These concepts are based on perspectival temporal and modal asymmetries of the local observer that ground the distinction between sequences running from past to future and those running from future to past, or, more generally, the orientation of sequences with regard to the passage of time. These concepts—causality (lawlike regularities together with antecedent conditions), states, and hidden variables—play a fundamental role in complexity sciences, particularly those branches that make heavy use of heuristic methods for describing the behaviour of the system, characterizing its structural and functional features, and predicting its evolution. Any significant revision of the canonical model of directional-flow-like time may potentially harbour devastating outcomes for these frameworks, operative not only in physics, chemistry, and biology, but also in neuroscience, economics, and the social sciences.

BOLTZMANN'S COPERNICAN SHAKEDOWN OF THE TIME-CONSCIOUS SUBJECT

Drawing attention to the observational and subjective biases within the directional-dynamic picture of time and temporal asymmetries, and pointing out the negative connotations of such biases for the concepts of description, causal explanation, modelling, and prediction is by no means a recent line of inquiry. In what Huw Price calls 'a Copernican moment' and Hans Reichenbach distinguishes as 'one of the keenest insights into the problem of time',[145] Ludwig Boltzmann summarizes the problem in the following remarks, worth quoting in their entirety:

> Just as the differential equations represent simply a mathematical method for calculation, whose clear meaning can only be understood by the use of models which employ a large finite number of elements, so likewise general thermodynamics (without prejudice to its unshakable importance)

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145 See H. Price, 'The Flow of Time', in C. Callender (ed.), *The Oxford Handbook of Philosophy of Time* (Oxford: Oxford University Press, 2011), 282; and Reichenbach, *The Direction of Time* (Los Angeles: University of California Press, 1956), 128.

also requires the cultivation of mechanical models representing it, in order to deepen our knowledge of nature–not in spite of, but rather precisely because these models do not always cover the same ground as general thermodynamics, but instead offer a glimpse of a new viewpoint. Thus general thermodynamics holds fast to the invariable irreversibility of all natural processes. It assumes a function (the entropy) whose value can only change in one direction—for example, can only increase—through any occurrence in nature. Thus it distinguishes any later state of the world from any earlier state by its larger value of the entropy. The difference of the entropy from its maximum value—which is the goal [*Treibende*] of all natural processes—will always decrease. In spite of the invariance of the total energy, its transformability will therefore become ever smaller, natural events will become ever more dull and uninteresting, and any return to a previous value of the entropy is excluded.

One cannot assert that this consequence contradicts our experience, for indeed it seems to be a plausible extrapolation of our present knowledge of the world. Yet, with all due recognition to the caution which must be observed in going beyond the direct consequences of experience, it must be granted that these consequences are hardly satisfactory, and the discovery of a satisfactory way of avoiding them would be very desirable, whether one may imagine time as infinite or as a closed cycle. In any case, we would rather consider the unique directionality of time given to us by experience as a mere illusion arising from our specially restricted viewpoint.[146]

Boltzmann then continues,

For the universe, the two directions of time are indistinguishable, just as in space there is no up or down. However, just as at a particular place on the earth's surface we call 'down' the direction toward the center of the earth, so will a living being in a particular time interval of such a single world distinguish the direction of time toward the less

146 L. Boltzmann, *Lectures on Gas Theory 1896–1898* (New York: Dover, 2011), 401–2.

> probable state from the opposite direction (the former toward the past, the latter toward the future). By virtue of this terminology, such small isolated regions of the universe will always find themselves 'initially' in an improbable state. This method seems to me to be the only way in which one can understand the second law—the heat death of each single world—without a unidirectional change of the entire universe from a definite initial state to a final state.
>
> Obviously no one would consider such speculations as important discoveries or even—as did the ancient philosophers—as the highest purpose of science. However it is doubtful that one should despise them as completely idle. Who knows whether they may not *broaden the horizon of our circle of ideas*, and by stimulating thought, advance the understanding of *the facts of experience*?[147]

Thermodynamics is a thriller, but we all know how its plot unfolds: the film shows the expansion of a gas in a sealed bottle. There is an imaginary compartment with a trapdoor in the bottle (equilibrium $state_1$). Inside this compartment the gas is pressurized. Next the film shows the imaginary door being opened. We can easily anticipate where the story is headed. The gas starts to spread (far from equilibrium) and it finally fills the entire bottle (equilibrium $state_2$). The montage of this film is asymmetrically oriented: once the trapdoor is released, we see gas filling the entire bottle, but never coming back to its original confinement in the imaginary compartment. And even if we watch the movie backwards, we can still tell what the plot is. This is the observed time-asymmetry of an irreversible process. However, there is also a different montage—a subplot—for this film. It shows the molecules of gas colliding with one another and freely moving in every direction. Whether we see this version on fast forward or on rewind, we still cannot tell whether the gas is expanding in one direction or another. This is the time-symmetry of the underlying microscopic mechanical laws. So how can we reconcile the first version of the film with the second?

