MECHANICS AND INFINITE SPACE

A GRAMMATICAL INVESTIGATION INTO THE CONCEPTS OF FAUSTIAN PHYSICS

ADAM KRELLENSTEIN

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Eine Ehrenrettung der Scholastik steht, wenn nicht alles täuscht, auch in dieser Beziehung bevor, sie ist schon im vollen Gange. Kopernikus wird von Ptolemäus geschlagen werden. Die heliozentrische These begegnet nachgerade einem geistigen Widerstand, dessen Unternehmungen wahrscheinlich zum Ziele führen werden. Die Wissenschaft wird sich philosophisch genötigt sehen, die Erde in alle Würden wieder einzusetzen, die das kirchliche Dogma ihr wahren wollte.

—Thomas Mann[1]

1 Mann, *Der Zauberberg*, 503 [Translation: "The honor of the scholastics will be vindicated in this regard as well, if I am not mistaken. Indeed the process is well under way. Copernicus will be routed by Ptolemy. The theory of heliocentrism is now being opposed by intellectual forces whose efforts will presumably attain their desired goal. Science will find itself philosophically constrained once again to grant earth all the honors that Church dogma wished to preserve for it." (*The Magic Mountain*, chap. 6)]

INTRODUCTION

The aim of this work is to serve as an investigation into the logic, or grammar,[1] of the words and concepts relating to the natural world, for instance 'motion,' 'determinism,' 'observation,' and 'space,' the same way one might examine the grammar of expressions of 'pain' in the philosophy of mind[2] or the significance of 'Romanticism' in the philosophy of history[3]. The practice of natural philosophy, in contrast to that of Natural Science, explicitly does not make use of theoretical or empirical methods of any kind. Like other branches of philosophy, the philosophy of nature is concerned with what is *necessary* rather than what is accidental (i.e., incidental); it is concerned not with constructing ever-more sophisticated models for predicting the behavior of particular phenomena, but rather with improving our understanding of the fundamental, foundational concepts of our world-view for its own sake.

> For there seemed to pertain to logic a peculiar depth—a universal significance. Logic lay, it seemed, at the bottom of all the sciences.—For logical investigation explores the nature of all things. It seeks to see to the bottom of things and is not meant to concern itself whether what actually happens is this or that.—It arises, not from an interest in the facts of nature, nor from a need to grasp causal connexions: but from an urge to understand the basis, or essence, of everything empirical. Not, however, as if to this end we had to hunt out new facts; it is, rather, of the essence of our investigation that we do not seek to learn anything new by it. We want to understand something that is already in plain view. For this is what we seem in some sense not to understand. —Ludwig Wittgenstein[4]

Today, all modes of inquiry into the natural world that are not based, explicitly or implicitly, on the methods of Natural Science are understood to be patently anachronistic and ultimately valueless. The very existence of philosophy proper seems to threaten the scientific progress which we now commonly recognize to be our highest goal and best means of furthering

1 "*Essence* is expressed by grammar." (Wittgenstein, *Philosophical Investigations*, § 371)
2 Wittgenstein, *Philosophical Remarks*, § 65.
3 Spengler, *The Decline of the West: Form and Actuality*, 108.
4 Wittgenstein, *Philosophical Investigations*, § 89

our understanding of the world.[5,6,7] Accordingly, natural philosophy has been effectively dead as an academic discipline for most of the past two centuries,[8] and all efforts in that tradition are now regarded as something falling between idle fancy and sheer quackery.[9]

But Natural Science—and mathematical physics in particular[10]—is a grand edifice built on particular conceptual foundations, and it is within those foundations that many of the greatest problems lie. Questions such as "What is the nature of space?", "What counts as an observation?", and "Is the world fundamentally deterministic?"—widely held to fall within the domain of Natural Science[11,12]—are in fact philosophical problems, and they must be treated accordingly.[13] General Relativity, for instance, says nothing whatsoever about the nature of space and time;[14] rather, it merely provides a model for the precession of the perihelion of Mercury, the bending of light by massive bodies, and so forth. 'Space' and 'time' are concepts that may be used in the description of those predictions; but, notably, all of the same predictions might have been expressed perfectly well using entirely different concepts.

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5 "The only justification for our concepts and system of concepts is that they serve to represent the complex of our experiences; beyond this they have no legitimacy. I am convinced that the philosophers have had a harmful effect upon the progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism, where they are under our control, to the intangible heights of the *a priori*. For even if it should appear that the universe of ideas cannot be deduced from experience by logical means, but is, in a sense, a creation of the human mind, without which no science is possible, nevertheless this universe of ideas is just as little independent of the nature of our experiences as clothes are of the form of the human body. This is particularly true of our concepts of time and space, which physicists have been obliged by the facts to bring down from the Olympus of the *a priori* in order to adjust them and put them in a serviceable condition." (Einstein, *The Meaning of Relativity*, 2)

6 "Only rarely did it seem to me [that philosophy of science has] anything to do with the work of science as I knew it. [...] I am not alone in this; I know of *no one* who has participated actively in the advance of physics in the post-war period whose research has been significantly helped by the work of philosophers." (Weinberg, *Dreams of a Final Theory*, 133–34)

7 "Philosophical clarity will have the same effect on the growth of mathematics as sunlight has on the growth of potato shoots. (In a dark cellar they grow yards long.)" (Wittgenstein, *Philosophical Grammar*, 381)

8 "And then, during the 18^{th} and 19^{th} centuries, natural philosophy died. It split into empirical science on the one hand, and philosophy on the other." (N. Maxwell, "In Praise of Natural Philosophy: A Revolution for Thought and Life," 2)

9 "It has become a tradition among those who talk glibly about science that the romantic *Naturphilosophie* of Schelling and his followers represents the lowest degradation of science and that only by completely freeing themselves from that nightmare were modern biology and medical science able to resume their scientific progress. The incident has been used by empiricists as a moral to warn us against speculative philosophy in the natural sciences." (Cohen, *The Meaning of Human History*, 208)

10 "All science is either physics or stamp collecting," (Ernest Rutherford, quoted in Black, "A Lend-Lease Program for Philosophy and Science," 168)

11 "The elements of the physical reality cannot be determined by *a priori* philosophical considerations, but must be found by an appeal to results of experiments and measurements." (Einstein, Podolsky, and Rosen, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" 777)

12 "How can we understand the world in which we find ourselves? How does the universe behave? What is the nature of reality? Where did all this come from? Did the universe need a creator? Most of us do not spend most of our time worrying about these questions, but almost all of us worry about them some of the time.¶ Traditionally these are questions for philosophy, but philosophy is dead. Philosophy has not kept up with modern developments in science, particularly physics. Scientists have become the bearers of the torch of discovery in our quest for knowledge." (Hawking and Mlodinow, *The Grand Design*, 5)

13 "If therefore philosophy were to succeed in creating a system such that in all cases mentioned it stood out clearly when a question is not justified so that the drive towards asking it would gradually die away, we should at one stroke have resolved the most obscure riddles and philosophy would become worthy of the name of queen of the sciences." (Boltzmann, "On Statistical Mechanics," 167)

14 "I had just read Weyl's book *Space, Time and Matter*, and under its influence was proud to declare that space was simply the field of linear operations.¶ 'Nonsense,' said Heisenberg, 'space is blue and birds fly through it.' " (Bloch, "Heisenberg and the Early Days of Quantum Mechanics," 27)

The role of philosophical thought in the development of our concepts of physics is, characteristically, widely misunderstood. Thought experiments,[15] for instance, are described as experiments "performed in the laboratory of the mind"[16] and based on "empirical data [that are] well-known and generally accepted,"[17] which expresses the intellectual fixation on empirical inquiry. Certainly, a thought experiment is nothing more than a logical argument in the form of a hypothetical construction.[18,19] As Galileo investigated the relativity of motion with his thought experiment describing the motion of objects falling from the mast of a moving ship,[20] so we aim to elucidate the meaning of other such concepts integral to physics. A thought experiment—and philosophical reasoning more generally—can say nothing in regards to whether, for instance, some lead ball dropped from the mast of a ship will actually fall parallel to the mast (because of the wind, say); but it makes clearer what we mean when we say in this case, "The ball fell *down*."[21]

Ernst Mach especially made great strides in natural philosophy when he attempted to ground the science of mechanics in the analysis of sensations. Not because everything is a mere sensation[22] (when I drop a rock on my toe it is not a sensation that has injured me[23]), but because "the meaning of a word is its use in the language."[24] So the meaning of the word 'distance' is seen in how distance is measured (e.g., with a rigid rod, *per* Einstein[25]).

