"The solution is to be read between the lines of the physicist's writings."

Newtonian Mechanics

Before Einstein, Leibniz proposed the reduction of time order to causal order, but it was in relativity that this idea fully matured and married our theory of the world. And although Einsteinian relativity has given us a quantitative understanding of time order, it cannot do the same for time direction due to its symmetrical nature and inability to transit from causal relationships to probabilistic relationships.

In any case, our job is to explicate the qualitative properties of time. Of the five Reichenbach posits in his attempt to characterize all of it, one interesting point strikes me: The specificity of evidence for past events as opposed to the generality of evidence for future events.

Laws defining causal connections can give us neither order nor direction. Looking into laws governing physical processes: It is made explicit why those in the domain of Newtonian mechanics and Einsteinian relativity cannot give us a direction of time. Since their laws/equations of motions are second-order differential equations or functions of squares of the concerned quantity, they are compatible with both a process and its reversed version; in a nutshell, mechanical processes are reversible.

However, these laws can define direction-invariant properties such as 'between-ness'. Unlike velocity, observables such as position which are free of temporal direction do not depend on irreversible processes for representation and can be used to compare time order. (Note the continuity assumption made over here: That in the spacetime neighborhood of a strict coincidence/position observation, one knows the approximate coincidences/position observations. Only then may we infer practical coincidences, i.e., the directions of the object's motion.)

Thus, the causality these reversible laws define is asymmetric, and we may yet extract an order of time from them. Constructing causal nets on these grounds, we state an empirical order property that they possess which is known to us by the general theory of relativity: That there are no closed causal nets. Had this not been true, the genidentity/physical identity of the thing would have to be distinguished from its logical identity, and events would not have been temporally ordered. But the past does not come back.

Intervention is defined only after presupposing a direction of time. Upon reversing said direction, intervention reappears under the guise of an alternative cause. The assertion about an unchanging past but variable future reduces to an order statement.

Thermodynamics and Microstatistics

Entropy, a quantity defined by thermodynamical rather than mechanical parameters, *usually* either stays constant (reversible processes-but these may be said to take place only in approximation) or increases (irreversible processes).

The original entropy of nonstatistical thermodynamics is defined only for states of equilibrium, unlike Boltzmann's statistical entropy, which allows us to explain probabilistically the movement towards equilibrium. Another point of divergence between the two definitions of entropy owes to the fact that non-normalized (in the sense of probability) thermodynamical entropy cannot be identified with normalized statistical entropy unless we identify statistical entropy with the log of the absolute number of arrangements rather than their relative number.

However, this absolute entropy violates the additivity postulate because it cannot be consistently normalized ("paradox of normalization", Gibbs' paradox). In fact, additive openness is a feature of relative entropy as well (the product rule of probabilities is not strictly satisfied because there is a small chance that the individual probabilities change), but is typically neglected by virtue of Stirling's approximation.

The concept of statistical entropy is then developed/applied in the context of physical space and velocity space. We see that the degree of separation or order tends to decrease with the inexorable increase in entropy-a higher degree of order means that the same-order class is small.

Statistics satisfying the "equiprobability of all arrangements" assumption and the "distinguishability of elementary particles" assumption are called Maxwell-Boltzmann statistics.

The first assumption is said to be empirical; and so, in the sense in which all empirically founded assumptions are teleological, so is this one. If not justifiable on a priori grounds, can it be derived from the causal laws of physics and transferred to another domain of experience?

The causal laws define a hypersurface in phase space. The path from a given starting point is treatable as both determinate and as a probability sequence. By Liouville's theorem, a phase point stays in equal volumes for equal times. Coupled with the observation that disordered states occupy a large area on the surface, we derive the equiprobability assumption. However, note that we have assumed, in this derivation, the *ergodic hypothesis:* A phase point passes eventually through every point of the energy surface. This, Boltzmann's version of it, is incorrect, and the valid modification of it (the ergodic *theorem*) asserts that it comes eventually arbitrarily close to every point. Furthermore, the hypothesis is derivable from the causal laws alone, as shown by von Neumann: "There is always some subspace for which the ergodic hypothesis is true; and for this subspace, the ergodic theorem is always satisfied. Since the ergodic theorem is trivially satisfied for volume elements into which the phase point does not enter [equal sojourn times of zero], the theorem can be asserted unconditionally."