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147 Ibid., 402–3 (emphases mine).

In the first version of this film we are actually dealing with two laws: the law of approach toward equilibrium, and the second law of thermodynamics. As noted by Jos Uffink and fleshed out by Meir Hemmo and Orly R. Shenker, these two laws express two entirely different sets of facts and require different kinds of explanation.[148] It is an experimental fact—and the extension of the first law as the thermodynamic version of the law of the conservation of energy—that energy tends to change its form (it is not created ex nihilo). But this change is such that the amount of energy exploitable for work decreases over time. This is what is described by both the law of approach toward equilibrium and the second law, but under different explanatory frameworks. The law of approach toward equilibrium is a schematic generalization of our observed experience in so far as it does not by itself tell us which state is the equilibrium state for a given set of constraints in the system. This specificity of the equilibrium state can only be derived nomologically from experience, it cannot be obtained as an a priori theorem of thermodynamics. Whereas the second law of thermodynamics is about the increase of entropy as the '[ordering] of states of equilibrium in time, according to which the amount of energy which is in the form of heat, relative to the amount of energy which is in mechanical or other forms of energy (which are more readily exploitable to produce useful work), cannot decrease'.[149]

With these necessary notes in mind, in the passage by Boltzmann cited above, what vexes the physicist is not the puzzles of the directional-dynamic picture of time, but rather the unproblematic and innocent nature of the assumption that time does in fact have an objective temporal direction. There is a circularity involved in postulating a direction

148 See J. Uffink, 'Bluff Your Way in the Second Law of Thermodynamics', in *Studies in History and Philosophy of Science* vol. 32–3 (Elsevier, 2001), 305–94; and M. Hemmo and O.R. Shenker, *The Road to Maxwell's Demon: Conceptual Foundations of Statistical Mechanics* (Cambridge: Cambridge University Press, 2012).

149 Ibid., 26. Hemmo and Shenker argue that by virtue of these differences, the law of approach to equilibrium and the second law present two different accounts of time-asymmetry that must be explained and tackled on their own terms.

for time based on the observation of irreversible processes *in time*, and inferring the irreversibility of processes on the basis of a canonical, albeit implicitly stated, *arrow of time*. For Boltzmann, the real conundrum is not why entropy increases with time, but why it was ever so low to start with. Formulated differently, rather than asking why entropy increases toward the future, we should ask why it decreases toward the past. The source of Boltzmann's problem lay precisely in what he had initially treated as a key to solving the problem of the second law of thermodynamics: Where does the time-asymmetric characteristic of the second law—which states that entropy increases over time—come from, given the time-symmetric laws of the underlying mechanics? Again, how can the two different versions of the film be made compatible?

Toward the end of the nineteenth century, figures such as Boltzmann and Gibbs had begun to develop a fully statistical (proto-computational/information-theoretic) account of thermodynamics. For Boltzmann, however, this was part of a broader project, one whose aim was to provide 'complete descriptions' of physical phenomena. The stepping-stone of this descriptive project was Boltzmann's reformulation of the concept of scientific description at once removed from the dominant influence of earlier phenomenalist and psychological accounts of description (such as Mach's) and sufficiently fine-grained to be capable of integrating statistical, epistemological, phenomenological, real-ideal, subjective-objective levels and types of description in a nonarbitrary (i.e., intrinsic) manner. To this end, Boltzmann provided three general levels or types of description: pure or abstract description based on inferential generalization of differential equations rather than on a correspondence to observed facts, indirect description based on a probabilistic framework of statistical description, and a level of description concerning unobservables. As Adam Berg argues in *Phenomenalism, Phenomenology and the Question of Time*,[150] Boltzmann's reframing of thermodynamics (specifically the second law) through statistical

