of a relation of representation between subject and object — the kind of uncertainty involved if, in a game of poker, you operate with probability assessments of states of affairs, such as the existence of an ace on my hand. In that case, of course, you are not really considering the possibility that I may have cards on my hand which are anything but fully determinate and immutable, it is just that your gaze is incapable of penetrating the cardboard. Or, it is possible to interpret probabilities and indeterminacies as characteristics which could be partly in the matter itself too — the kind of uncertainty you think of when you consider whether you want to invite your friends to a garden party for your birthday next summer. The first kind of probabilities is about ignorance about things which are determinate, the second kind involves the possibility of things being indeterminate, i.e., about determinacy as something which becomes. However, it is not uncontroversial whether the second example is really an instance of the second kind of probability, or just another instance of the first kind. The real existence of probability and indeterminacy in the second sense is exactly what is at issue.

In the simple systems which can be completely described by the laws of classical mechanics, it is possible to give a complete prediction of a system's future behaviour, once we have a precise and complete description of the system's state at any particular point of time. For instance, once we know the positions and velocities of all of the celestial bodies in the solar system at this point of time, if there were no forces operating from outside and if the celestial bodies were themselves perfectly solid so that the aforementioned tidal forces did not leak energy out of the system, then by the laws of mechanics one could infer the total description of the state — positions and velocities — at any other point of time, no matter how remote. For the moment, at least, we can bracket out the computational difficulties of solving the differential equations involved in the many-body problem — the fact that as soon as more than two bodies are involved it is necessary to rely on approximative methods. This technical problem can be bracketed out because it is not very controversial that such problems do have fully determinate solutions whether or not it is possible to complete a perfect determination by any actual process of calculation. A mechanical law such as the classical description of gravitation is, in Hans Reichenbach's words, "strict or causal law" and "expresses a *strict implication*, or *nomological implication*" in contrast to a "probability law" which "expresses merely a *probability implication*" [4]

It should be noted here that this nomological implication, in an ideal mechanical system, of the complete details of a state at $t=t_0 + \Delta t$ given the complete details of the state at $t=t_0$ (and given the mechanical law or laws of course), works just as well in the reverse temporal direction, retrodicting the state at $t=t_0 — \Delta t$, as it does in the forward direction of prediction. Not only are the functions of time equally determined and calculable both ways, it is even that the laws of mechanics are in fact invariant to a reversal of the parameter of time, so that the exact reverse of any history of movements satisfying the equations would satisfy them just as well. In other words, if a twin sister system to our perfect mechanical system would be in the a state at $t=t_0$ in which the position of each particle or planet is exactly the same but the velocity is the exactly the opposite, it would exhibit a perfect temporal mirror image of the entire history of movements. If we can imagine an entire world as an ideal system of mechanical parts governed by "nomological implication" of this perfectly time symmetric form, then of course we find again the vision we began with: the meditation upon an idea of time so separable from the happenings of the world that we can conceive of it as not only halted but turned to run in the reverse. And, of course, the only perspective in which this would make any difference is one out of the world — out of the entire world we just assumed to be the ideal mechanical system.

We have reached the point where this meditation enters the ongoing discussions of time's arrow in metaphysical interpretations of thermodynamics and statistical mechanics.

According to Reichenbach, Boltzmann's discoveries imply that 2LT is not really a law of the strict, "nomological" type even if it looks like one in its classical form. Rather, the establishment of a statistical mechanical model of simple thermodynamic systems has relegated this law to "the statistical category", so that the requirement of increasing entropy in spontaneous natural processes is no longer something that holds with necessity but merely something highly probable. In fact, so probable that the statistical frequency of observations of even one small macroscopic example of decreasing entropy arisen by chance fluctuations — something like the spontaneous coffee heating discussed above — would be once in a timespan many orders of magnitudes greater than present figures for the age of the universe (discounting of course the omnipresent instances of entropy decrease in an open system by a process which produces a larger entropy increase in another open system). Although this makes the difference between the