15 Cf., "At the core of the discussion sits a relatively simple epistemological challenge that is presented in a particularly powerful manner by numerous thought experiments that the history of science has to offer. They suggest that we can learn about the real world by virtue of merely thinking about imagined scenarios. But how can we learn about reality (if we can at all), just by thinking in such a way? Are there really thought experiments that enable us to acquire new knowledge about nature without new empirical data? If so, where does the new information come from if not from contact with the realm of investigation under consideration in an imagined scenario? Finally, how can we distinguish good from bad instances of thought experiments? These questions seem urgent with respect to scientific thought experiments, because many 'recognize them as an occasionally potent tool for increasing our understanding of nature [...] Historically their role is very close to the double one played by actual laboratory experiments and observations. [...] ' " (Brown and Fehige, "Thought Experiments")

16 J. R. Brown, *The Laboratory of the Mind*, 1.

17 Kuhn, "A Function for Thought Experiments," 241.

18 "What Mach calls a thought experiment is of course not an experiment at all. At bottom it is a grammatical investigation." (Wittgenstein, *Philosophical Remarks*, 52)

19 "Thought experiments are arguments." (Norton, "Are Thought Experiments Just What You Thought?," 354)

20 "[D]rop a lead ball from the top of the mast of a boat at rest, noting the place where it hits, which is close to the foot of the mast; but if the same ball is dropped from the same place when the boat is moving, it will strike that distance from the foot of the mast which the boat will have run during the time of fall of the lead, and for no other reason than that the natural movement of the ball when set free is in a straight line toward the center of the earth." (Galilei, *Dialogue Concerning Two Chief World Systems—Ptolemaic & Copernican*, 126)

21 "Or like saying that a die must fall on one of six sides. When the possibility of a die's falling on edge is excluded, and not because it is a matter of experience that it falls only on its sides, we have a statement which no experience will refute—a statement of grammar. Whenever we say that something *must* be the case we are using a norm of expression. Hertz said that wherever something did not obey his laws there must be invisible masses to account for it." (Wittgenstein, *Wittgenstein's Lectures, Cambridge, 1932–1935*, 16)

22 "Bodies do not produce sensations, but complexes of elements (complexes of sensations) make up bodies. If, to the physicist, bodies appear the real, abiding existences, whilst the 'elements' are regarded merely as their evanescent, transitory appearance, the physicist forgets, in the assumption of such a view, that all bodies are but thought-symbols for complexes of elements (complexes of sensations)." (Mach, *The Analysis of Sensations*, 29)

23 "If I wanted to eat an apple, and someone punched me in the stomach, taking away my appetite, then it was [not] this punch that I originally wanted." (Wittgenstein, *Philosophical Remarks*, § 22)

24 Wittgenstein, *Philosophical Investigations*, § 43.

25 "If, in pursuance of our habit of thought, we now supplement the propositions of Euclidean geometry by the single proposition that two points on a practically rigid body always correspond to the same distance (line-interval), independently of any changes in position to which we may subject the body, the propositions of Euclidean geometry

One does not perceive facts about distance itself, but about the distance between such-and-such objects;[26,27] rather, distance is a concept that may be used in the description of the relationship between all objects of a specific form,[28] and the logic of the concept is, *pace* Mach, knowable *a priori*.[29]

This work, then, is an attempt to revive natural philosophy as a discipline independent from, and complementary to, Natural Science. It is not an attempt to construct a particular model (a 'picture') of the world[30]—which may or may not accord with reality[31]—but rather to describe our models *themselves*.[32] (My description of the picture is not a description of reality. . . the *picture* is.) Its goal is to dispel confusion and obfuscation manifest in our thought and language.[33] In particular, we shall strive to characterize the pictures of the natural world that are found in the **Faustian**[34] (i.e., West-European–American) tradition of science and philosophy. The foundational principles of this tradition (Conservation of Energy, the Equivalence Principle, Newton's Laws of Motion, etc.), commonly described as 'natural laws' and as applicable across all physical domains,[35,36] are nothing more than the grammatical features of the sorts of pictures that our science has developed.[37,38] By describing these pictures from Natural Science, and their limits of applicability, we hope to arrive at a position to tackle long-standing philosophical problems rooted in persistent

then resolve themselves into propositions on the possible relative position of practically rigid bodies." (Einstein, *Relativity*, 3)

26 "Time, space, and mass in themselves are in no sense capable of being made the subjects of our experience, but only definite times, space-quantities, and masses." (Hertz, *The Principles of Mechanics*, 139)

27 "We ought not to forget that any description of the world by means of mechanics will be of the completely general kind. For example, it will never mention *particular* pointmasses: it will only talk about *any pointmasses whatsoever*." (Wittgenstein, *Tractatus Logico-Philosophicus*, § 6.3432)

28 Cf. "Space, time, colour (being coloured) are forms of objects." (Wittgenstein, *Tractatus Logico-Philosophicus*, § 2.0251)

29 "Moreover, when his empirically minded Aristotelian opponent asks him, 'Did you make an experiment?' Galileo proudly declares: 'No, and I do not need it, as without any experience I can affirm that it is so, because it cannot be otherwise.' " (Koyré, "Galileo and the Scientific Revolution of the Seventeenth Century," 13)

30 "The proposition is a model of reality as we imagine it." (Wittgenstein, *Notebooks 1914–1916*, § 27.10.14)

31 "A system of propositions is laid like a yardstick against reality." (Wittgenstein, *Philosophical Remarks*, 317)

32 "Philosophy is the doctrine of the logical form of scientific propositions (not only of primitive propositions)." (Wittgenstein, *Notebooks 1914–1916*, 106)

33 "Only very slowly and gradually will all these illusions recede and I regard it as a central task of philosophy to give a clear account of the inappropriateness of this overshooting the mark on the part of our thinking habits; and further, in choosing and linking concepts and words, to aim only at the most appropriate expression of the given, irrespective of our inherited habits. Then, gradually, these tangles and contradictions must disappear." (Boltzmann, "On Statistical Mechanics," 167)

34 Spengler, *The Decline of the West: Form and Actuality*, 183.

35 "The workings of our minds and bodies, and of all the animate or inanimate matter of which we have any detailed knowledge, are assumed to be controlled by the same set of fundamental laws, which except under certain extreme conditions we feel we know pretty well." (Anderson, "More is Different," 393)

36 "First and foremost, the laws are universal [. . .] The laws are taken to apply unfailingly everywhere in the universe and at all epochs of cosmic history. No exceptions are permitted." (Davies, *The Mind of God*, 82–83)

37 "Mechanics determines one form of describing the world by saying that all propositions used in the description of the world must be obtained in a given way from a given set of propositions — the axioms of mechanics. It thus supplies the bricks for building the edifice of science, and it says, 'Any building that you want to erect, whatever it may be, must somehow be constructed with these bricks, and with these alone'." (Wittgenstein, *Tractatus Logico-Philosophicus*, § 6.341)

38 "We do not believe *a priori* in a law of conservation, we *know a priori* the possibility of its logical form.¶ All those propositions which are known *a priori*, like the principle of sufficient reason, of continuity in nature, etc., etc., all these are *a priori* insights relating to the possible ways of forming the propositions of natural science." (Wittgenstein, *Notebooks 1914–1916*, § 23.4.15)

misunderstandings of the logic of our world-view and,[39] in the process, to show how the concepts fundamental to that world-view are all connected to each other and to the deep symbols of Faustian culture.[40]

39 "I think I can safely say that nobody understands quantum mechanics [. . .] " (Feynman, *The Character of Physical Law*, 129)

40 "But before the curtain falls, there is one more task for the historical Faustian spirit, a task not yet specified, hitherto not even imagined as possible. There has still to be written a *morphology of the exact sciences*, which shall discover how all laws, concepts and theories inwardly hang together as forms and what they have meant as such in the life-course of the Faustian Culture. [...] We shall inquire whence came these forms that were prescribed for the Faustian spirit, why they had to come to our kind of humanity particularly and exclusively, and what deep meaning there is in the fact that the numbers that we have won became phenomenal in just this picture-like disguise." (Spengler, *The Decline of the West: Form and Actuality*, 425)

1

THE GRAND WORLD-MACHINE

> *[Western physics], as a science, is an immense system of* indices *in the form of names and numbers whereby we are enabled to work with Nature as with a machine. As such, it may have an exactly-definable end.* *—Oswald Spengler*[1]

In the Faustian conception of Nature, the world is like a great *machine*.[2,3] Underlying all of the "apparent chaos"[4] of the world, there is supposed to exist the "objective reality"[5,6,7] of an inner mechanism[8] that is eternal, absolute, and perfectly knowable.[9] We say that **Mechanical** models are the only true pictures of the world[10] and that the principles of Mechanics thereby represent reality itself.[11] The central aim of Natural Science is then

1 Spengler, *The Decline of the West: Form and Actuality*, 378.

2 "My aim is this, to show that the celestial machine is not like a divine creature, but like a clock (and he who believes there is an animate force in a clock assigns the glory of the craftsman to the work), as nearly all the diversity of motions are caused by a simple, magnetic and corporeal force, just as all the motions of a clock are caused by the simplest weight." (Johannes Kepler, quoted in Snobelen, "The Myth of the Clockwork Universe: Newton, Newtonianism, and the Enlightenment," 177)

3 "The entire universe is a machine in which everything is made by figure and movement." (René Descartes, quoted in Barbour, *The Discovery of Dynamics*, 409)

4 "[T]he system of concepts that is unambiguously coordinated with the world of experience is reducible to a few basic principles, from which the whole system can be logically derived. With every important new advance the scientist finds his expectations exceeded, in that the fundamental laws, under the pressure of experience, become more and more simplified. With amazement he beholds the apparent chaos fitting into a sublime order that is to be attributed not to the dominion of his own mind but to the constitution of the world of experience." (Albert Einstein, quoted in Cassirer, *Determinism and Indeterminism in Modern Physics*, 67)

5 Einstein, Podolsky, and Rosen, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" 777.

6 Deutsch, "Quantum Theory as a Universal Physical Theory," 4.

7 Hawking and Mlodinow, "The (Elusive) Theory of Everything," 70.

8 "[Nature's] fundamental laws do not govern the world as it appears in our mental picture in a very direct way, but instead they control a substratum of which we cannot form a metal picture without introducing irrelevancies. The formulation of these laws requires the mathematics of transformations." (Dirac, *The Principles of Quantum Mechanics*, vii)

9 "Physics is an attempt conceptually to grasp reality as it is thought independently of its being observed. In this sense one speaks of 'physical reality.' " (Einstein, "Autobiographical Notes," 81)

10 "All physicists agree that the problem of physics consists in tracing the phenomena of nature back to the simple laws of mechanics." (Hertz, *The Principles of Mechanics*, xxi)