150 A. Berg, *Phenomenalism, Phenomenology, and the Question of Time: A Comparative Study of the Theories of Mach, Husserl, and Boltzmann* (Lanham, MD: Lexington Books, 2015), 76.

mechanics should be seen within the scope of this descriptive analysis as a multilevel complex system of coding with distinct descriptive levels that require different appropriate systems of coding, noetic contents, and methods of analysis as well as appropriate spaces for bridging these levels. Within the scope of this multilevel descriptive analysis, which became the skeletal framework of modern scientific theories, Boltzmann developed his statistical theory of the nonequilibrial (i.e., irreversible and time-asymmetric) behaviour of macroscopic systems. He introduced the concept of the 'macrostate' as part of his attempt to relate the second law of thermodynamics to the probability calculus. Physically objective and correlatively defined between the observer and the observed, macrostates are sets of *microstates which by themselves cannot be distinguished by a given observer*.[151] Macrostates are objective insofar as they intrinsically express the one-to-many or many-to-many correlations between the underlying microstates. The introduction of the macrostate is required, then, in order to distinguish thermodynamic regularities that would otherwise be indistinguishable at the level of mechanical microstates. Microstates are, on the other hand, the instantaneous states of the universe. In Boltzmann's framework, a microstate of a single molecule is represented by a point in the state space of that molecule, where the state space represents the space of all the microstates a system can inhabit. This state space is a six-dimensional space comprised of three spatial positions and three momentum dimensions or degrees of freedom. This state space of a single molecule is called μ-space or molecular space.

Boltzmann then associated an entropy value with each macrostate and with each microstate giving rise to that macrostate. In this framework, entropy could be seen as a tendency to evolve toward more probable macrostates, and its increase as information regarding the qualitative dynamic behaviour of macroscopic systems. From the perspective of this new multilevel descriptive analysis, the problems of the second law (i.e., why does entropy increase over time?) and the observed irreversibility and

151 In Boltzmann's vocabulary, 'distribution of state' stands for macrostate and *komplexion* stands for microstates.

time-asymmetry of physical processes in time despite the time-symmetry and reversibility of the underlying mechanical-physical laws, could thus be reframed as the problem of moving from microscopic to macroscopic descriptions. The solution to these problems could then be formulated by devising a statistical mechanical framework that accommodates a conception of macrostate (pertaining to the macroscopic level) expressed in terms of physical probability or permutability, and intrinsically correlated to the microstate (associated with the microscopic level) responsible for it. Within this statistical mechanical resolution, entropy, then, is defined as a tendency toward more probable macrostates, the probability of which is logarithmically defined.

We will not able to delve further into the details of how Boltzmann constructed his solution, but, very briefly, it involved a procedure that would make explicit the connections between statistical and thermal thermodynamic descriptions through the introduction of the concept of macrostate formulated in terms of its probability, and a six-dimensional partition-velocity phase space (the μ-space) which allowed the bridging of microstates and macrostates, microscopic descriptions and macroscopic descriptions. Following Maxwell, Boltzmann began to examine the effects of collisions on the distribution of velocities of molecules of a gas. He introduced a space divided into a finite array of small rectangular cells or intervals of equal size or volume in position and momentum.[152] Once available velocities are partitioned into these cells, then there is an effective combinatorial-computational procedure for examining the effects of collisions on the number of molecules whose velocities entered these cells. It is noteworthy that, in this solution, macrostates do not depend upon the identity of individual molecules entering these cells. They depend upon the identity of the cells in which varying numbers of molecules or particles have been thus distributed.

152 In its original formulation, Boltzmann characterized particles entering the grid boxes or cells in terms of their energy, but he then demonstrated that this formula fails to achieve the Maxwell probability distribution.

Using this combinatorial procedure, Boltzmann was able to argue (1) that the distribution of velocities corresponds to the Maxwell probability distribution, in which the quantity E or H, equivalent to negative entropy, can be said to be decreasing, and (2) that this distribution is independent of the initial distribution of velocities. No matter how particles are initially assigned to the available velocity cell-partitions, we still obtain the same probability distribution, which accounts for the monotonic decrease of H. Demonstrating that the quantity H always monotonically decreases—its lowest value being the state of thermal equilibrium—was proof of the unidirectional and irreversible increase of entropy and the time-asymmetric behaviour of physical processes at the macroscopic level in spite of the reversibility and time-symmetry of the underlying microscopic mechanics.