[4]) H. Reichenbach: *The Direction of Time*, Berkeley 1971, p. 55

"nomological type" laws of mechanics and the "statistical type" 2lt completely academic, that is, completely irrelevant in any pragmatic perspective, it is of great importance for Reichenbach, because of its speculative implications. It implies (since Reichenbach follows the widespread agreement that all real world time assymmetries should be attributed to 2lt) that all of the spontaneous processes with the notorious time-assymmetric characteristics of the real world may in principle just as well run in the reverse. We then have what Reichenbach enthusiastically calls "a nucleus of a theory of the flow of time" including a theory of directed causality[5]. In effect, the theory is a detailed unfoldment of Boltzmann's observation that if a system is in a state of a certain low probability at time $t=t_0$, (say, all molecules gathered in one half of the container) and if there are other more probable states availabe (more even distribution throughout the container) then after a little while the system will most probably have shifted towards more probable states. What needs to be added, of course — and Reichenbach praises Boltzmann for having added it in order to ward off a symmetry argument criticism (originally raised by Loschmidt) on the statistical reconstruction of thermodynamics — is that "after a little while" contains an arrow of time, but that this can only be *defined* in terms of entropy, in the statistical sense. The resulting vision is that there is an arrow of time wherever there is an entropy slope, and that the slope determines the arrow's direction. In effect, we then have a singular "cause" of every directness of processes: the simple fact of existence of a state of great (cosmic) extension and unfathomably small probability (low entropy, or high degree of order) at some point of time. Given such a state, entropy will — with a probability differing from 1 by an extremely small number — be rising towards the maximum of thermodynamic equilibrium when the system's development is traced in any temporal direction — both directions hence defining an arrow of time for the respective regions of sloping.

[5]) H. Reichenbach: *The direction of time*, Berkeley 1971, p.55.

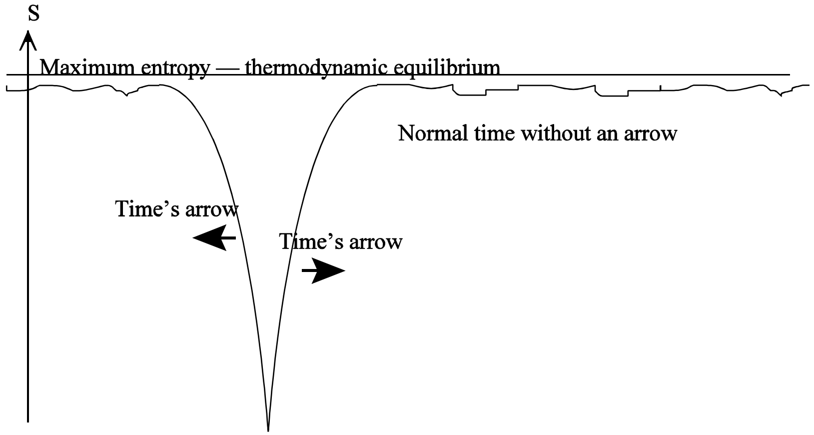

fig. 1: Reichenbach and many others have illustrated this statistical-entropic view of the second law and time’s arrow by graphs like the above. Usually the extremum is shown as a hill rather than a valley, which is of course just a trivial turning of the axis of entropy, but it has the (unintended?) advantage of echoing the Aristotelian idea that things naturally “fall” towards their natural place at equilibrium. More curiously, the graph is usually shown with a flat rather than a pointed extremum. But the requirement of a chance fluctuation sufficiently large to produce an inhabitable universe will require coincidences of an improbability zillions of orders of magnitude greater than the monstrous size it already has, if the fluctuation is to stay at the extremum for a while, and this is quite unnecessary. Because, as Boltzmann, Reichenbach and many others argue, the simple fact of being at a certain temporal distance from a state of low entropy is enough to “pre”-dict with great certainty a state of larger entropy. However, I follow the other authors in making the “error” of showing the “normal” small fluctuations in and out of thermodynamic equilibrium as only a few orders of magnitude smaller than the extreme “twin universe happening”. They ought to be “shown” as far below the threshold of visibility, in comparison, so that the graph would show a straight horizontal line for the sections representing the unfathomable aeons of “normal time”. I shall return to this fantastic idea of the accidental occurence of complete cosmoses below, in the discussion of the “Anthropic Principle”.

The view of the arrow of time as local and dependent on chance fluctuations still strikes even modern minds as far-fetched and deeply counterintuitive. But the underlying view of the metaphysical nature of mechanical microprocesses, and of 2lt as statistical in the sense that it summarizes an inacsessible determinate and deterministic microworld, is still so dominant that I dare call it the standard interpretation. Price, for example, subscribes to it with great emphasis although for a reason which is probably one of style he likes to present his view as dissident: “Thermodynamic equilibrium is a natural condition of matter, and it is *departures* from this condition that call for explanation... The puzzle is not about how the universe reaches a state of high entropy, but about how it comes to be starting

from a low one...”[6] Here, of course, “starting” must be read in the sense that does not assume any arrow of time other than the one defined by a local entropy slope — because, as we shall see, Price himself takes great pains to help others escape their fallacies of carrying into the meditation hall, as if on their dirty shoes, implicit arrows where there should a priori be none.

Chaos and the arrow

Now, the rising trend of chaos theory and nonlinear dynamics has become involved, according to Price, in a general tendency of repeating this class of fallacies which is not basically different from fallacies made earlier by many authors in the field, all the way back to Boltzmann’s own initial formulations, before he added the entropic-statistical account of time’s arrow in response to Loschmidt’s symmetry objection.