So, we see that a deterministic solution of gas statistics exists. There is no reason, however, to believe that this is the only or correct solution.

Before proceeding, let us formulate the hypothesis of determinism: There exists a sequence of descriptions for a given state which predicts the future states with a certain probability. This sequence converges to an ultimate description and the probability converges to unity in tandem.

The immediate issue is that of the possibility of having to describe an infinitely large volume, which would require infinitely many parameters, an impossibility. Einstein's relativity vanquishes this problem: It has made it necessary for us to know information only up to finitely back in the past for a future prediction due to its speed-of-light constraint, and made it "probable" that the universe is spatially finite. It remains, however, incredibly improbable that the whole universe emits signal which coincide at a given point in spacetime in order to enable us to construct the final description.

Let us reformulate the determinism hypothesis by referring only to a finite spatial volume and insisting that we know its boundaries throughout the relevant period. The difficulty in this is that, for small volumes, it is possible that we can make predictions knowing only simultaneous boundary conditions and not earlier ones, making the condition of a deterministic world unnecessary for perfect predictions. We escape this by surrounding our initial volume by an arbitrarily larger volume and saying that to make a prediction on the smaller volume using a description of/the boundary conditions of the larger volume means to assert the achievability of the prediction regardless of how big our larger volume is. Restricting formal reference to the larger volume, we may now formulate determinism.

Indeterminism merely denies the possibility of an ultimate description. Deciding between these two is now an empirical matter. In the face of arguments against determinism (there need not be only finitely many inner parameters of a system for a perfect description; the known causal mathematical relationships may be only approximately valid), let us look for evidence for it.

The nonuniform convergence (descriptive accuracy increases in growing time, predictive power decreases in growing time) of the lattice schema presented (which represents the outcome of all the observational evidence available in classical physics) can be taken as a lack of evidence for the determinism hypothesis. It asserts that a final description does not manifest itself in observable relationships. Therefore, we conclude that there is no reason to accept the validity of the deterministic interpretation of thermodynamical statistics-or indeed, of the claim that classical physics has a deterministic presupposition.

Consider a lattice of mixture wherein each horizontal row represents the history of a molecule. Taking only nitrogen molecules for the moment (we can account for a nitrogen-oxygen mixture by using a superposition of two lattices of this kind), the fraction of molecules in each side will be half, and the probability of one molecule to be in a given side is half. This gives the horizontal and vertical probability. We subsequently factor in the aftereffect in horizontal (if a particle is in one side, it will likely remain there after a very short interval), adding that it goes to zero for very large gaps. We add that there is no aftereffect in the vertical in this case.

Now, are the first and third assertions derivable from the second? Yes, if the lattice satisfies the condition of *independence,* that is, the behavior of each molecule is independent of the others (the aftereffect on each row is independent of the elements in another row; this becomes invalid for real gases) and if it satisfies the condition of *lattice invariance* (the horizontal probability of finding a "B" after a "B" in the k^{th} row is equal to the vertical probability of finding "B" in the i^{th} column assuming the preceding column has a "B" in the same row). The latter, significantly, allows us to make *an inference from the time ensemble to the space ensemble;* the world line of one individual is reflected in the cross-section of the world lines of a group. (Whether the latter condition is satisfied is an empirical matter, and not derivable from the laws of probability. This is shown by constructing an infinite lattice wherein we put "B" everywhere to the left of the lattice diagonal line and leave the rest randomized. The independence condition holds, but in every column, the vertical probability is 1 and unequal to the horizontal probability because lattice invariance is not satisfied. Physically, this lattice represents pulling out the dividing wall reversibly.)

Mixing is thus governed by aftereffect, independence and invariance (entailing also that convergence of horizontal and vertical probabilities is also a general feature of all lattices of mixture).