However, as reflected in the quotes cited earlier, Boltzmann later expressed doubts about his solution and began to examine the challenges raised by adopting a resolutely atemporal perspective. Given the fact that the statistical argument itself is merely a combinatorial-counting procedure and lacks any time-asymmetry, and that therefore there is no reason to apply the increase of entropy to a unique sequence that runs from the past toward the future, it can equally be applied to a sequence running from the future to the past. In which case, as mentioned earlier, what really demands explanation is not the increase of entropy toward the future (i.e., what appears to be a natural state of things) but the ever so low entropy in the beginning, in so far as the statistical argument gives us equal reason to expect an increase of entropy toward the past. It places the burden of explanation on the earlier low entropy rather than the later high entropy. In light of the statistical argument (i.e., equal probability of increase in entropy in either direction, past-to-future and future-to-past), the global decrease of entropy toward the past now appears as an unnatural condition and so itself demands explanation. In other words, for Boltzmann, changing the perspective from temporal to atemporal had turned something natural (low entropy in the past) into something unnatural (high entropy in the past) and therefore, in line with the motivations of scientific explanation, which demand that we account for 'unnatural conditions', called for a shift in explanatory focus. This raised challenges that have vast implications not only for our models of processes and our methods for the metricization of events, but also for what we take to be the established facts of our experience—yet to date these implications have gone largely unheeded.

Even though Boltzmann shifted his efforts toward a reinterpretation of thermodynamics from an atemporal perspective, the deep problematic aspects of his initial solution to the problem of the second law were carried over into his new interpretation, given in the context of the 'cosmological hypothesis',[153] and which was supposed to be free of any particular temporal bias. But what is this problematic aspect which, despite being spotted—at least partially—by Boltzmann, still resurfaced in his later interpretation? The problem with Boltzmann's initial solution was that he had unintentionally imported subjective characteristics of experience into his combinatorial procedure via the introduction of macrostates. In other words, the phenomenal assumptions regarding the facticity of observed time-asymmetry for the ensemble's macrostate were illicitly applied to the description of microstates. In this sense, Boltzmann had not really bridged the gap between statistical

153 'Philosophers had attempted to derive the properties of time from reason, but none of their conceptions compares with this result that a physicist derived from reasoning about the implications of mathematical physics. As in so many other points, the superiority of a philosophy based on the results of science has become manifest. There is no logical necessity for the existence of a unique direction of total time; whether there is only one time direction, or whether time directions alternate, depends on the shape of the entropy curve plotted by the universe.

Boltzmann has made it very clear that the alternation of time directions represents no absurdity. 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, after reaching a high-entropy state and staying in it for a long time, enters into a long downgrade of the entropy curve, then, for this section, time would have the opposite direction: human beings that might live during this section would regard as positive time the transition to higher entropy, and thus their time would flow in a direction opposite to ours. Since these two sections of opposite time directions 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.' Reichenbach, *The Direction of Time*, 128.

mechanical entropy and thermal entropy belonging to different levels of description, but had only elided the distinction between the two descriptive levels by illegitimately transporting the underlying assumptions of one into the other. Indeed, Boltzmann did notice this problem, but what he did not recognize was the *extent* to which the time-asymmetric assumptions specific to the macroscopic description had distorted the statistical-objective description associated with microscopic systems. What he had taken as innocently given initial and boundary conditions were themselves infected by the biases specific to observer-observer correlations. In other words, Boltzmann did not fully realize that the biases of unidirectional time had already infiltrated the law-like principles through which the parameters of the microscopic systems such as initial conditions were being defined and chosen. Following Boltzmann's Oxford lecture, this problem was first recognized by George H. Bryan and Samuel Burbury; it has recently been refined by Huw Price and encapsulated under the principle of molecular or microscopic innocence (μInnocence). μInnocence is the apparently obvious intuition that 'interacting systems are bound to be ignorant of one another until the interaction actually occurs; at which point each system may be expected to "learn" something about the other'.[154]

But what exactly is the problematic nature of this intuition with respect to Boltzmann's later work on bridging statistical entropy with thermodynamic entropy, the so-called Boltzmann's principle formulated by the equation $S = k \log W$? It is the implicit time-asymmetric assumption within Boltzmann's principle of molecular collision or chaos (*stoßzahlansatz*)—the idea that the velocities of two particles that have not collided yet can be said to be uncorrelated, and can therefore be identified as an initial condition, already presupposes a privileged temporal-causal asymmetry. Why? Because