11 "If therefore we can liberate ourselves from an old and unfounded prejudice and from the lazy philosophy that tries to hide a sluggish lack of knowledge behind a pious face, then I hope to found a sure conviction on incontrovertible grounds: that the world recognizes a mechanical development out of the universal laws of nature as the origin of its constitution;" (Kant, "Universal Natural History and Theory of the Heavens or Essay on the Constitution and the Mechanical Origin of the Whole Universe According to Newtonian Principles," 282)

the incremental discovery[12,13] of this hidden mechanism,[14,15,16] which, for all of its intricacies, may be mysterious, but is never irregular nor inconsistent.[17,18,19]

Faustian culture comprehends the challenges of modeling and measurement exclusively in terms of the presence of 'confounding factors' which impede one's clear view of objective fact.[20,21,22] Every model of the world is understood to be a convenient[23] *approximation*[24,25,26] of the underlying reality, in that some more or less important details are left out of it,[27] and it is even called 'incorrect' therefore,[28,29] as if adding further detail to any picture of reality should bring it closer to *being* reality. We are led to

12 "But like the *Rain-bow* in a *Cloud* of mine. / Yet there's a *Law* by which I *discompose* / The *Ashes*, and the *Fire* it self *disclose*, / But in his *Emrald* still *He* doth appear, / They are but *Grave-clothes* which he scatters here. / Who sees this *Fire* without his *Mask*. his *Eye* / Must needs be *swallow'd* by the *Light*, and *die*." (Philalethes, *Anthroposophia Theomagica*, 54)

13 "The very word 'discovery' has something bluntly un-Classical in it. Classical man took good care not to take the cover, the material wrapping, off anything cosmic, but to do *just this* is the most characteristic impulse of a Faustian nature." (Spengler, *The Decline of the West: Form and Actuality*, 278)

14 "[T]he final aim of Natural Science is to discover the motions underlying all alteration, and the motive forces thereof; that is, to resolve itself into Mechanics." (Hermann von Helmholtz, quoted in Spengler, *The Decline of the West: Form and Actuality*, 377)

15 "For us there exists nothing but mechanical knowledge, no matter how miserable a substitute it is for true knowledge, and accordingly only one true form of scientific thought, that of mathematical physics." (Emil du Bois-Reymond, quoted in Cassirer, *Determinism and Indeterminism in Modern Physics*, 6)

16 "The specific tendency of all Western mechanics is toward an intellectual *conquest by measurement*, and it is therefore obliged to look for the essence of the phenomenon in a system of constant elements that are susceptible of full and inclusive appreciation by measurement [...] " (Spengler, *The Decline of the West: Form and Actuality*, 377)

17 "[N]or are we to recede from the analogy of Nature, which is wont to be simple, and always consonant to itself." (Newton, *The System of the World*, 398)

18 "Subtle is the Lord, but malicious He is not." (Albert Einstein, quoted in Pais, *Subtle is the Lord*, vi)

19 "[T]he heavenly bodies move with such regularity, orderliness, and symmetry that it is truly a marvel; and they continue always to act in this manner ceaselessly, following the established system, without increasing or reducing speed and continuing without respite [...] " (Oresme, *Le Livre du ciel et du monde*, 282)

20 "The experiment is to be freed from all accidental circumstances that were a disturbing factor in the beginning; it is to be purged of possible experimental errors." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 86)

21 The sentiment is that *reality gets in the way of seeing reality*. Thomas Aquinas, "No one can say that intelligibility is impeded by corporeal matter alone. For if that were the case, since matter is called corporeal only insofar as it is subject to a corporeal form, it would follow that matter has the characteristic of impeding intelligibility from the corporeal form. But this cannot be, because the corporeal form itself is actually intelligible, like other forms, insofar as it is abstracted from matter. Hence in no way is there composition of matter and form in the soul or in the intelligence in such wise that essence in them would be understood as it is in corporeal substances." ("On Being and Essence," chap. 4)

22 "And therefore what is sensuously felt, what is very significantly designated the plenum [...] , is felt as a fact of the second order, as something questionable or specious, as a resistance that must be overcome by philosopher or physicist before the true content of Being can be discovered." (Spengler, *The Decline of the West: Form and Actuality*, 398)

23 "[A]ll general physical concepts and laws [...] are obtained through idealization. In this way they take on that simplified form [...] which makes it possible to reconstruct and therefore understand any fact even of a complex nature by means of a synthetic combination of these concepts and laws." (Mach, *Knowledge and Error*, 140)

24 "Physical laws rest on atomic statistics and are therefore only approximate [...] " (Schrödinger, *What is Life?*, 10)

25 "[I]n order to understand physical laws you must understand that they are all some kind of approximation." (Feynman, Leighton, and Sands, *Mainly Mechanics, Radiation, and Heat*, chap. 12–1)

26 "The key step is the selection, from the entire universe, of a subsystem to study. The key point is that this is always an approximation to a richer reality." (Smolin, *Time Reborn*, 39)

27 "One after another, the characteristic features of time have proved to be approximations, mistakes determined by our perspective, just like the flatness of the Earth or the revolving of the sun. The growth of our knowledge has led to a slow disintegration of our notion of time. What we call 'time' is a complex collection of structures, of layers. Under increasing scrutiny, in ever greater depth, time has lost layers one after another, piece by piece [in the history of physics]." (Rovelli, *The Order of Time*, 4)

28 "Since all models are wrong the scientist cannot obtain a 'correct' one by excessive elaboration. On the contrary following William of Occam he should seek an economical description of natural phenomena." (Box, "Science and Statistics," 792)

29 "We cannot remove a system from the universe, so in any experiment we can only decrease, but never eliminate, the outside influences on our system. In many cases, we can do this accurately enough to make the idealization of an isolated system a useful intellectual construct." (Smolin, *Time Reborn*, 39)

speak as though the difference between the model and the system itself ('reality') were contained in these very details,[30] and we hold the entire world then to be ultimately comprehensible by such iterative analysis and measurement.[31,32]

In the Faustian view, the world is *very* complex and *very* difficult to comprehend because it comprises very *many* sub-systems. Indeed, it is a feature of every machine that each of its constituent parts is a machine in its own right and one that obeys the same physical laws as those that govern the larger whole.[33] The engine in a car is a smaller machine than the car itself, and if you place an engine on a hill, then it will roll down the hill just like a whole car. Lunar dynamics are like planetary dynamics, are like galactic dynamics, and so forth.[34] It is no coincidence that the theory of classical mechanics was developed with machines and planetary motion in mind, with Isaac Newton's explicit goal in its canonical formulation having been the description of the dynamics of these two particular physical domains according to a shared set of principles.[35,36] Whenever a model does not accord with reality, it is understood to be because there exist additional dynamical factors that have not yet been accounted for (either intentionally or otherwise), just as the movements of a clock are surprising when there remains some corner of the internal

30 "In the same way it is necessary to introduce new constants, such as the dielectric constant, when the behavior of gases in the presence of electric or magnetic fields is studied. And each such introduction of a new factor brings about a closer approximation to reality." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 86)

31 "The assumption that we can increase our measurements beyond any limitation of precision is ultimately always based on the presupposition of infinite divisibility." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 176)

32 "The world is constituted progressively and is finally—with respect to Nature as its abstractable component—constituted according to horizons in which something existent is constituted as actual in being-possibilities predesignated at any time [...] " (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 223)

33 "If [the principle of the reductive analysis of physical systems] were not valid, then we could never make any predictions about any experiment without knowing everything about the universe." (Weinberg, *Foundations*, 177)

34 The Rutherford–Bohr planetary model of the atom is a clear example of a misguided attempt to apply this paradigm at the quantum scale. (Bohr, "I. On the Constitution of Atoms and Molecules"; Rutherford, "The Scattering of α and β Particles by Matter and the Structure of the Atom")

35 "Progress was much rather initiated by Newton's at once applying the basic laws discovered by Galileo to the motion of what is most remote from us, namely celestial bodies; for it was precisely on this path that Newton found those tensions and completions of Galileo's laws which in turn could be applied to more complicated terrestrial motions, so that he succeeded in working out a theory of the motion of bodies so perfect that to this day it has become the foundation not only of mechanics but of the whole of theoretical physics." (Boltzmann, "On the Principles of Mechanics," 130)

36 "Modern physics studies, in the first line, the motion of ponderous bodies, i.e., the motion of bodies which surround us. Thus it is from the effort to explain the facts and the phenomena of common, every-day, experience—the act of falling, the act of throwing—that proceeds the trend of ideas which leads to the establishment of its fundamental laws. Yet it does not proceed therefrom exclusively, or even principally, or in a direct way. Modern physics does not originate from earth alone. It comes, just as well, from the skies. And it is in the skies that it finds its perfection and end.¶ This fact, the fact that modern physics has its 'prologue' and its 'epilogue' in the skies, or, to speak a more sober language, the fact that modern physics takes its origin from the study of astronomical problems and maintains this tie throughout its history, has a deep meaning, and carries important consequences. It expresses the replacement of the classic and medieval conception of the Cosmos—closed unity of a qualitatively determined and hierarchically well ordered whole in which different parts (heaven and earth) are subject to different laws—by that of the Universe, that is of an open and indefinitely extended entirety of Being, governed and united by the identity of its fundamental laws; it determines the merging of the *Physica coelestis* with *Physica terrestris*, which enables the latter to use and to apply to its problems the methods—the hypothetico-deductive mathematical treatment—developed by the former;" (Koyré, *Metaphysics and Measurement*, 1–2)

mechanism still unexplored.[37,38,39] My own perspective presents me with a limited view of objective reality,[40] in the same way that one's unique circumstance prevents one from knowing the 'true motion' of any object in absolute space.[41]