Chaos theory and nonlinear dynamics are expressions of the development I mentioned initially, of expanding the fields of relevance for physics and other natural sciences into a world of dynamical systems characterized by flux, phase transitions, complexity, and by being far from states of thermodynamic equilibrium. We can start by noting that it must be uncontroversial that such an expansion of scope means, under anything resembling our current conditions, an entry into a much larger world of objects of study; because whether or not thermodynamic equilibrium is, with Price’s words, the “natural condition of matter”, it is not the typical condition of matter around here. The equilibrium systems describable by mechanics are, as we discussed in connection with 2lt’s form in classical thermodynamics, an exception, or more accurately, a limiting case nowhere perfectly instantiated although sometimes approached very effectively under careful delimitation and purification of relevant systems. Even the systems and processes close to thermodynamic equilibrium, which are the scope of traditional thermodynamics whether classically or statistically approached, have a similar status of ideal limiting cases, carefully tamed and maintained compartments in an environment generally much more wild, heterogenous and unstable. Price and Bricmont do not question the value of such work in expanding the scope of the sciences (although perhaps they do find it a welcome implication of their arguments that such expansions would be merely towards the inclusion of a curious field of special applications), and as I mentioned initially they are particularly careful about praising Prigogine’s work as scientifically sound and

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[6]) Huw Price: *Chaos Theory and the Difference between Past and Future*, in Soulsby, M. (ed): *Time, Order and Chaos: The Study of Time Vol. IX*. Madison, CT: International Universities Press, 1997.

innovative. However, they both find that there is a general tendency of misinterpreting this work in a way which attributes to chaos, complexity or nonlinearity the power of providing again the "natural arrow" which has been shown, ever since the advent of the standard interpretation, to be a "dead horse". And they both see Prigogine's philosophical work with Stengers as advocating such mistakes. Therefore, they both offer their assistance in correcting the mistakes through reinvocation of the classical symmetry argument.

Price's and Bricmont's arguments are both directed primarily against "a general trend", and only secondarily against Prigogine and Stengers. However, it is difficult to discuss the general trend of drawing metaphysical implications from chaos theory etc. There are great differences within this litterature. Some authors have indeed seen in chaos theory etc. some kind of proof that a universe of mechanical and reversible microprocesses would "by itself" become a cosmos of directed and self-organizing processes. For such views, Price's and Bricmont's symmetry criticism can indeed disclose a metaphysical inconsistency which must be handled somehow. Other authors, notably Prigogine and Stengers, are not so interested in deriving anything from mechanical and reversible microprocesses, rather they are questioning this kind of metaphysical problem and — as far as I can see — beginning to suggest a greater and more serious metaphysical problem which is becoming visible by virtue of the new scientific and technological experience.

To see what Price's and Bricmont's symmetry argument is all about it is not necessary at all to speak of chaos, nonlinearity and dynamic systems. In fact it may be an advantage to bracket out, to begin with, all of the characteristics of these emerging structures in science; because Price's and Bricmont's central argument ignores this content of their own discussion to a remarkable degree.

I will look at a particular example of a "commonsense temporalist" argument of the type which invites this kind of standard symmetry objection. The example has not as far as I know been treated by Price or Bricmont, but I will expose it to exactly the same kind of critique. The method of this critique is very easy to generalize as soon as you have seen one example, so after this meeting we can all walk out into Aarhus and criticize false asymmetries. The example has the advantage of being constructed with obvious extreme simplicity. On the other hand, the example has the immediate disadvantage that it isn't explicitly about entropy, but as the physicists present will see the example is closely analogous to the logical hub of Boltzmann's H-theorem.

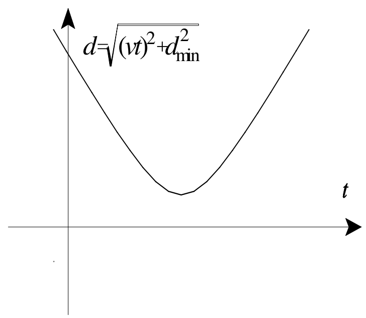
I quote the example from Whitrow who has borrowed it from Popper and Milne. According to Whitrow it illustrates that irreversible behaviour is deeply involved in even the simplest possible physical systems

The system considered consists of any number N>1 of particles which are not all at rest relative to each other, and which are for the sake of simplicity assumed to move freely along straight lines, not affected by any forces. Such a system

> *"...will eventually, that is at some finite time later, be an expanding system, even if it were originally a contracting one. On the other hand, an expanding system of uniformly moving particles will never of its own accord become a contracting one... Thus, the simplest possible kinematic situation automatically reveals the irreversibility of time."*[7]