Note that it is incorrect to use the probabilistic/statistical interpretation of thermodynamics to argue that time may occasionally run backwards, and that the past may come back: These are order properties unrelated to the time direction of thermodynamics.

We now attempt to solve the *paradox of the statistical direction:* How can the irreversibility of macroprocesses be reconciled with the reversibility of microprocesses? The latter implies that, in an entropy curve, transitions to high entropy and transitions to low entropy occur with equal frequency. However, this issue appears resolved when, for the entropy curve, we see that inferring from temporal direction to entropic direction tells us that entropy (likely) increases on both sides of time (and thus that the curve presupposes no direction of time). But we see that for this very reason (the symmetry of the entropy curve), we are unable to make any inference from entropic direction to temporal direction. Now, since this symmetric entropy curve and the reversibility objection pertain to a time ensemble, let us try to get our job done by utilizing space ensembles.

Our attempt to define a direction of time failed here because our everyday equation of time direction and entropic movement refers not to the time ensemble of a system's entropy but, rather, the space ensemble of systems' entropies wherein said systems are similar branch systems which emerge/branch out as a low-entropy state out of the entropy curve for a larger system and approach disorder.

Note our current assumptions, now: The entropy curve of the universe is undergoing a long upgrade and branch systems remain isolated for infinitely long.

Make a lattice of mixture: Each row represents the time evolution of one system. It is found that lattice invariance is valid in only one way (for future events, i.e. towards the right) here, and fails for preceding events: The horizontal probability of finding a high-entropy "B" in the i^{th} place *before* a low-entropy "A" is *less than* the vertical probability of finding "B" in the i^{th} column assuming the preceding column has an "A" in the same place. It is likelier that low entropy is succeeded by high entropy rather than preceded by.

The causal laws of physics spoke of and imposed reversibility upon only time ensembles for individual system. An empirical fact about their spatial correspondents breaks the imprisoning symmetry in one swift stroke.

However, this direction is limited to being defined for monotonic sections of the entropy curve of the universe. Furthermore, we can know that we are at an upgrade in two ways: By our deterministic laws (which allow us to infer the fact), or by our theoretical consideration of entropic space ensembles. Note that this is not enough to pin down our notion of temporal direction, however; it is necessary that the independent condition of the branched subsystems also emulating the curve of the universe be satisfied. (Note also that this definition of direction holds for an infinitely large universe whose entropy is undefined: We merely need to limit our consideration to one section and add that our conclusions should hold if this system is the subsystem of a sufficiently large system.)

"The first to have the courage to draw this conclusion was Ludwig Boltzmann. His conception of alternating time directions that are merely sectionally defined by statistical processes represents one of the keenest insights into the problem of time. He refers our time direction to that section of the entropy curve on which we are living. If it should happen that 'later' the universe enters into a long downgrade of the entropy curve, time would have the opposite direction. Since these two sections would be separated by aeons of high-entropy states in which living organisms cannot exist, it would forever remain unknown to the inhabitants of the second time section that their time direction was different from ours. Life is restricted to temperate zones of transition in the entropy curve. Boltzmann compares this problem with the question whether we or our antipodeans 'really' have an upright posture. Boltzmann speaks of the possibility that the universe may consist of different domains, separated by wide empty spaces, which simultaneously have opposite time directions. With his statistical definition of a time direction that is restricted to a section of the total time of the universe, Boltzmann has shown the way to solve the paradox of the statistical direction, the problem of reconciling the unidirectional nature of macrotime with the reversibility of microprocesses. This result is Boltzmann's great contribution to physics and philosophy."

We now consider the assumptions we had made regarding the branch structure. It is not possible to infer from knowledge regarding the entropy of the universe the fact that the entropy curves of the branch subsystems are parallel to each other. It is, however, possible to infer this if we are given the fact that branch systems are transposable to a lattice of mixture as constructed previously, and that they are connected to the main curve by two ends, a low one and a high one.