Yet the principles of Mechanics, while very effective within the particular domain for which they were developed,[42] are totally useless at describing even such a mundane phenomenon as the motion of a turbulent fluid,[43,44] for which there is no action and reaction, no inertia, and no center of mass. A turbulent fluid comprises no distinct, enumerable 'parts' that themselves act like smaller versions of the fluid itself. Insofar as a fluid does have constituent elements, these elements are of a sort different from that of the greater whole (i.e., the molecules of a fluid are not themselves fluids).[45] If someone asks me to explain the motion of a clock, I might answer by describing the motions of its parts; but if someone asks me to explain the motion of a fluid, I would not answer by describing the motions of its atoms.[46] Even when the dynamics of a *small* number of atoms may be described according to certain physical laws, it does not follow that a

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37 "To study nature is to search into [His] workmanship: every new discovery opens to us a new part of his scheme." (Maclaurin, *An Account of Sir Isaac Newton's Philosophical Discoveries*, 3)

38 "If an explosion occurs when a ball is dropped, we say that some phenomenon must have occurred to make the cause proportional to the effect. On hunting for the phenomenon and not finding it, we say that it has merely not yet been found." (Wittgenstein, *Wittgenstein's Lectures, Cambridge, 1932–1935*, 16)

39 "Every expansion of knowledge due to the steady increase of observational data and the refinements of measuring instruments meets with a corresponding characteristic simplification." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 37)

40 "It is one of the tacit, but none the less firm, presuppositions of nature-research that 'Nature' [...] is the same for every consciousness and for all times." (Spengler, *The Decline of the West: Form and Actuality*, 103)

41 "But because the parts of space cannot be seen, or distinguished from one another by our senses, therefore in their stead we use sensible measures of them. For from the positions and distances of things from any body considered as immovable, we define all places; and then with respect to such places, we estimate all motions, considering bodies as transferred from some of those places into others. And so, instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs; but in philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them. For it may be that there is no body really at rest, to which the places and motions of others may be referred.¶ [...] [I]t is possible, that in the remote regions of the fixed stars, or perhaps far beyond them, there may be some body absolutely at rest; but impossible to know, from the position of bodies to one another in our regions whether any of these do keep the same position to that remote body; it follows that absolute rest cannot be determined from the position of bodies in our regions." (Newton, *The Motion of Bodies*, 8–9)

42 "We are fortunate that the principles of Newtonian mechanics could be developed and verified to great accuracy by studying astronomical phenomena, where friction and turbulence do not complicate what we see." (Jaynes, *Probability Theory*, 329)

43 "How far we are from actually solving all these equations, that is being able in all cases to obtain from them a genuinely clear picture of the processes in question, a simple glance at a foaming brook or at the water waves churned up by a large steamer will tell. How impotent analysis really is to read from the hydrodynamic equations the details of all these phenomena!" (Boltzmann, "On the Principles of Mechanics," 131)

44 "I am an old man now, and when I die and go to Heaven there are two matters on which I hope for enlightenment. One is quantum electrodynamics, and the other is the turbulent motion of fluids. And about the former I am really rather optimistic." (Horace Lamb, quoted in Goldstein, "Fluid Mechanics in the First Half of this Century," 23)

45 "The atomist is mistaken only in that he assumes *mechanical* atoms, i.e., the finitude of *mechanical* divisibility." (Schelling, *First Outline of a System of the Philosophy of Nature*, 20)

46 "The concept of pure motion detached from any other change stands out in full clarity only in the study of rigid bodies, where indeed we have a perfectly immutable structure in which nothing changes save spatial position. Now there are in nature no perfectly rigid bodies but certainly solid ones that are subject to only imperceptible changes of shape during motion. As for changes in shape in liquids and gases, these one tries, without straining the facts, to reduce to the motions of their smallest constituent parts. Indeed to the eye they resemble changes of shape of a sandheap, which consists of individual perceptible grains. Nevertheless, in the case of actual fluids there is something hypothetical about the assumption that there too each individual particle is identifiable at all times, for experience shows that we are given only the constancy of total mass and weight." (Boltzmann, *Theoretical Physics and Philosophical Problems*, 142)

very large number of atoms may be described in the same way, despite the fact that there is no magic number which distinguishes 'small' from 'large' in any given context.[47,48] This is not merely a practical limitation,[49] as it would be with a large and complex machine. One wouldn't try to improve upon a model of a turbulent fluid by adding a few more molecules here and there in order better to account for the failures of that model.

One recognizes plenty of circumstances under which Mechanical principles are not applicable, yet *non-Mechanical* models—models we use to predict, for instance, the behavior of thermodynamic or biological systems—are described as nothing more than expedient for use in the absence of a true Mechanical theory or sufficient observational data.[50] One is inclined to say that it is merely harder to apply the principles of Mechanics in these cases. In fact, the success of our Mechanical models at making predictions in the *degenerate* cases of a variety of systems (laminar flow,[51] the two-body problem,[52] simple harmonic oscillators,[53,54] etc.) is widely seen as an indication of the universality of Mechanical principles; but insofar as those cases are exceptional, they demonstrate the general inapplicability of the Mechanical paradigm to the domains in question.[55]

Consider the difference between *throwing a sandbag*, on the one hand, and *rolling a die*, on the other. This difference seems to be merely a matter

47 Cf. the sorites paradox. (Hyde and Raffman, "Sorites Paradox")

48 Non-Mechanical systems include those that are qualitatively *too* large, *too* small, *too* complex, etc. *qua* machines. (If you imagine a machine with too many constituent elements, you are now talking about a statistical mechanical system; if you consider a too-small machine, you are dealing with quantum mechanics; if you take a system that is too complex, you are now studying biology; and so forth.) Niels Bohr noted, "The essential non-analyzability of atomic stability in mechanical terms presents a close analogy to the impossibility of a physical or chemical explanation of the peculiar functions characteristic of life.¶ In tracing this analogy, however, we must remember that the problems present essentially different aspects in atomic physics and in biology. While in the former field we are primarily interested in the behaviour of matter in its simplest forms, the complexity of the material systems with which we are concerned in biology is of a fundamental nature, since even the most primitive organisms contain large numbers of atoms." ("Light and Life")

49 Cf. "A closed hydrodynamical system of finite mass may ostensibly be treated mathematically as a finite collection of molecules—usually a very large finite collection—in which case the governing laws are expressible as a finite set of ordinary differential equations. These equations are generally highly intractable, and the set of molecules is usually approximated by a continuous distribution of mass." (Lorenz, "Deterministic Nonperiodic Flow," 130)

50 "Logically, the problem is one of inference (i.e., plausible conjecture) rather than deduction, since in almost all real problems of physics, biology, and economics our information is far too meager to permit any deductive proof that our predictions must be right. Indeed, it is often too meager to justify any definite predictions at all." (Jaynes, "Macroscopic Prediction," 254)

51 "Lack of periodicity is very common in natural systems, and is one of the distinguishing features of turbulent flow [. . .] It is sometimes possible to obtain particular solutions of these equations analytically, especially when the solutions are periodic or invariant with time [. . .] Ordinarily, however, nonperiodic solutions cannot readily be determined except by numerical procedures." (Lorenz, "Deterministic Nonperiodic Flow," 130)

52 The n-body problem is provably unsolvable for $n \geq 3$, but we think of classical mechanics as describing the natural laws for all such systems, just as though $n = 2$ were the norm and $n \geq 3$ were instead the exception. Cf. Gowers, Barrow-Green, and Leader, *The Princeton Companion to Mathematics*, 495–96.

53 "Unfortunately, there are really very few problems which can be solved exactly by analysis. In the case of the harmonic oscillator, for example, if the spring force is not proportional to the displacement, but is something more complicated, one must fall back on the numerical method." (Feynman, Leighton, and Sands, *Mainly Mechanics, Radiation, and Heat*, chap. 10–1)

54 Duffing, *Erzwungene Schwingungen bei veränderlicher Eigenfrequenz und ihre technische Bedeutung*.

55 "For essentially every physical theory we have (Navier-Stokes theory, general relativity, quantum field theory, *etc.*), we have very little detailed knowledge of the structure of generic solutions. Usually, we know exact solutions only under conditions of perfect or near-perfect symmetry or some other unrealistic assumption (two bodies, no external perturbative influences, [. . .]), and then argue that we can apply such solutions to real physical systems, because the approximation is adequate in appropriately controlled circumstances. That is to say: we have no real idea *at all*, in a representational sense, 'what the world would be like if the theory were true or largely true of it', for any physical theory." (Curiel, *Schematizing the Observer and the Epistemic Content of Theories*, 3)

of degree—of the size of the moving body, of the elasticity of its collisions with the floor, and so forth. Yet the canonical models that we use to describe these two systems are different not only in what they depict, but also in how they depict it—they have different grammars, and they adhere to entirely different physical principles. The model of the sandbag treats the force with which the bag is thrown and the bag's mass, friction, elasticity, etc.; it shows where the sandbag will land and which side of the sandbag will be facing up when it does. The model of the die roll, however, looks more like, "I hold the die in my hand and then throw it. The die bounces until eventually it comes to a stop with a random side facing up." The model for the sandbag toss is Mechanical and 'deterministic' in that we say that its future state is determined by its initial conditions, i.e. the values for the various model parameters. By contrast, the die roll is an example of a 'non-deterministic' and non-Mechanical model: given the same initial state ('I hold the die in my hand'), the result is not knowable in advance—it is unpredictable.