It is easy to see that Whitrow is right that this ideal system will, sooner or later, become an expanding one, with any reasonable definition of its size, e.g. the largest or the average distance between any two particles; and that once it is expanding it will expand forever, never contract again. What is a misunderstanding however, is the conclusion that this reveals any irreversibility. This is shown by a very simple symmetry consideration:

All constituents of the system are very obviously carefully constrained to be paradigmatically time-symmetric stuff. The unaccelerated movement of the particles are obviously temporally symmetrical, their interactions definitely doesn't introduce any asymmetry since there is no interaction, and the size of the system referred to is measured in an instant and is therefore unaffected by time reversal. Hence we can draw up the variation of the size of the system with time. If there are only two balls the variation of the size with time is particularly simple to compute of course. The time dependent distance is



(v and d_{min} being arbitrary constants: the magnitude of relative velocity, and the minimum distance)

This is obviously perfectly time symmetric behaviour. Of course with more particles and some reasonable definition of size, we will get tougher calculations but very similar results. What could Whitrow find irreversible here?

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7) G.J. Whitrow: *Natural Philosophy of Time*, 1981

Well, Whitrow was not comparing the system's size at particular points of time, but its state in terms of "expansion", its *change* of size, the sign of the first derivative of the size. Clearly enough, this state changes from C to E and never returns to C again, Whitrow says. But here we can apply the sharp knife of symmetry. Reverse the sign of the time axis. What used to be an initial state of contraction now becomes a final state of expansion, and vice versa. Therefore after the reversal we don't have E → C but, exactly as we did before, C → E, time reversal changed nothing. And of course what is required for there to be irreversibility is exactly that reversal makes a *difference* in the kinds of sequence which can be observed.

Just because of this system's specifically ideal reversible equations of movement, including its non-interaction with anything external, we can conclude, from any configuration of positions and speeds at any time $t=t_0$, that contraction has been going on since $t=\div\infty$, just as well as we can conclude that expansion will go on towards $t=\infty$. Whitrow in fact refers to an objection of this nature, made by T. Gold, but he dismisses it as

> *"...irrelevant, since the particles can be thought of as initially at finite distances apart when they are set in motion. The essential point is that, if the particles all move uniformly in straight lines and continue to do so throughout, approach precedes recession but recession never precedes approach."*

Clearly this only makes things worse. Obviously Whitrow now relies on the assumption that such a system must be "set in motion" at some initial time, whereupon it can go on moving freely forever. This imposes a temporally asymmetric border condition which itself produces all the asymmetry Whitrow sees. If he would remove this condition, or impose a similar condition regarding the time when the particles are *stopped* irreversibility would disappear. The reason Whitrow feels we must impose initial but not final conditions is of course a commonsense notion of causality: cause comes before effect. Intuitively we don't like a cloud of particles to have traveled from infinity into a present state of final extension, whereas the idea of a cloud of particles beginning to move on towards infinity from any particular present configuration of finite distances and speeds doesn't bother us. In the former case we are lacking a causal reason, in the latter we identify this reason as the "setting in motion".

So, the example does not do the work it was supposed to. It does not give us irreversibility from reversibility unless we add something. Not very surprising.

Or at least the example doesn't do the work the defenders of the standard interpretation take it to claim to do. We might well try a more friendly reading of Whitrow's example, questioning the symmetry diagnosis. Maybe, after all, mixed up with the kind of argument captured by the symmetry debunking, and not very explicitly, Whitrow's example could be said to be doing something very different from what the standard symmetry debunking strategy addresses. It could be an attempt to state just what it is that makes the difference between a simple system *viewed as purely formal* — i.e., as a set of linear functions of a variable t — and a similar system *viewed as real and physical* — i.e., as something really happening, thus involving real, ordinary, commonsense, asymmetric causation. However, if this is Whitrow's point, it would seem that he undermines it somewhat by choosing to describe a system perfectly idealized in a way which removes every causal influence leaving only simple reversible movements — a system thoroughly reduced to the purely formal — thus strongly suggesting the standard notion of a substrate of pure reversibility.

The standard interpretation's diagnosis goes as follows: our well known life and world are so pervaded with temporal asymmetry that even in attempts of systematic philosophical reflection it is difficult to think consistently about modifications such as the reversal of the arrow of time. You might say, our real life practical logic doesn't permit it. Whitrow, even while trying to speak about a system he has idealized and simplified in the manner of theoretical physics, can't help imposing upon it his commonsense notion that this is supposed to be a *real physical system moving in real time* as opposed to a mathematical example of a function of a parameter called t.

Applications of the standard symmetry objection — just as the positions they criticize — rest on implicit metaphysical assumptions.