This uniformity is called *statistical isotropy.* Like Heisenberg's uncertainty principle, this is not a causal law but, rather, falls under a scantily populated but important class: It is a *cross-section law*. Causal connection is absent between the systems.

<u>**Macrostatistics**</u>

In microstatistics, the concept of *order* (class of arrangements) fell back on the concept of *macroscopic distinguishability* and thus fails for macrostatistics. Here, we characterize order by considering the 'simple' rules describing the arrangement. Two arrangements are of the same order if they are rule-indistinguishable for all simple rules. Presuming the equiprobability of all arrangements allows us to conclude the inverse equivalence between the size of a class of arrangements and order and order and probability. Shuffling is *quasi-irreversible* because order can be restored by intervention (unlike the microstatistical analogue).

Everyday life consists of macrostatistical phenomena. Picking up from the hypothesis of the branch structure, we see that an ordered macrostate (the effect) (disintegrating slowly into disorder) is the result of interaction at the (past) lower end of the branch (the cause).

Does this identification hold for a reversed time direction (that is, for the as-yet open possibility that the direction of time was opposite to that of increasing entropy)? Yes: Explanations are now in terms of finality rather than causality. The future produces the past;

one would say that the ordered state occurred in order to facilitate the interaction it engages in.[1]

The origin of the specificity of evidence for past events as opposed to the generality of evidence for future events is now revealed. Interaction is a singularity, whereas order can disintegrate to disorder in many different ways.

Let us take a step back and see how far macrostatistics can take us without presuming the hypothesis of the branch structure.

In macrostatistics, the principle of common cause states that an improbable coincidence always stems from a common cause. This alone allows us to impose a time direction: A common cause means a statistical deviation in the occurrence of a pair of events, whereas a common effect does not mean a statistical deviation in the occurrence of a pair of events.

Now to unearth the relationship between this principle and the second law. Take an ensemble of systems in which one type of systems contains state A and another, state B, each system-type represented by a lattice of its own and originating from a state C. The lattices are coupled by the event C being in the first column of both, apart from which they are independent. Superposing these two lattices and using the statistical definitions of common cause gives us a variation of the aftereffect condition: A variation because A and B are superposed on the same row, and one does not exactly precede the other. Furthermore, lattice invariance holds, but only initially: The states considered may be of very low entropy and thus do not recur soon after entropy increases. This ‘rudimentary’ lattice can therefore be subject to the same laws as a lattice of mixture. Applying the cause-effect conclusions of the hypothesis of the branch structure (by taking the joint occurrence of A and B to be the effect-state) now yields nothing but the principle of common cause; therefore, the latter (statistical dependence in a space ensemble stems from a common cause) is merely another representation of the former.

A record, or information, is a probability disjunction. Intensional information is the initial probability distribution; extensional information tells us (via our false predictions) how to get from this to the actual probability distribution.

When dealing with more than two events, one particular probability cannot give us a full measure of information (a full valuation of the various event-likelihoods). Attaching weights to each event’s probability based on the number of occurrences gives us the a full measure of information. We cleverly set weights and a constant (to ensure nonnegativity) such that information is mathematically the additive inverse of entropy. Differential information, otherwise a measure of extensional information, is shown to be nonnegative and additive (for independent events). Finally, entropy is exhibited to be a direct measure of extensional information (maximal entropy implies maximal ignorance implies minimal intensional information). An interesting remark made here is that there is no analogue to Gibbs’s paradox in information theory: Information is always additive (for independent events); there is no procedure in information theory analogous to opening a window between two gases.

[1]Reichenbach postpones the discussion on why the time direction of psychological experience is causality-oriented but unfortunately and sadly, his demise preceded him penning it down.

We have shown that one of the conceptual arms of entropy is the concept of information. Let us now look at things the other way round.

When we rewrite the principle of common cause in terms of information theory (differential information between observed conjunctions and chance frequencies), we see that unusual coincidences entail a high information which in turn is equivalent to a low entropy. Therefore, information is supplied only by postineraction states.