The probability of a die roll is often said to be nothing more than a consequence of the manner in which we happen to understand a fundamentally deterministic underlying mechanism.[56,57] One says that the die roll is merely very complicated in its mechanism and that until one comprehends it its behavior merely *seems* random,[58,59,60] but that of course the result was in some sense determined beforehand.[61,62,63] The idea is

56 "Random events do not, therefore, exist in classical physics. Randomness is an appearance originating from the ignorance of initial conditions or from the inability to measure them or to compute explicitly the motion. These three kinds of limitation occur together when one throws dice, and this is why the result is said to be random, although it is not in principle." (Omnès, *Understanding Quantum Mechanics*, 43)

57 "[In the future, it will be the case that b]elief in 'physical probabilities' expressing a volition of the coin is recognized finally as an unfounded superstition. The existence of an underlying mechanical theory is proved beyond question; and the long success of the previous statistical theory is seen as due only to the lack of control over the initial conditions of the tossing.¶ Because of recent spectacular advances in the technology of experimentation, with increasingly detailed control over the initial states of individual atoms, we think that the stage is going to be set, before very many more years have passed, for the same thing to happen in quantum theory; a century from now the true causes of microphenomena will be known to every schoolboy and, to paraphrase Seneca, they will be incredulous that such clear truths could have escaped us throughout the 20th (and into the 21st) century." (Jaynes, *Probability Theory*, 329–30)

58 "That which is wonderful in science is contrary to that which is wonderful in the art of the juggler. For the latter would wish to make us believe that we see a very simple causality, where, in reality, an exceedingly complex causality is in operation. Science, on the other hand, forces us to give up our belief in the simple causality exactly where everything looks so easily comprehensible and we are merely the victims of appearances. The simplest things are *very* 'complicated'—we can never be sufficiently astonished at them!" (Nietzsche, *Dawn of the Day*, § 6)

59 "In practice, only mathematical models have ideal symmetry and thus perfect degeneracy. Almost all physical systems are subject to interactions across vast ranges of scale from strong to weak. The 'unpredictable' directions of the order parameter are in real cases usually set by small asymmetries in the boundary conditions. For frost on a windowpane these may be slight impurities or dust. Such small effects are not sufficient to interfere with the reductionistically determined properties of order such as the strength of the ice matrix, and for the matrix as for the melted liquid state they would be un-noticeable. Only the degenerate properties can amplify such weak effects into large-scale macroscopic patterns." (Smith and Morowitz, *The Origin and Nature of Life on Earth*, 467)

60 " 'How does thought manage to represent?'—the answer might be 'Don't you really know? You certainly see it when you think.' For nothing is concealed." (Wittgenstein, *Philosophical Grammar*, 104)

61 "What does determinism profess?¶ It professes that those parts of the universe already laid down absolutely appoint and decree what the other parts shall be. The future has no ambiguous possibilities bidden in its womb; the part we call the present is compatible with only one totality. Any other future complement than the one fixed from eternity is impossible. The whole is in each and every part, and welds it with the rest into an absolute unity, an iron block, in which there can be no equivocation or shadow of turning." (James, "The Dilemma of Determinism," 150)

62 "At certain moments nature makes a choice." (Paul Dirac, quoted in Langevin, *La notion de corpuscules et d'atomes*, 33)

63 "Does this idea mean that nature is really free to choose the outcome of an experiment?" (Smolin, *Time Reborn*, 148)

that if we were to throw two dice in '*exactly* the same way,' then the result would be the same. But what standard of precision could there be for the specification of the initial state of the die roll? We wouldn't say that we have to know the *exact* parameters of the sandbag throw to predict its behavior... unless of course we wanted to predict its behavior *exactly*.[64] That is, the die roll is not *more difficult* to observe in the same way that a sandbag being thrown *faster* is. In a thought experiment, if one allows oneself to observe the die roll with that level of precision so as to be able to predict its behavior, then one must also allow the die roll to move too quickly to be measured with sufficient precision.[65] In order to predict the outcome of the die roll, we should have to make qualitative, rather than quantitative, changes to our model, and in such a way as to deny the existence of the very difficulty that we are attempting to penetrate.

Imagine I present you with a sealed box and say, "This machine prints out random numbers, and I'll bet you that it will print out an even number next." How would you know that I had not rigged the device to output certain numbers in a particular order? Even if you see the machine print out a long string of digits in which no pattern is discernible, how could you know that inside the box there was no rotating drum etched with a code, as in a player piano, where the code determines in advance how the machine will behave? Were that the case, one *would* say that the box's behavior merely 'seems' unpredictable, but that it actually isn't, because of the hidden internal mechanism. So a lottery game would never employ such a machine to produce the winning numbers.[66] You can open up a machine, look inside it, and come to understand thereby absolutely everything that will ever happen with it. But can you examine the inside of a die (or of my throwing arm) and discover therein a code that spells out which side the die will land on? The behavior of the box cannot be predicted unless the box is opened. We ask, *what is the box that is to be opened?*

64 " 'Inexact' is really a reproach, and 'exact' is praise." (Wittgenstein, *Philosophical Investigations*, § 88)
65 "Can God create a rock so heavy that He cannot lift it?"
66 Machines may act as *pseudo*-random number generators only.

2

PREDICTION AND TIME

> *Statistics belong, like chronology, to the domain of the organic, to fluctuating Life, to Destiny and Incident and not to the world of laws [...] And if, now, suddenly the contents of that field are supposed to be understood and understandable only statistically and under the aspect of Probability—instead of under that of the* a priori *exactitude which the Baroque thinkers unanimously demanded—what does it mean? It means that the object of understanding is ourselves. Nature "known" in this wise is the Nature that we know by way of living experience, that we live in ourselves.* —*Oswald Spengler*[1]

The predominance of the Mechanical world-view is such that many physicists hold to the belief that even quantum systems are fundamentally 'deterministic'[2] at some 'lower level'[3]—that there exist 'hidden variables'[4] which govern quantum behavior and make it merely appear unpredictable.[5,6] Ironically, this conviction itself entails the reification of the mathematical representations of different quantum mechanical possibilities, the very existence of which then presents us with the philosophical problem of their 'reality'.[7,8] The quantum mechanical wave function, which represents probabilities in state space,[9] is supposed to be a 'real wave,'[10,11] and a 'superposition of states' is supposed to be a state itself.[12]

1 Spengler, *The Decline of the West: Form and Actuality*, 421–22.
2 Brans, "Bell's Theorem Does Not Eliminate Fully Causal Hidden Variables."
3 Donadi and Hossenfelder, "Toy Model for Local and Deterministic Wave-Function Collapse."
4 't Hooft, *The Cellular Automaton Interpretation of Quantum Mechanics*.
5 Albert Einstein wrote, "I, at any rate, am convinced that [God] is not playing at dice." (*The Born-Einstein Letters*, letter 52) One might answer this with "God plays dice every time that *anyone* does."
6 Sivasundaram and Nielsen, *Surveying the Attitudes of Physicists Concerning Foundational Issues of Quantum Mechanics*.
7 "Dynamic and statistical laws were not regarded as two complementary methods and directions, as two different modes of description; they were instead opposed as the 'determined' and the 'undetermined.' Thus the new problems that were introduced by the second law and by the development of quantum theory were discussed under the heading of 'indeterminism,' a title which gives rise to the most dangerous equivocations. It seemed to open the doors to a liberum arbitrium indifferentiae, a state of freedom which was hardly distinguishable from caprice." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 89)
8 "Probability is the most important concept in modern science, especially as nobody has the slightest notion what it means." (Bertrand Russell, quoted in E. T. Bell, *The Development of Mathematics*, 587)
9 Bohm, "A Suggested Interpretation of the Quantum Theory in Terms of 'Hidden' Variables. I," 167.
10 "[D]oes a ψ-function of the quantum theory represent a real factual situation [...] ?" (Einstein, "Autobiographical Notes," 83)
11 "No one can understand [the quantum theory] until he is willing to think of ψ as a real objective field rather than just a 'probability amplitude'. Even though it propagates not in 3-space but in 3*N*-space." (J. S. Bell, *Speakable and Unspeakable in Quantum Mechanics*, 128)
12 "At the heart of much debate concerning quantum theory lies the quantum state. Does the wave function correspond directly to some kind of physical wave? If so, it is an odd kind of wave, since it is defined on an abstract configuration

Schrödinger's cat is considered to be both dead *and* alive before its observation, instead of simply dead *or* alive.[13] The paradox arises when we then ask what this superposition is, even as we invented the very concept of 'superposition' in order to be able to describe quantum phenomena while avoiding the direct treatment of probability (and even as we use the existence of that invented concept as evidence[14] of the absolute truth of the quantum mechanical theory).[15]

Probabilistic models (such as those of quantum mechanics) inherently specify the direction of time insofar as the probability in the model draws a distinction between the state of the model in the future and the state of the model in the past ('The die bounces until *eventually* it comes to a stop.') With non-Mechanical systems in general, I cannot say precisely what will happen, but I do know that I will learn it, and that fact represents the temporal asymmetry itself.[16] I know that a lottery machine will *eventually* eject a ball from its chamber—it is *which* ball it will be (and *when*) that is a matter of chance. When I roll a die, I can say definitely that it will eventually come to rest with *some* side facing up, and while any particular current of river may twist and turn and even move upstream a short ways, the river as a whole—every river—flows ceaselessly down to the sea. So we can talk about a thermodynamical model of a clock wherein the clock will eventually run down; but one cannot predict when or how this will occur, and we would not be inclined to call such a prognostication a description of 'how the clock will behave,' which is what constitutes the scope of the original Mechanical picture. We know the end, but not how that end will happen to be reached.[17]

Mechanical models are deterministic and predictable, and a model whose future state is perfectly predictable (i.e., knowable) is one for which

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space, rather than the three-dimensional space we live in. Nonetheless, quantum interference, as exhibited in the famous two-slit experiment, appears most readily understood by the idea that it is a real wave that is interfering. Many physicists and chemists concerned with pragmatic applications of quantum theory successfully treat the quantum state in this way." (Pusey, Barrett, and Rudolph, "On the Reality of the Quantum State")

13 "It is one of the most deep rooted mistakes of philosophy to see possibility as a shadow of reality." (Wittgenstein, *Philosophical Grammar*, 283)