The symmetry objection is a simple method of exposing inconsistency: it shows that *if* someone assumes a fundamentally real microphysical world of atemporal substance, without any temporal asymmetry, and if he also assumes that the macroscopic world is phenomena made up of the way a sequence of microstates appear to observation of limited precision, *then* any claim he makes of something breaking the symmetry to produce consistent irreversibility on the macro level can be given a temporally inverse mirror image. If there is a reason for entropy to be increasing in one temporal direction, there is a similar reason it should increase in the other.

So, the assumption behind the symmetry objection is that the opponent subscribes to the metaphysical model of a primary reality of symmetrical substance. If the opponent had different metaphysical assumptions about ultimate reality, or perhaps avoided making such assumptions, obviously the objection would loose power. Someone claiming for example, as Eddington did, a deeper metaphysical necessity for thermodynamical irreversibility than for other laws of nature, could hardly be charged of sneaking in something through the back door in order to produce apparently necessary macroscopic irreversibility.

Therefore, when Bricmont and others take the symmetry argument to be so universally powerful they must have a further premise. It is not so explicit but they seem to assume, in effect, that any *serious* opponent would have to work on the basis of the ontological or metaphysical privilege of symmetrical substance. The requirement that serious opponents must do so could be enforced, for example, by equating reluctance to accept this metaphysics with resistance to science per se. Or, more or less equivalently, by taking the general power and legitimacy of the process of science as the power and legitimacy of this metaphysics. In this sense the implicit premise may be a continuation of the project I mentioned before, of establishing and delimiting what counts as truly and basically scientific by means of reversibility. This "political" reading of Bricmont is supported by the strongly polemical tone of the arguments and by his frequent reference to a general cultural climate hostile to science.

It is argued sometimes that scientific evidence does in fact support or even imply the metaphysics of reversible substance. Thus Henryk Mehlberg: "It seems to me that it would be either a miracle or an unbelievable coincidence if all the major scientific theories somehow managed to co-operate with each other so as to conceal time's arrow from us" — obviously implying that 2LT does not belong to "major" scientific theory. But if reversibility plays a role in a suggested metaphysical delimitation of what counts as basic and pure physical theory — that is, if all of the undeniably dominant practical evidence of irreversibility is suggested to be per definition not what "major" theory is about — how could physical theory "discover" irreversibility?

This observation has nothing to do with an attack on the process of physics for being anything less than correct and rational. Even without the assumption of an ontology of purely and reversibly mechanical substance on the micro-level there could be very good reasons for physics to concentrate and isolate wherever possible those aspects of nature describable in terms of conservation and reversibility, just as there are very good reason for statics to be interested in systems which can be abstracted from change and movement. I will return to these good reasons in a following article.

Prigogine and Stengers are criticized by Bricmont and Price for claiming or suggesting "that chaos theory explains important differences between past and

future" (Price). Chaos in this context does not mean the old Chaos of Greek cosmogony or the type of distribution of objects prevalent in certain offices at the university; it refers to a property of many physical systems, implying that the classical type of deterministic behaviour is not observable in practice, because a given variation in the outcome can be produced by arbitrarily small variations in the initial state. As Price, Bricmont and many before them have pointed out, the existence of chaotic behaviour in this sense on the macroscopic level does *not positively disprove* that there is not an underlying microscopic level of particles behaving perfectly reversibly and deterministically. So they assume microscopic determinism and reversibility to still hold. Bricmont seems even to imply that the existence of chaotic behaviour *further secures* the traditional image of a perfectly determistic behaviour on a fundamental level, because the new analyses of chaos and nonlinearity shows that such features should be *expected* in many cases, given a determinsitic micro-level.

However, the arguments of Prigogine and Stengers amount to a very different kind of observation: the fact that chaos, statistics, complexity and nonlinearity are increasingly prevalent in new fields of natural science could be the beginning of what they call "the end of certainty". Contrary to Bricmont's reassurance, we could take chaotic phenomena at the macro-level as opening an interesting alternative the standard interpretation: if instability and probability are becoming prevalent in models and descriptions, we might try to *drop* the assurance that classical determinism reigns invisibly at an inacsessible basis of things. Prigogine and Stengers argue that assuming chaotic and stochastic phenomena to exist even at the micro-level, models can indeed be built which would predict the amplification of chaotic behaviour to become significant in *some* types of macroscopic systems, but also the cancelling out of fluctuations in other types of systems leading to close approximations to purely mechanical behaviour on the macro-level in those cases. Prigogine and Stengers do not postulate this as a solid system of metaphysical interpretation. Although they do not share the typical 20th C shyness of explicitly addressing the question of metaphysical interpretations of physics, and although they give insightful discussions of metaphysical proposals by classical and contemporary philosophers, their kind of proposal is a rather soft one. Instead of attacking the standard interpretation, they gently investigate possibilities of slightly expanding some of its elements so that our interpretation of the relationship between sciences and the world might benefit as much from the new kinds of phenomena and models as it has from the classical ones.The core of this proposal is that we can take dynamic systems and chaotic behaviour as revealing just as much about "the nature of matter" as we have become accustomed to mechanics doing.