154 See G.H. Bryan, 'Letter to the editor', *Nature* 51 (1894), 175; S.H. Burbury, 'Boltzmann's minimum theorem', *Nature* 51 (1894), 78–9; H. Price, *Time's Arrow and Archimedes' Point* (Oxford: Oxford University Press, 1996), 120; and also the so-called Loschmidt's paradox in the context of Josef Loschmidt's critical response to Boltzmann: J. Loschmidt, 'Zur Grösse der Luftmolecule', *Sitzungsber. Kais. Akad. Wiss. Wien. Math. Naturwiss.* 73 (1876), 128–42.

in so far as microscopic mechanics is time-symmetric and initial microstates are equiprobable, there is no reason to expect the velocities of particles to become correlated as a result of their collisions. Under *stoßzahlansatz*, we anticipate outgoing products of collisions to be dynamically correlated even if they never interact in the future. In other words, we always expect the number of outgoing collisions $(\vec{v}_1, \vec{v}_2) \rightarrow (\vec{v}_1{}', \vec{v}_2{}')$ to be proportional to $f(\vec{v}_1) f(\vec{v}_2)$ where $\vec{v}_1$ and $\vec{v}_2$ are the velocities of particles before the collisions.[155] But we never expect the converse—that the incoming components of a collision will be correlated if they have never encountered each other in the past, i.e., if the molecules have never interacted. As Huw Price suggests, this is a time-asymmetric intuition which has no place in the statistical/information theoretic description of the system. And yet Boltzmann's entire *stoßzahlansatz* is built upon it.[156]

It is as if, as soon as we put in place an incorrect framework for our encounter with the physical universe, no matter what we do from that point onwards, everything will appear to be an incoming chaos. If no direction of time is initially privileged in the description of initial and boundary conditions, since the statistical argument by itself has no time-asymmetric component, then once we adopt an atemporal perspective there is no reason for us to presume that the time-asymmetric explanatory schema of an initial microstate explaining a final macrostate will be tenable. Earlier-than (low entropy) and later-than (high entropy) as atemporal determinations of before and after can very well be contaminated by the biases of a temporal time-asymmetric viewpoint. Accordingly, Boltzmann's true challenge—not fully appreciated even by himself—now boils down to a much more

155 It should be noted that such a classical collision scenario presupposes an implicit 'existence function' since only in classical physics we can assume that particles exist before as well as after the collision. Whereas once we apply collision mechanics to elementary particle physics, particles may appear or disappear through the course of collision. Therefore, if the existence function e is defined on particles and instants, the value of e for a particle p at time t in the classical scenario always equals 1 (i.e., the particle exists). In a nonclassical scenario, the value of the existence function e is $\{0,1\}$.

156 Price, *Time's Arrow and Archimedes' Point*, 26.

fundamental question: How can we suggest that an initial microstate can explain a final macrostate, if what is really in need of explanation is the temporal asymmetry that grounds such an explanatory schema?

It does not take too much critical acuity to realize that a similar question can be posed with regard to those frameworks of causal explanation—specifically utilized in the context of reductionism—that rely on identification of some antecedent conditions and a temporally directed causal arrow through which—thanks to the convenient mediation of time-asymmetry—the distinction between 'the causal' and 'the explanatory' effectively fades away. Nevertheless, the real significance of Boltzmann's challenge is only revealed in its full force when it is treated as a general epistemological critique: How can we justify a chain of inference that follows an explanatory arrow whose ground of justification—its explanans—is nothing more than the past state of affairs as an observable item or an empirical footprint? This question can of course equally be applied to a chain of epistemological inference that runs from the future to the past. In both cases, what needs to be justified is exactly what is taken to be the ground of justification. Thus epistemological neutrality appears to be in sharp conflict with temporally charged modes of epistemological inference. Hoping to retain some aspects of the former while drawing conclusions from the latter in a practical trade-off is more like wishful thinking than a pragmatic paradigm of scientific knowledge.

INDUCTIVE DOGMAS AND COGNITIVE BIASES OF TIME-ASYMMETRY

The illegitimate imposition of time-asymmetric descriptions exclusive to macrostates onto descriptions of microstates in order to explain the behaviours of the former via the mechanics of the latter, therefore, bespeaks a much broader range of complications arising from our epistemological (and not merely perceptual-observational) biases in coordinating our observational frameworks with our theoretical-inferential frameworks. Accustomed to the cosiness of our intuitions and under the theoretical influence of our local subjective biases, we are frequently liable to project our subjective assumptions onto the world and, in doing so, to posit that which itself requires explanation (qua subjective characteristic) as an objective explanatory feature.