14 "[E]very physical observation is so constituted that it *proves the basis of a certain number of imaged presuppositions;* and the effect of its successful issue is to make these presuppositions more convincing than ever." (Spengler, *The Decline of the West: Form and Actuality*, 378)

15 "The quantum theory, as has been repeatedly emphasized, stands in far greater contrast to classical physics than does the general theory of relativity. The latter, in spite of its fundamental transformation of the concepts of time and space, can be incorporated without great difficulty into the mode of thought of classical physics. Planck says of it that it has brought classical physics to its consummation, as it were, in that by the amalgamation of time and space, it has also united the concepts of mass and energy and those of gravity and inertia in a single higher point of view. Of the quantum theory, however, he remarks that it had the effect of a dangerous foreign explosive which has already caused a gaping rift throughout the entire structure. 'The introduction of the quantum hypothesis therefore does not represent a modification, as was the case with relativity theory, but a breach in the classical theory.'" (Cassirer, *Determinism and Indeterminism in Modern Physics*, 109)

16 "Both the sources of blurring—quantum indeterminacy, and the fact that physical systems are composed of zillions of molecules—are at the heart of time. Temporality is profoundly linked to blurring. The blurring is due to the fact that we are ignorant of the microscopic details of the world. The time of physics is, ultimately, the expression of our ignorance of the world. Time is ignorance." (Rovelli, *The Order of Time*, 140)

17 "The cause is hidden; but the [...] power of the fountain is well known." (Ovid, *Metamorphoses*, 199)

there is no distinction between the past and the future.[18,19] Indeed, the Laws of Mechanics give no indication as to the temporal order of events—they do not specify an 'arrow of time'.[20,21] There is no 'cause and effect', but rather a perfect symmetry between action and reaction, according to Newton's Third Law.[22,23] There is no distinction between a weight pushing down on a spring and the spring pushing up on the weight: forces are no longer causes of motion[24,25] but instead merely (reversible) alterations in motion.[26,27] So every point on the face of a clock represents (infinitely many) times in both the past and the future,[28] and a pendulum swings both ways.[29]

The reversibility of time in Mechanics is closely related to the reducibility of models in the Mechanical framework. We see this when we compare

18 "[A]n intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it—an intelligence sufficiently vast to submit these data to analysis—it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present to its eyes." (Laplace, *A Philosophical Essay on Probabilities*, 4)

19 "[W]e showed that many stars would eventually collapse and produce closed trapped surfaces. If one goes to a larger scale, one can view the expansion of the universe as the time reverse of a collapse. Thus one might expect that the conditions of theorem 2 would be satisfied in the reverse direction of time on a cosmological scale, providing that the universe is in some sense sufficiently symmetrical, and contains a sufficient amount of matter to give rise to closed trapped surfaces." (Hawking and Ellis, *The Large Scale Structure of Space-Time*, 348)

20 Eddington, *The Nature of the Physical World*, chap. IV.

21 "The fundamental equations of mechanics do not in the least change their form if we merely change the algebraic sign of the time variable. All purely mechanical processes can therefore occur equally well in the sense of increasing and decreasing time. But we notice even in ordinary life that future and past do not correspond at all so perfectly as the directions right and left, that on the contrary they are clearly distinguishable." (Boltzmann, "On Statistical Mechanics," 170)

22 "In a system of bodies which conforms to the fundamental law there is neither any new motion nor any cause of new motion, but only the continuance of the previous motion in a given simple manner." (Hertz, *The Principles of Mechanics*, 147)

23 Cf. "When we analyze the basic phenomenon on which the mechanical explanation of nature is built, we find that precisely this phenomenon contains no shadow of a real explanation [. . .] If the two billiard balls at the instant of collision were to exchange their colors instead of altering their direction of motion, the one would be just as much and as little understandable as the other." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 16)

24 "It may be said generally that since Galileo, classical physics has renounced the task of answering any question 'why?' and that it is only by virtue of this renunciation that it has been able to solve the specific task which it has undertaken. It no longer seeks to know why events occur but only that they occur and how they occur, and it is satisfied with establishing definite laws for both the nomological and the ontological structure of the world." (Cassirer, *Determinism and Indeterminism in Modern Physics*, 106)

25 "Before Galileo, the theory of terrestrial motions had been dominated by the concept of cause. The important thing was to find a qualitative explanation (in terms of essential nature etc.) of why any particular body moved in the way it did. Galileo by no means threw off this way of thinking entirely. Instead, he augmented it by an approach that, at least up to the present day, has proved to be far more fruitful. He stopped looking for *causes* of motion and instead, like the early astronomers, sought merely to *describe* actually observed motions. He no longer asked: *why* does the stone fall, but *how* does the stone fall? In the *Discorsi*, he comments that innumerable books had been written explaining why bodies fall towards the ground with an accelerated motion but adds drily that 'to just what extent this acceleration occurs has not yet been announced'." (Barbour, *The Discovery of Dynamics*, 357)

26 "The change of motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed." (Newton, *The Motion of Bodies*, 13)

27 "[I]n very many cases the forces which are used in mechanics for treating physical problems are simply sleeping partners, which keep out of the business altogether when actual facts have to be represented." (Hertz, *The Principles of Mechanics*, 11–12)

28 I can draw a picture of the face of a clock to indicate at what time an event happened [in the past], or to indicate a time at which an event will happen [in the future], and there might not be any difference between those two drawings themselves.

29 "On this blueprint of nature that is assumed to be already known, the following conditions—among others—are entered. Motion means change of place. No motion or direction of motion is preferred to another. Every place is like every other. No point of time is superior to any other. Every force is determined only by—*is* only—its consequences in motion, that is to say, by the magnitude of change of place in the unit of time. Every event must be read into this blueprint of nature." (Heidegger, "The Age of the World View," 344)

Mechanical systems with thermodynamic systems.[30] Consider a number of particles bouncing elastically around in a container. If the number of particles is small, then the entire behavior of the system both forward and backward in time may be fully comprehended according to Newton's Laws; if the system contains uncountably many particles, however, then it will behave like a gas[31] and in accordance with the principles of statistical mechanics. The entropy of the whole will then tend toward a maximum,[32] whatever the microbehavior may be, and this manifests as a temporal asymmetry in thermodynamic systems.[33] The qualitative complexity of the model determines whether or not the model is Mechanical, insofar as Mechanical models may be analyzed reductively as some number of constituent elements (and *thereby* their behavior predicted).[34]

Analogously, in the domain of living systems,[35] Natural Selection proceeds by infinitesimal, incremental, and probabilistic steps (gene mutations, the reproductive success of individuals, etc.)—steps that, in large aggregates, provide for the directed process of evolution.[36] So, Natural Selection cannot explain any particular event in the history of a biological system,[37,38] just as the Second Law of Thermodynamics cannot explain the transition to any particular microstate in a thermodynamic system. The various stages of evolution that lead to any particular biological feature are not themselves directed toward the 'survival of the fittest'[39,40] any more than the motions of individual particles in the gas-in-a-box[41] are directed toward the maximization of the entropy of the system as a whole, which is in fact the *cause* of the change in macrostate. Like statistical mechanical

30 "How can the irreversibility of macroprocesses be reconciled with the reversibility of microprocesses? It is this paradox which the physicist has to resolve when he wishes to account for the direction of thermodynamical processes and for the direction of time." (Reichenbach, *The Direction of Time*, 109)

31 Clausius, "XI. On the Nature of the Motion which we call Heat," 113.

32 "Every process occurring in nature proceeds in the sense in which the sum of the entropies of all bodies taking part in the process is increased. In the limit, i.e., for reversible processes, the sum of the entropies remains unchanged." (Planck, *Treatise on Thermodynamics*, § 133)

33 "[T]he Second Law by introducing irreversibility has for the first time brought into the mechanical-logical domain a tendency belonging to immediate life and thus in fundamental contradiction with the very essence of that domain." (Spengler, *The Decline of the West: Form and Actuality*, 421)

34 "You can't *build* clouds. And that is why the future you *dream* of never comes true." (Wittgenstein, *Culture and Value*, 41e)

35 "[I]t is absurd [. . .] to hope that another *Newton* will arise in the future, who shall make comprehensible by us the production of a blade of grass according to natural laws which no design has ordered." (Kant, *Kant's Critique of Judgement*, 312–13)

36 "Darwinian dynamics is a special case within the more general class of order-forming, non-equilibrium stochastic processes." (Smith and Morowitz, *The Origin and Nature of Life on Earth*, 571)

37 The very term 'natural history' shows the affinity between the study of living systems and that of history proper, which is also the study of Life. Oswald Spengler, "These cultures, sublimated life-essences, grow with the same superb aimlessness as the flowers of the field." (*The Decline of the West: Form and Actuality*, 21)

38 "I have always thought that Darwin was wrong: his theory doesn't account for all this variety of species. It hasn't the necessary multiplicity. Nowadays some people are fond of saying that at last evolution has produced a species that is able to understand the whole process which gave it birth. Now that you can't say." (Ludwig Wittgenstein, quoted in M. O'C. Drury, "Conversations with Wittgenstein," 160)

39 "[N]ature, considered as mere mechanism, could have produced its forms in a thousand other ways without stumbling upon the unity [of organization] which is in accordance with such a principle [of purpose]. It is not in the concept of [mechanical] nature but quite apart from it that we can hope to find the least ground a priori for this." (Kant, *Kant's Critique of Judgement*, 260)

40 Cf. "the blind watchmaker". (Dawkins, *The Blind Watchmaker*, 9)

41 Gibbs, "On the Equilibrium of Heterogeneous Substances," 165–68.

systems, living systems are qualitatively, not quantitatively, more complex than Mechanical ones.[42,43]

The 'time' that we find in our theory of classical mechanics—that we measure with a clock—is not the same 'time' that we find in our models of thermodynamical, hydrodynamical, and quantum mechanical phenomena.[44] It is not the 'time' that we would represent by the flowing of a river.[45] Imagine trying to measure *quantities of time* with a river... how would you define an hour? You could place some markers an equal distance apart along the river's banks and throw an object into the water upstream of the first; then you could say that one hour passes whenever the object floats from one marker to the next. But how would you know that the river was moving at the same speed from marker to marker? How many markers would you have to put in place? You would need a large number in order to compensate for local turbulence; but the greater the number (the greater the distance), the more systemic bias there would be due to variations in the geography of the system.