Curiously this gentle proposal, the central point of Prigogine's and Stengers' joint work as far as metaphysics is concerned, seems to go completely unnoticed by Price and Bricmont, in spite of their declared intention of criticising the *metaphysical* implications that Prigogine, Stengers and others have drawn from chaos theory etc. Instead, Price and Bricmont criticise a much more conservative position, which is very far from the intentions of Prigogine and Stengers as far as I can see (and I would like to use this conference presentation as an occasion to put this as a question to Stengers): The position which is criticized is a kind of chaos-theory version of Whitrow's argument to the effect that the standard interpretation's cosmos of perfectly time-symmetric and deterministic microparticles would, *because* of chaos theory's exclusion of the actual possibility of perfect prediction, of itself produce an arrow of time.

Taking for universally applicable exactly those assumptions to which Prigogine and Stengers have been reinterpreting as special and limiting cases, their critics can bring up the symmetry argument. Given symmetry and determinism at the fundamental microscopic level, then *if* chaotic physical systems seem to introduce a strong temporal asymmatry via unpredictability, this will be the case under time reversal as well. If we happen to observe systems behaving chaotically in one temporal direction only, this will be the effect of other asymmetries, either due to asymmetries in the way the observer observes, or to asymmetries in the border conditions of the chaotic systems in question. In any case the real explanation is the entropy slope common to obsever and observed. As Bricmont observes it is very important not to mix up micro level and macro level properties of the system — given the standard interpretation, lack of discipline here will invariably be the fault line through which apparent irreversibility creeps in. And as Price observes, the source of irreversible behaviour cannot possibly be chaos in that case, it must be the "miraculously" non-equilibrium border conditions which must apply to the entire cosmos or vast portions of it at least, in order for the entropy slope to be present.

After these remarks there is an obvious way to defend Prigogine and Stengers against the charges of symmetry inconsistency. One might simply observe that they suggest a metaphysical interpretation different from the "symmetry at the bottom" of the standard interpretation — that what they propose implies, in fact, an alternative metaphysical interpretation of "process all the way down". I am going to suggest such a processual interpretation myself (in the following papers), and in an earlier version of this article I suggested that Prigogine and Stengers' points in "Order out of Chaos" contain, implicitly, the same kind of suggestion. Stengers criticized this for suggesting that the work of Prigogine and of Prigogine and Stengers is in need of an "escape" by means of speculative metaphysics to be saved from the symmetry objection. I agree with Stengers' criticism: It is more

accurate to say that "Order out of Chaos" *departs* from the heavy claims of a powerful but not absolutely dominant school of metaphysical interpretation. The points made by Prigogine and Stengers correspond very well with process metaphysics, but they do not depend on specific metaphysical constructions. It may be just because Prigogine's and Stengers' discussions ofmetaphysical implications are not solidified into radical claims that it is possible for critics as Price and Bricmont to assume that the symmetry objection is relevant. However, Prigogine and Stengers sometimes illustrate their points with examples of complexity or chaos which are obviously constructed out of simple, idealized, and even temporally symmetrical constituents — e.g., the "baker transformation". The use of such an illustration does not commit the writer to a general metaphysical claim that the stuff of the world is just like the example in every respect. But it may have led some readers to believe that Prigogine and Stengers still subscribe to the metaphysics of "symmetry at the bottom" but have instead delivered or attempted to deliver the miraculous "production of asymmetry out of symmetry without adding something". This could be why authors such as Price and Bricmont find the standard symmetry argument critique relevant.

The Anthropic Principle — the soul of the standard interpretation?

Even Boltzmann's $\mathcal{H}$-theorem, an achievement which forms a crucial step in the statistical mechanical reconstruction of thermodynamics, is the target of Price's standard symmetry argument debunking. Price quotes Loschmidt, a contemporary and colleague of Boltzmann, for a symmetry objection to Boltzmann's use of the $\mathcal{H}$-theorem, an objection Price praises as a paradigmatic demonstration of the usefulness of this type of argument. The main lines of the arguments are these:

First, Boltzmann's $\mathcal{H}$-theorem shows that in a system composed of a large number of particles moving linearly and colliding elastically as molecules in a gas are supposed to do, a certain function of all the velocities, $\mathcal{H}$, behaves in a way very analogous to macroscopic thermodynamic entropy (which is of course defined in terms of heat exchange and temperature, not of the assumed underlying molecular "disorder"). Given some initial distribution of velocities, the spontaneous redistributions of velocities through collisions will tend towards an equilibrium distribution characterized by a maximum of such a microscopically defined entropy analogue. To be a bit more precise, this is a statistical result and does not really hold for *every possible* initial state, it holds statistically, that is, for a very vast majority of the possible initial states, equilibrium as well as non-equilibrium — for all of those which are *typical* in a certain reasonable sense expressed technically in the term of "molecular chaos".