The same biases can be detected within theories in which computation is strongly coupled with the postulate of positive entropic increase for irreversible processes. For example, in the thermodynamics of computation it is often held that the physical implementation of any logically irreversible operation such as erasure results in an increase of entropy. The amount of increase is *k*log2 per bit of erased information. Once an observer, via measurements, obtains information concerning which macrostate is the actual state of the observed system, then such information can be manipulated. But macroscopic manipulation of this information—particularly through irreversible logical operations such as erasure and conjunction—results in positive entropy production. In simpler terms, the physical implementation of computation (i.e., physical computers) always exacts an entropy cost. However, there is no a priori necessary connection between the orthodox theory of thermodynamics and the theory of computation which would allow one uncontroversially to associate the logical properties of computation with the principles of classical mechanics. The problem—that of the exact link between thermodynamics and computation, between the physical implementation of logical operations and the fundamental laws of physics—is by no means a settled issue yet.

The information obtained and manipulated is information concerning the macrostate, and the macrostate is observer-related. Therefore the entropy cost of the manipulation or physical implementation of irreversible logical operations is also observer-related, and depends on the specificity of the physical implementation. What is erased, in this sense, is precisely the inferential link or mapping (rather than the memory of the observer itself) between the past macrostate and the present macrostate. In other words, erasure means that the *observer* cannot infer the past macrostate from the present 'recently observed' macrostate (cf. Russell's paradox, discussed below).[157]

157 For a far more sophisticated and detailed engagement with the positive entropic interpretation of the physical implementation of irreversible logical operations, see Hemmo and Shenker, *The Road to Maxwell's Demon*, particularly chapter 12.

It might be objected that time-asymmetry and temporal descriptions are only useful fictional instruments (at best subjectively, at worst speculatively metaphysical) that allow us to talk about nontemporal events and processes. It is true that, as Adolf Grünbaum—that most astute debunker of the mysteries of space and time—has spelled out, our sense of time as a flow is only a qualitative conception devoid of metrical components.[158] But as we have seen, this qualitative conception is liable to corrupt the metrical ingredients of our scientific frameworks even when its interference is least expected. Objections that dismiss temporal descriptions and time-asymmetry as useful idealizations or metaphysical fictions can reinforce our obliviousness to the influence that our temporal intuitions exert upon models and methods we assume to be unaffected by any objective or subjective account of time-asymmetry. In doing so, rather than giving reason for making a radical scission from temporal intuitions, they give more reason for further postponement of the overdue critical task—namely, the examination of the extent of the distorting effects temporal intuitions have had and continue to have on scientific models and methods.

Reference to the empirical success of confirming observations regarding time-asymmetric behaviours runs, from different directions, not only into the old and new riddles of induction concerning future observations, as stated by Hume and Goodman,[159] but also into the problematics of the reliability hypothesis concerning the memory-driven knowledge of past observations, as formulated by Russell's 'five minutes ago' paradox:[160]

> In investigating memory-beliefs, there are certain points that must be borne in mind. In the first place, everything constituting a memory-belief is happening now, not in that past time to which the belief is said to refer. It is not logically necessary to the existence of a memory-belief that the event remembered should have occurred, or even that the

158 A. Grünbaum, *Philosophical Problems of Space and Time* (Dordrecht: D. Reidel, 1973).

159 N. Goodman, 'The New Riddle of Induction', in *Fact, Fiction, and Forecast* (Cambridge, MA: Harvard University Press, 1979), 59–83.

160 See Appendix.

> past should have existed at all. There is no logical impossibility in the hypothesis that the world sprang into being five minutes ago, exactly as it then was, with a population that 'remembered' a wholly unreal past. There is no logically necessary connection between events at different times; therefore nothing that is happening now or will happen in the future can disprove the hypothesis that the world began five minutes ago. Hence the occurrences which are called knowledge of the past are logically independent of the past; they are wholly analysable into present contents, which might, theoretically, be just what they are even if no past had existed.[161]

As observers, we take our memories to be reliable reflections of actual states of affairs, and, given that the content of our memory is that entropy was lower in the past based on *memories* of previous observations, our microscopic retrodiction concerning low initial entropy should also be seen as reliable. But according to Russell's five minutes ago paradox, since the contents of our memories are not derived from mechanics, and to the extent that there are many-to-one correlations between our memory states and the universe (as opposed to a one-to-one correlation), successful retrodictions can be false memory-beliefs, the falsity of which is a matter of logical tenability. Russell, however, attempts to stave off the hazardous effect of his paradox by discrediting it as simply 'uninteresting'[162] and instead in the last instance saves the memory-driven knowledge of the past.