By contrast, time as measured with a clock is readily quantified. If the distance between any pair of teeth on a gear of a clockwork mechanism is too wide or too narrow, then that introduces no bias in the operation of the mechanism. So one may also measure time by the motions of the heavens: a 'day' is the period between two sunrises, a 'year' between two equinoxes, and so forth. The planets repeat their motions over and over, as a pendulum swings without friction. That is, a clock with a heavy pendulum, rigid gears, and no friction behaves much like a celestial body in orbit. The decomposability and analyzability of Mechanical models allow for and require a *spatial* conception of time,[46] wherein 'spans of time' may be divided up and measured by, say, the ticks of a second hand that are laid end to end against an event, like rigid rods laid against a body to measure its length.[47] Newtonian time is absolute, universal, and objectively knowable as a fundamental feature of the very fabric of our

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42 "And so, too, a corpse seems to us quite inaccessible to pain.—Our attitude to what is alive and to what is dead, is not the same. All our reactions are different.—If anyone says: 'That cannot simply come from the fact that a living thing moves about in such-and-such a way and a dead one not', then I want to intimate to him that this is a case of the transition 'from quantity to quality'." (Wittgenstein, *Philosophical Investigations*, § 284)

43 "Biology is hard because there's so *much* of it." (Munroe, "XKCD")

44 "'Time has only one direction' must be a piece of nonsense.¶ Having only one direction is a logical property of time." (Wittgenstein, *Notebooks 1914–1916*, § 12.10.16)

45 "If we look at a river in which numbered logs are floating, we can describe events on land with reference to these, e.g., '*When* the 105th log passed, I ate dinner'. Suppose the log makes a bang on passing me. We can say these bangs are separated by equal, or unequal, intervals. We could also say one set of bangs was twice as fast as another set. But the equality or inequality of intervals so measured is entirely different from that measured by a clock." (Wittgenstein, *Wittgenstein's Lectures, Cambridge, 1932–1935*, § 13)

46 "All that has been said about time in 'scientific' philosophy, psychology and physics [...] touches, not at any point the secret itself, but only a spatially-formed representative phantom. The livingness and directedness and fated course of real Time is replaced by a figure which, be it never so intimately absorbed, is only a *line*, measurable, divisible, reversible, and not a portrait of that which is incapable of being portrayed; by a 'time' that can be mathematically expressed in such forms as $\sqrt{t}$, t^2, $-t$, from which the assumption of a time of zero magnitude or of negative times is, to say the least, *not* excluded." (Spengler, *The Decline of the West: Form and Actuality*, 124)

47 "The key point, strongly emphasized by Galileo, is that two well attested physical phenomena, the law of free fall and the law of inertia, make it possible to convert a purely geometrical ruler into a 'ruler of speeds'." (Barbour, *The Discovery of Dynamics*, 516)

reality.[48] In Relativity theory, of course, time is just another dimension of the space-time manifold (albeit one with an imaginary unit[49,50]) and causality is represented by nothing more than the relative position of events in that four-dimensional continuum.[51]

48 "Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration [. . .] " (Newton, *The Motion of Bodies*, 6)

49 "Without [the idea of Minkowski space-time] the general theory of relativity [. . .] would perhaps have got no farther than its long clothes." (Einstein, *Relativity*, 57)

50 "One might think this means that imaginary numbers are just a mathematical game having nothing to do with the real world. From the viewpoint of positivist philosophy, however, one cannot determine what is real. All one can do is find which mathematical models describe the universe we live in. It turns out that a mathematical model involving imaginary time predicts not only effects we have already observed but also effects we have not been able to measure yet nevertheless believe in for other reasons. So what is real and what is imaginary? Is the distinction just in our minds?" (Hawking, *The Universe in a Nutshell*, 59)

51 "Associated with each event, p, in spacetime is a light cone [. . .] We assign the label 'future' to half of the cone and the label 'past' to the other half. The events lying in the interior of the future light cone represent events which can be reached by a material particle starting at p; these comprise the 'chronological future' of p. The chronological future of p together with the events lying on the cone itself comprise the 'causal future' of p, which physically represents events which, in principle, can be influenced by a signal emitted from p." (Wald, *General Relativity*, 188)

3

MOTION AND RELATIVITY

> *Every physics [. . .] must break down over the motion-problem, in which the living person of the knower methodically intrudes into the inorganic form-world of the known.* —*Oswald Spengler*[1]

When I say that an object is moving, I could mean that it is moving *translationally*, like a clock on a conveyor belt, or that it is moving *internally*, like a clock with a swinging pendulum or one spinning in place.[2,3] These two different kinds of motion are measured differently: Translational motion is measured in terms of the change in the relative distance between two bodies, for instance with rigid rods or with a laser rangefinder. Internal motion is measured in terms of changes in the shape, configuration, or orientation of the body ("The little hand is now over the numeral 7.") The relationship between translational and internal motion is the relationship between a body as an indivisible whole and a body as an arrangement of parts—on the one hand, the internal motion of the ticking clock is the translation of the *parts* of the clock, where each of the parts is itself moving as a whole; on the other hand, a change in the distance between a clock on a conveyor belt and some other body (e.g., the conveyor belt) may be described as the internal motion of a *composite* body (e.g., the whole assembly line) of which the first and the second bodies are constituents.[4]

All measurements of translational motion are made relative to some 'frame of reference'. If I point a Doppler radar gun at an object myself, then I'm measuring the speed of that object relative to my own body; if I affix

1 Spengler, *The Decline of the West: Form and Actuality*, 418.

2 "Hence the statement that the motion of a simple body is simple holds true in particular for circular motion, as long as the simple body abides in its natural place and with its whole. For when it is in place, it has none but circular motion, which remains wholly within itself like a body at rest. Linear motion, however affects things which leave their natural place or are thrust out of it or quit it in any manner whatsoever." (Copernicus, *Nicholas Copernicus on the Revolutions*, book 1, chap. 8)

3 "Moving force is of two kinds: either the locomotion of a body (*vis locomotiva*) which forces another to leave its place, or internal motion." (Kant, *Opus Postumum*, 1; later deleted by Kant)

4 Cf. "Perhaps one might say that the difficulties would not arise if I and if we were able to fly and have two earths as basis-bodies, being able to arrive at the one from the other by flight. Precisely in this way the one body would be the basis for the other. But what do two earths mean? Two pieces of one earth with a humanity. Together, they would become one basis and, at the same time, each would be a body for the other. Surrounding them would be a common space in which each, as body, possibly would have a movable place, but motion would always be relative to the other body and nonrelative to the synthetic basis of their being together. The places of all bodies would have this relativity. However, one would always still have to ask, motion and rest with respect to which of the two basis bodies?" (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 227)

the radar gun to another body and read the results from a distance, then I'm measuring the speed of the first body relative to the second. In either case, the position of the radar gun establishes the frame of reference for the measurement of translational motion. What is the frame of reference for a measurement of internal motion, however? When I observe the hands of a clock rotating around the center of its dial, does it matter where I make that observation from or how I am moving when I do? One might say that the hand of the clock is moving toward or away from some other point on the clock's face... indeed, I might attach lasers to the frame of the clock and point them at the hands; but that is now a description of translation—of the motion of each part separately—and that is not how one normally reads a clock.[5]

In Mechanics, where all bodies are divisible and the dynamics of the whole are the same as the dynamics of its constituent parts, *there are no descriptions of internal motion*[6,7,8,9]—only translation is ever described, and even rotation is understood always as the *cyclical* (e.g., circular) motion of the parts of the whole,[10] that is, as translation where the direction of motion is constantly changing.[11,12] All motion is specified in terms of frames of reference.[13] So, instead of saying, for instance, "the clock is moving at ten meters per second," in Mechanics we say, "the clock

5 "Think of the recognition of *facial expressions*. Or of the description of facial expressions—which does not consist in giving the measurements of the face!" (Wittgenstein, *Philosophical Investigations*, § 285)

6 "[S]uppose a vortex together with all the Planets, or a ship along with everything within it floating in the sea, or a man walking in a ship together with the things he carries with him, or the wheel of a clock together with its constituent metallic particles. For unless you say that the motion of the whole aggregate cannot be considered as proper motion and as belonging to the parts according to the truth of things, it will have to be admitted that all these motions of the wheels of the clock, of the man, of the ship, and of the vortex are truly and philosophically speaking in the particles of the wheels." (Newton, "De Gravitatione et Aequipondio Fluidorum," 126–27)

7 "Mechanics is the theory of the motion of natural bodies, that is change of place (relative change of position) that is not connected with any change of their other properties. According to this definition mechanics must also explore under what conditions a body does not change its place; that is, is at rest." (Boltzmann, "Lectures on the Principles of Mechanics," 224)

8 "In modern science, as well we know, motion is considered as purely geometrical translation from one point to another. Motion, therefore, in no way affects the body which is endowed with it; to be in motion or to be at rest does not make any difference to, or produce a change in, the body whether in motion or at rest. The body, as such, is utterly indifferent to both." (Koyré, *Metaphysics and Measurement*, 4)

9 "However, the reasoning used primarily by Newton [to justify his Third Law of Motion] applies to point particles without structure and is not concerned with the motion of material bodies composed with a large number of particles, in or out of thermal equilibrium." (Pinheiro, "On Newton's Third Law and its Symmetry-Breaking Effects," 1)