For the ideal registering instrument, the extensional information related to the probability disjunction of the first set of events turns out to be equal to the intensional information related to the probability disjunction of the coincidence of two correlated events (in other words, the accurate measurement of the observable) (up to an additive constant). Now, since (intensional) information is additive, we seem to have in our hands a violation of the second law: more recordings (increasing intensional information) (in time) mean decreasing entropy (extensional information) (in time). (Note the inverse relationship between intensional and extensional information.) This is understood when we see that increasing disorder refers to the time ensemble of one state, whereas increasing information refers to a space ensemble of postinteraction states. Information increases over space in positive time and entropy, over time in positive time. All the time ensembles of information's space ensemble increase in disorder, i.e., information only decreases over time if left alone.

A macrostatistical causal net/time order is constructed on the basis of the macrostatistical relation of *causally between.* An analysis mirroring the one on Newtonian mechanics is performed on the net. Direction comes about by applying the principle of common cause.

This same net is now constructed in a different manner: Define a *mark* as an irreversible intervention. One event is *causally relevant* to another if a mark in it crops up in the other; and if two events share a mark, one of them must precede or come after the other. It is evident now that a directed causal net can be yielded by this notion. This causal net can be analyzed on the basis of marking, rather than the assumption of the local comparability of time order…assuming the order of marks and the order of macrostatistics is equivalent. Let us look into this.

The assumption is made that if two events share a mark, they coincide abnormally frequently. This is called *positive relevance*, a special form of *causal relevance* (which may be positive or negative statistical deviation). The next assumption is that if a mark is made on an event, it may or may not occur in another event (and so as such leaves other probabilities untouched). The third assumption, the *continuity of mark,* is that if a mark occurs in one event on a causal line, it occurs in all the events on the same line. (It is shown mathematically how violation of this violates the screening-off relation.) The final assumption is that if a set of events screen one event from another, and a mark made in the first shows in the third, the mark must show in at least one of the set of events. We are now in a position to define causal relevance equivalently on purely macrostatistical grounds: If no set of events before or simultaneous with the given event screen it from a given later event such that the two events are abnormally coincident, the given event is causally relevant to the later event.

Quantum mechanics

The fundamental causal laws of quantum mechanics are not irreversible. While Schrodinger's equation is dependent only on the first power of the time variable, there are two distinct equations of evolution corresponding to the two possible directions of time, and observationally verifying any one over the other would require presupposing of a direction of time.

The indeterminism of quantum mechanics is stated: The final description exists, but is imperfect. This conclusion is based on the assumption of the *synoptic principle:* The wavefunction gives the most complete description possible. Let us justify this principle.

The *principle of anomaly* states that giving an exhaustive interpretation by assigning values to phenomena as well as interphenomena is equivalent to assigning values to all observables in the wavefunction (including noncommuting ones) and leads to causal anomalies in interphenomena. If the synoptic principle is true, the if-part of the principle of anomaly cannot be satisfied. Interphenomenon observation becomes impossible and interphenomena can be excluded from discourse and interpreted in a suitable, causal anomaly-eliminating manner (for e.g. calling them waves/particles at our convenience).

A conditional describing a law of nature cannot require a violation of another law of nature under threat of *physical meaninglessness* (they do possess *logical meaning,* and may be said to be vacuously true.) The discussion ends with an interesting reconceptualization of the uncertainty principle: That it tells us that there is no way of determining microcosmic quantities in terms of macrocosmic ones beyond a certain fidelity.

Three necessary conditions for defining the material genidentity/material physical identity of a macroscopic object: Continuity of change, spatial exclusion and verifiability of interchange of spatial exclusion. (Note that the first two characteristics cannot be macroscopically verified, and macroscopic verification of the third could just as well imply functional genidentity). To contrast, functional genidentity (say, some kinetic energy) violates the second and third characteristic.

Does material genidentity exist as a meaningful concept at all? This presupposes the existence of material genidentity of elementary particles. Measurements of entropy are based on statistical properties of particles which are based on the material genidentity of the particles. This is how we may verify material genidentity (more specifically, its third characteristic, which is what defines 'arrangement'). And in fact, verification tests in the quantum realm have given a negative answer to the question, and tells us that particles are indistinguishable (giving rise to the Bose-Einstein statistics).