Russell's line of reasoning in defence of a memory-driven knowledge of the past runs like this: Such knowledge depends not on the occurrence of more instances of identical observations, but rather on two suitable belief-supporting series in which memory-images can be classified. The first series classifies memory-images in terms of the less or more remote periods of the past to which such memory-images refer (henceforth, P-series). The second series classifies memory-images based on the degree of our confidence in their accuracy (henceforth, Q-series). In the Q-series, what warrants our

161 B. Russell, *The Analysis of Mind* (London: George Allen & Unwin, 1921), 159–60.

162 Ibid., 160.

confidence or lack thereof is the $sense_2$ of familiarity among the memory-images themselves as being $sensed_1$ as more or less familiar (familiarity by degree). The more familiar memory-images give us a $sense_2$ of accuracy of those images and thus the belief or judgment that what is happening now has happened before. In the P-series, the $sense_2$ of the nearness or distance of memory-images is given on the basis of how we remember (again a matter of degree) a remembered event as the time between the remembering and the remembered varies. Those rememberings that are more recent have more remembered context either because memory-images are $sensed_1$ as successively following their precursors, or because some $sensations_1$—so-called akoluthic sensations or memory-based sensations[163]—are apprehended as present, others as fading and thus apprehended as the marks of just-pastness. Now, in so far as our rememberings always start from what has more context (i.e., is more recent) and the fading increases as the time increases, the P-series gives us a $sense_2$ qua justified belief that the series of memory-images being so remembered extends from present to just-past to past (the fading of sensations belonging to the akoluthic phase). Accordingly, the combination of P-series and Q-series—the belief-supporting feelings of the pastness and the familiarity of memory-images—provide us with a justified and reliable knowledge of the past.

As you may already suspect, based on how I have numerically distinguished the occurrences of the word 'sense', the problem with Russell's reasoning is that what is $sensed_1$ qua organized sense-impression—the feeling *of—by itself* does not so readily and directly translate into $sense_2$

163 'At the beginning of stimulus we have a sensation; then a gradual transition; and at that end an image. Sensations while they are fading called "akoluthic" sensations. When the process of fading is completed (which happens very quickly), we arrive at the image, which is capable of being revived on subsequent occasions with very little change.' Ibid., 175. Russell's terms *akoluthic sensations* and *akoluthic stage* are borrowed from the work of Richard Wolfgang Semon. According to Semon, as soon as each sensation is experienced, it enters the akoluthic phase wherein it durationally affects or persists in the mind in a faint or subconscious manner. This manner of sensing then makes it possible for one sensation to be *associated* with another sensation in the akoluthic phase.

qua judgement or belief proper. The myth of the given rears its head once again here. But even setting this issue aside, by themselves the senses$_1$ of the more familiar and the sense$_1$ of the more remembered context are too arbitrary. There can be many-to-many mappings or thematic affinities between the elements of both P-series (rememberings and remembereds) and Q-series (the more familiar, the less familiar, the vaguely familiar, and the unfamiliar) in such a way that ordering becomes a matter of entirely arbitrary selection.

Moreover, the more significant issue is not that the sense$_1$ can be illusory, but rather that the sense$_2$ of the memory-images being thus-and-so recognized and remembered (as knowledge of the past) is first and foremost a statistical inference rather than a proper logico-semantic judgement. In other words, the semantic sense$_2$ is a linguistic whitewash over the fact that it is merely a statistical or inductivist inference just like sense$_1$. The difference between the two is that the former is at the level of the linguistic and the latter is at the level of the causal. Despite Russell's contention, sense$_2$ is nothing more than or superior to sense$_1$, other than being what linguistically bespeaks or betokens the causal-statistical sense$_1$.