Now, if this derivation of a general trend of evolution of such systems is supposed to show how the macroscopic irreversible behaviour described as the tendency towards equilibrium can be explained as resulting from the statistical effect of a myriad of underlying reversible processes, it is very obvious that we can apply the standard symmetry consideration again to show something is wrong. The asymmetric tendency towards equilibrium requires something to be added to the reversible substrate. What is added is, just as we saw it in Whitrow's example, a reference to an asymmetrical border condition, that is, a reference only to an initial condition. *Assuming* an initial condition of non-equilibrium the evolution is towards equilibrium. But as a very simple symmetry consideration shows, *assuming* instead a similar final condition of disequilibrium, the evolution is the opposite (the possibility of an initial condition of equilibrium does not need treatment, since its predicted evolution is to stay in equilibrium, which is the same either way). And assuming symmetrical border conditions, all macroscopic asymmetry disappears again. Related symmetry objections can be raised regarding the condition of molecular chaos.

Under the assumption of a perfectly reversible microphysical substrate, it may be possible to give accurate descriptions of the way many kinds of macroscopic systems strive towards equilibrium defined in suitable terms, via microphysical second law analogues — but only by adding something. Since, by the symmetry argument, the reversible substrate and the basic physical laws governing its behaviour cannot supply what is missing, this must be added in the form of boundary conditions. In this case truly, as Price puts it, "the real puzzle of thermodynamics is: Why is entropy low in the past". It would indeed be a very great puzzle, because the past initial low-entropy state required in order for the present physical conditions to have evolved, the huge and steep entropy slope making life and the whole cascade of irreversible phenomena it participates in and depends on, corresponds to an unfathomably tiny portion of the possible initial states (what is commonly known as "an astronomical number" would be a wild understatement). Clearly this "puzzle" threatens the idea of physical explanation as accounting for something as the combined result of physical laws and border conditions: it tends to let the unexplained contingent border conditions do almost all of the work of explanation.

Boltzmann's response was just as classical as the objection: it has become famous as a particularly explicit early version of the type of argument which has been named "the anthropic principle":

A universe of reversible microprocesses existing over an infinite axis of time would, over timescales long enough, produce a fluctuation of any magnitude. An entropy slope the size of the entire universe as we know it could be one of the

slopes of one of these unfathomably rare fluctuations in a universe of microscopic reversible substrate. There would still be no arrow of time on the micro-level, but whenever there is a slope, it would define, locally, an apparent one on the macro-level. We observe a region with the exceedingly abnormal property of being on such an entropy slope, because this property is a condition for the existence of life, and hence, for the existence of observers, and hence, for the possibility of observation. In other words, a selection rule is suggested, solving the puzzle by selecting for processes on an entropy slope, and securing at the same time that this slope will always appear to be "forward".
Or, again in other words, a major or even totally dominant part of the physical explanation of the structure of the universe we know is that we know it.

Anthropic principle explanations of the apparently unusual fact that the universe has a physical structure which makes it inhabitable, out of the many possible structures which appear from one theoretical view or the other to have been equally possible a priori, have been discussed extensively, particularly in connection with physical cosmology, over the past decade or two.
[Barrow and Tipler's famous book about it contains an impressive overview of applications, historical roots e.g. in theological design arguments, and eschatological speculations about the future of the universe and the human race which dwarf The Space Odyssey 2001.]
In the context of 20th century cosmology the anthropic selection rule is not usually suggested to operate on fluctuations in a universe existing for unfathomable aeons, instead it is suggested to operate on the initial (big bang) conditions of a multitude of possible universes, or on the branching universes of the many-world interpretation of quantum mechanics, or even on variations of the basic laws of nature (where it is argued that very tiny variations of the constants of nature would make life impossible).

Popper has criticized Boltzmann's anthropic argument for being idealist, and for running counter to the sturdy realism Boltzmann was otherwise a spokesman of, and Prigogine and Stengers quote Popper's criticism with approval. So we can note that the kind of selection principle they suggest to "break the symmetry" is not of this anthropic nature.

Although many have been fascinated by it as a classically beautiful piece of cosmological speculation, the anthropic principle does indeed lead to metaphysical problems of a very classical kind too. Although Price and Bricmont both acknowledge the anthropic principle as a possible strategy for dealing with the problem of accounting for the very special border conditions required for a substrate of reversible microphysics to produce a strongly irreversible phenomenal world, they are aware of some of the problems.