Noteworthy is the fact that quantum energy phase space is divided into cells of size h.

We have also physical processes defined by Fermi-Dirac statistics by virtue of their adherence to Pauli's exclusion principle. Let us now see how these two statistical procedures imply the nonexistence of material genidentity.

The discussion of genidentity is the discussion of an interphenomena. For Bose-Einstein statistics, if we employ as our extension rule the axiom that all the particles are distinguishable, we arrive at unequally probable arrangements, which entails dependence between events and, finally, nonlocal causal anomalies. For Fermi-Dirac statistics, distinguishability alone does not lead to anomalies; but in conjunction with the exclusion principle, it entails a nonlocal force of repulsion.

The concluded nonexistence of material genidentity and existence of functional genidentity is treatable as inductive evidence for the synoptic principle. Let us now see what notions of entropy the alternative statistics produce.

Rather than a particle lattice, quantum statistics utilizes a state lattice. Here, we define as an arrangement what was in the Maxwell-Boltzmann statistics a distribution, i.e., two arrangements are identical if have the same occupation numbers for corresponding states; as for distributions, we say that two are identical if they have the same occupation *frequencies,* i.e., the number of states having a given number *n* of particles is equal for all *n*.

Having reinstated the equiprobability of arrangements, the expression for entropy is now derived. For Fermi-Dirac statistics, since the occupation number is either zero or one, entropy turns out to be nonzero only when states with differing energy levels are considered.

Note that the state-lattice version of Maxwell-Boltzmann statistics does not yield equiprobable arrangements (indeed, the column with equal occupation numbers throughout its length would be the most probable).

We compute the probability of finding a state in a given occupation number at a particular point of time for all three statistics. For Maxwell-Boltzmann statistics, the most probably occupation number for all states is the one wherein the state has the average number of particles. For Bose-Einstein statistics, the empty state (r=0) turns out to be the most probable one *or*, possibly, the one-particle state (r=1). For Fermi-Dirac statistics, r is either 0 or 1, and we note that the average number of particles per state is always less than or equal to unity.

In general, then, we see that statistical equilibrium for these quantum statistics is not given by equidistribution of particles. Furthermore, we end up with an important difference between quantum-statistical entropy and classical-statistical entropy: Gibbs' paradox is no more. (If particles are indistinguishable, arrangements will not increase by virtue of exchanges upon opening a partition. But wait: What if we deliberately choose two different gases? Reichenbach refers to the concept of *partial likeness* for circumventing this.)

We see that dilution (average number of particles per state decreases) and/or heating (temperature increases entailing an increase in the denominator, i.e. total states) results in a convergence of all three statistical procedures to Maxwell-Boltzmann statistics. A neat illustration: A box is divided into cells in the classical realms and these are homogenous; however, these cells are further divided into smaller cells wherein quantum effects are manifest and it is in these smaller cells that the gas is inhomogenously distributed.

Another way to maintain material genidentity, with its own associated causal anomalies, is explicated: Going from t_1 to t_2, all the particles jump from one state to another, and from an active condition to a frozen (unobservable) condition; and if a particle in a frozen state goes to another state, it cuts off that state from all other particles.

When we remove the condition of conservation of particles from the Bose-Einstein statistics, we arrive at Planck's radiation law.

The spontaneous production and annihilation of a positron-electron pair is reinterpretable as an electron travelling backwards in time to avoid the causal anomaly of spontaneity; however, this forces us to give up not only time direction but also time order in the microcosm, for it is only one causal chain which gets reversed; we also see the possibility of closed causal nets. The asymmetry between the number of positrons and electrons in the Universe combined with statistics is what gives rise to time in the macrocosm.

A partial note from the incomplete conclusion: The psychological direction of time mirrors increasing entropy because the brain is subject to the same laws as an instrument, and records information in a similar manner.