Imagine you are a detective, investigating a crime scene in some desolate and dreary town in New England in the middle of winter. Near the site of the crime, you see traces which resemble the tracks made by a car's tires. You instantly associate the trace with the movement of a car based on memories of your previous observations. This association is purely statistical since the wind or some diabolically smart culprit bent on distracting you and wearing shoes with bizarre soles could also have formed these traces. Although this is highly improbable, it is neither probabilistically impossible nor logically untenable. The same holds for the previous observations of which you have a memory.

Our linguistic judgement regarding the trace being associated with a car is only a semantic-intentional counterpart of the statistical-anticipatory model of our memory as a part of our nervous system. It does not give us an epistemic status above our inferential retrodiction regarding what has caused the trace in the snow, nor does it entitle us to believe that the association of the track with a moving car has a more robust probability or an a priori logical necessity. It is not the case that sense$_2$ represents a belief proper as opposed to sense$_1$; its epistemic status is no higher than that of sense$_1$. It is in fact a belief biased by or formed by the structure and anticipatory model of our nervous system. To treat sense$_2$ as a special sort of belief with superior epistemic content is only an instance of linguistic legerdemain. This is not to say that the sensing$_2$ of the trace is not linguistic or conceptual (i.e., a piece of judgement), but rather that its linguistic features should not mask the fact that it is—like the causal sense$_1$—a retrodiction, and not a statistically or a priori logically necessary belief as such.

It then follows that Russell's emphasis on the distinction between the mere causal-statistical impressions of memory-images and justified conceptual beliefs with additional epistemic content turns out to be a feat of semantic dissimulation. The sense$_2$ of the trace is nothing but the linguistically-laden counterpart of the sense$_1$ which is causal and statistically retrodictive in its entirety. In view of the fact that the sense$_2$ is nothing but the linguistic intimation of the retrodictive aspect of the causal sense$_1$ and nothing more, Russell's memory-driven knowledge of the past falls again under the axes of the old and new riddles of induction, and those of his own five minutes ago paradox. The one-to-many (or even many-to-many) correlations between our memory and the rest of the universe make the issues of the unreliability of our memory-driven knowledge of the past and the possibility of the incursion of other causes in forming the track, both statistically probable and logically tenable. It is indeed tempting to dismiss the sceptical hypotheses regarding the memory-driven retrodiction of the past or predictions of the future observations as uninteresting, but interestingness is only a matter of subjective cognitive bias, and is not remotely connected to the interests of what is actually objective.

Returning to our crime thriller example, the objective investigation of the crime scene begins not with the detective linking the trace in the snow with a car's tires based on memory-driven associations in the past, but with the suspension of such cognitive biases. It is only when the detective breaks off from such belief-dispositions or entrenched cognitive biases that she can begin to conduct a true detection of the crime scene, thus cracking open the secrets of the crime scene beyond the level of associations which are no more than the product of an egocentric subject.

Whether the retrodiction of the past is obtained from memory-states themselves or from the inductive generalization of our memories, the knowledge of the low-entropy past hits a brick wall when there is no definitive memory of the past owing to one-to-many or many-to-many (rather than one-to-one) correlations between our memory-states and the states of the universe. Nevertheless, we can reasonably rely on our modest *contextual* theories in which our retrodictions of known past observations can be taken to be similar to our predictions of future observations. But the price to be paid for this bona fide modesty—admitting that we have no definitive memory of the past, and that our knowledge of the known qua observed past can never be overextended to knowledge of the unknown qua unobserved past—is the admission that the entropy gradient can increase or decrease as much toward the past as it can increase or decrease toward the future. The probability and logical tenability of both scenarios enjoy an equal rank.

One can always attempt to quash the logical tenability of the riddles of induction or, in the case of the five minutes ago paradox, resort to the epistemological reliability of the principle of simplicity. But to make a wholesale appeal to the epistemological reliability of successful observations through an argument from the standpoint of the principle of simplicity is like wielding a wooden club and claiming it is Occam's razor. For the principle of simplicity is only a pragmatically and contextually effective tool. It is neither truth-indicative nor is it a law indexing an inherent simplicity in the world that can be invoked in every context. Following Grünbaum, if simplicity or elegance were the best explanations in the toolbox of knowledge, then we should have all abandoned the Darwinian worldview in favour of the theistic one, for the latter boasts a far more elegant simplicity.[164]

164 A. Grünbaum, 'Is Simplicity Evidence of Truth?', *American Philosophical Quarterly* 45:2 (2008), 179–89.