First, the use of an anthropic argument requires that we have, as Price expresses it, independent reasons for asserting the existence of the enormous set of states upon which the principle acts as a selection principle. In Boltzmann's case, long before the acceptance of big bang cosmology, the assumption of a cosmos of infinite duration (or just vast enough) may have been quite plausible. I will not attempt to assess the plausibilities of corresponding present day assumptions of vast numbers of parallel, serial or branching (MWI) cosmoses, independent of the use of these assumptions in the anthropic principle type of reasoning [— I am not sure they make any sense without such reasoning].
A second problem discussed by both Price and Bricmont is that an anthropic selection operating on a suitably large set of possible configurations would lead us to expect the "cheapest" possible, that is, the least improbable kind of configurations compatible with the criterion, i.e. with the existence of the observer. If the observer is identified with a brain state or the whole human body or, to be very generous, with the physical configurations of all human organisms at once, then there are vastly more economical ways of stumbling on such state than those involving an entropy slope of the size and duration of the physical universe the natural sciences used to take for their object. Furthermore any low-entropy state, such as the one necessary for our existence, is by far most likely to be very close to the local minimum of entropy, so that there should be "future" in both temporal directions, no "past" — so that, in the end, what the anthropic principle predicts is not really an arrow of time in the sense of a difference between past and future, but a accidentally and momentarily produced "subject" state which is under the false impression of having a past. Curiously, Price discusses this absurd possibility but dismisses it as conflicting with the fact that we have a history of ongoing speculative and scientific attempts to understand time. It would be easy to raise a skeptical objection here, claiming that Price is not justified in assuming that this history exists as any more than a configuration of particles mimicking the traces of such a history. But I think it is more interesting to notice why Price is justified: he is obviously not willing to equate the sense of "existence of observers" with impressions. He implicitly makes the reasonable assumption that the fact of science is not adequately captured in result states in isolation from their involvements and histories. From the *process* of science.

The process metaphysical interpretation I will propose is radically different from the anthropic type of interpretation, even if again there are resemblances. In fact the anthropic principle pundits Barrow and Tipler quote Whitehead´s process metaphysics, along with the natural philosophies of Hegel and Schelling, as belonging to the philosophical foreshadows of the principle. What is similar is the notion that there is a kind of selection for a universe evolving, structured — and even, in a suitable sense, inhabitable. The great difference is that the anthropic principle gives a very special explanatory role in this to human observation or pure

consciousness, while process metaphysics proposes to see human life in a role we might follow Stengers in calling "democratic": as a basically typical, even if relatively outspoken, participant in the cosmos — and as primarily involved in action and construction rather than detached as observing mind.

The anthropic principle is, I suggest, an almost dialectically necessary conclusion of a modern metaphysical movement in which the mechanical ideal of immutable and non-teleological substance has been purified and hypostatized as ultimate reality. This movement has been described by some authors in terms of a generalized "Copernican shift", i.e., a general trend in which humanity and features well known in human life are "removed from the center of the cosmos". The idea of this shift is associated with the emergence of a modern science-based world-view purging anthropocentric, anthropomorphic, vitalistic and teleological modes of thought which are associated with prescientific thought — with analogical and metaphorical ways of extending categories of subjectivity onto things.
Now, with the "anthropic principle", it is as if the equally purified essence of the expelled subjectivity returns to claim not just a place in the sun but the role of ultimate foundation for the entire scientifically constructed world.

But what returns is not simply a subject which was always there in the history of ideas but a particular very modern kind of subject, a very strange animal indeed: one which denies to have played an ordinary worldly part in the processes digesting and constructing its world — powerless, and at the same time transcendentally almighty because all the ordinary processes in the world must join forces, as if by magic (Maxwell's demon) for it to be.

Or in terms of teleology: the scientific worldview progresses by pushing back commonsense teleology with the effect that final causes are finally moved to the edge of the world. There, e.g. in the big bang, teleology is paradoxically purified and maximized, so that the scientific worldview finds itself repeating the teleology it used to define itself in opposition to.

But it is the scientific worldview which progresses thus, not science as such which is rationally and irreversibly involved with constructing a world of projects, natural tendencies and irreversible processes.

Alternative to be proposed: irreversibility all the way down.
If so many metaphysical puzzles — or one dragon-headed difficulty — are involved in the attempt of understanding how a world full of process emerges from an underlying substrate of inert substantiality, why not investigate the possibility of turning this picture around? What if the stable structures of the

physical universe — particularly the natural constants, the laws of conservation and the patterns of reversible behavior — were arising, decaying or slowly moving, somewhat like the chemical elements and the continents that we used to think of as the paradigms of steadiness?

In a following article[8] I am going to suggest some elements for such a metaphysical reconstruction based on process — a possibility remarkably absent in most of the literature.

[8]) Chp. 4 in the present collection.