10 "It seems that Newton regarded centripetal force as of greater importance than all the other forces; it occupied his mind more than anything else in mechanics and it was his real point of departure for all considerations of this chapter of definitions. Indeed, his remarks on this definition begin with the words: 'Of this sort is gravity.'" (Jammer, *Concepts of Force*, 122)

11 "Just as a curve can be considered as consisting of an infinity of right lines, even if in truth it does not consist of them but because this hypothesis is useful in geometry, in the same way circular motion can be regarded as traced and arising from an infinity of rectilinear directions, which supposition is useful in the mechanical philosophy." (Berkeley, *De Motu and The Analyst*, § 61)

12 "Circular motion is relative motion along parallel lines with a continually changing direction and a distance remaining constant owing to a bond.¶ Circular motion in one body is motion with respect to the parts, with the distance remaining constant owing to a bond." (Huygens, *Œuvres complètes de Christiaan Huygens. Publiées par la Société Hollandaise des Sciences*, 507; author's translation)

13 Cf. "Just as it must be possible to write down any arbitrary number by means of the system of numbers, so it must be possible to write down any arbitrary proposition of physics by means of the system of mechanics." (Wittgenstein, *Notebooks 1914–1916*, § 6.12.14)

is moving at ten meters per second relative to the lamp."[14] What we are describing is the space between the two objects, rather than any object itself.[15] Objects are modeled as simple bodies, or conglomerations thereof, located at particular points in space.[16,17] If I try to measure the distance between two bodies with sizes and shapes, then the result of that measurement will depend on exactly which points on the two bodies it is that I choose to measure between.[18] For there to be only one answer, I should have to ignore any differences in the results, calling them insignificant; in order to talk about the motion of one body toward or away from any other body, I should have to model both bodies as internally at rest.[19]

How do we describe Mechanical measurements as objectively verifiable, even as measurements of relative motion are understood to be 'observer-dependent'?[20,21] There is a confusion between the observer and the frame of reference:[22,23] if I should measure the speed of a train using a radar gun attached to a moving car, then the frame of reference for that measurement is the car, but *I* am still the one making the observation. It is, in fact, the statement of relative motion—of the change in the space separating the

14 "Now I begin to see that I lack something in the expression of motion and rest. I should never say, a body is at rest, without adding with regard to what it is at rest, and never say that it moves without at the same time naming the objects with regard to which it changes its relation." (Immanuel Kant, quoted in Jammer, *Concepts of Space*, 132)

15 "Consequently, we are unable to ascribe motion to a determined body considered in itself. A body is only in motion in its relation to something else—some other body—which we assume to be at rest. We can, therefore, ascribe it to the one or to the other of the two bodies, *ad libitum*. All motion is relative." (Koyré, *Metaphysics and Measurement*, 4)

16 "[O]nly such forces exist as can be represented as a sum of mutual actions between infinitely small elements of matter." (Hertz, *The Principles of Mechanics*, 10)

17 "Mechanist physics had conceived all bodies as aggregates of material points acting directly on each other at a distance." (Boltzmann, *Theoretical Physics and Philosophical Problems*, 143)

18 Cf. "If one wishes to determine the distance of the moon to the earth, one wishes to know the distance of their places, and to this end one does not measure from any point of the surface, or of the interior of the earth, to any point of the moon at pleasure, but takes the shortest line from the central point of the one to the central point of the other, and therefore, in each of these bodies there is only one point that constitutes its place." (Kant, *Kant's Prolegomena and Metaphysical Foundations of Natural Science*, 152)

19 Heinrich Hertz wrote, "Those masses whose position still remains unknown when the coordinates accessible to observation have been completely specified are called concealed masses, their motions concealed motions, and their coordinates concealed coordinates. In contradistinction to these the remaining masses are called visible masses, their motions visible motions, and their coordinates visible coordinates.¶ Continually recurrent motions, and therefore cyclical motions, are frequently concealed motions; for these, when existing alone, cause no change in the mass-distribution, nor therefore in the appearance of things." (*The Principles of Mechanics*, 223–24) On this point, Wittgenstein remarked, "Hertz said that wherever something did not obey his laws there must be invisible masses to account for it. This statement is not right or wrong, but may be practical or impractical. Hypotheses such as 'invisible masses', 'unconscious mental events' are norms of expression [...] Whether all velocities can be accounted for by the assumption of invisible masses is a question of mathematics, or grammar, and is not to be settled by experience. It is settled beforehand." (*Wittgenstein's Lectures, Cambridge, 1932–1935*, 16)

20 "I use the word 'observer' in the sense in which it is conventionally used in Galilean relativity when we say that an object has a velocity 'with respect to a certain observer'. The observer can be any physical object having a definite state of motion." (Rovelli, "Relational Quantum Mechanics," 3)

21 "When you sit with a nice girl for two hours you think it's only a minute, but when you sit on a hot stove for a minute you think it's two hours. That's relativity." (Albert Einstein, quoted in "Einstein is Found Hiding on Birthday")

22 "Of necessity a motion is relative when experienced with respect to a 'basis-body' experienced at rest and in unity with my corporeal animate organism." (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 224)

23 "[Q]uantum mechanics, as it is enshrined in textbooks, seems to require separate rules for how quantum objects behave when we're not looking at them, and how they behave when they are being observed [...] The whole thing is preposterous. Why are observations special? What counts as an 'observation,' anyway? When exactly does it happen? Does it need to be performed by a person? Is consciousness somehow involved in the basic rules of reality? Together these questions are known as the 'measurement problem' of quantum theory." (Carroll, "Even Physicists Don't Understand Quantum Mechanics")

two bodies—that is the objective one, as the identity of the observer plays no part in it.[24,25,26]

When I examine the inner workings of a machine, I open up the box and look inside; I don't stick my hand in and feel around, for my body is a dynamical body like any other[27] and it would then change the system that I'm trying to observe (by getting stuck in the gears, say). My body—the observer's body—would then be an element in the system being observed, and it would need to be included in any model thereof.[28] Specifically in Mechanics, any interaction between the observer and the system in question is considered to be a 'disturbance,'[29,30,31] and observation of the natural world comprises only acts in which the observer's identity is irrelevant—in which the *I* plays no role.[32,33]

If I want to find out how a pendulum moves—and not merely how a pendulum moves when *I* measure it in *this* particular way—then I have to observe it from a distance. So, in Mechanics, the observer is always physically removed from the system that they are observing—a 'closed system' whose elements are in purely relative motion—as it is when two bodies are physically removed from one another that they are

24 "As soon as we perceive the objects around us we consider them in relation to ourselves—and rightfully so. For our entire fate depends upon whether they please or displease, attract or repel, benefit or harm us. This completely natural way of considering and judging things seems as easy as it is necessary. But it also makes us susceptible to a thousand errors that can shame us and embitter our lives.¶ Those human beings undertake a much more difficult task whose desire for knowledge kindles a striving to observe the things of nature in and of themselves and in their relations to one another." (Goethe, "The Experiment as Mediator of Object and Subject," 19)

25 "The less anthropomorphic science believes itself to be, the more anthropomorphic it is." (Spengler, *The Decline of the West: Form and Actuality*, 427)

26 The internal motion of another composite body is what is objective, as what is verifiable is that someone *else* is in pain. Ludwig Wittgenstein argued along these lines, "It can't be said of me at all (except perhaps as a joke) that I *know* I am in pain. What is it supposed to mean—except perhaps that I *am* in pain?¶ Other people cannot be said to learn of my sensations *only* from my behaviour,—for *I* cannot be said to learn of them. I have them.¶ The truth is: it makes sense to say about other people that they doubt whether I am in pain; but not to say it about myself." (Wittgenstein, *Philosophical Investigations*, § 246) Saying, "The only valid frames of reference are ones where the observer isn't accelerating" is analogous to saying, "only I know how much pain I'm in."

27 "A stone, the body of a beast, the body of a man, my body, all stand on the same level." (Wittgenstein, *Notebooks 1914–1916*, § 12.10.16)

28 "If I wrote a book 'The world as I found it', I should also have therein to report on my body and say which members obey my will and which do not, etc. [...] " (Wittgenstein, *Tractatus Logico-Philosophicus*, § 5.631)

29 "If, without in any way disturbing a system, we can predict with certainty (i.e., with probability equal to unity) the value of a physical quantity, then there exists an element of physical reality corresponding to this physical quantity." (Einstein, Podolsky, and Rosen, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" 777)

30 "Indeed the *finite interaction between object and measuring agencies* conditioned by the very existence of the quantum of action entails—because of the impossibility of controlling the reaction of the object on the measuring instruments if these are to serve their purpose—the necessity of a final renunciation of the classical ideal of causality and a radical revision of our attitude towards the problem of physical reality." (Bohr, "Can Quantum-Mechanical Description of Physical Reality be Considered Complete?" 697)

31 "The Greek honored the body, and aimed at the perfect representation of it, because he deified nature, and strove to approach her as closely as possible. The Christian, on the contrary, despised the Body. He looked on Nature herself as partaking of the Fall, and thereby impure, alien from God. The Body, thus conceived as the perishable vehicle of the Soul, was not a fitting symbol. He did not try to express his Ideal in the Body, but beyond it." (Lewes, *The Life and Works of Goethe*, 244)

32 "What has been missing [in History], till now, is *detachment* from the objects considered [...] In respect of Nature [as opposed to History], this detachment has long ago been attained, though of course it was relatively easy of attainment, since the physicist can obviously systematize the mechanical-causal picture of his world as impersonally as though he himself did not exist in it." (Spengler, *The Decline of the West: Form and Actuality*, 93)

33 " 'I' is not the name of a person, nor 'here' of a place, and 'this' is not a name. But they are connected with names. Names are explained by means of them. It is also true that it is characteristic of physics not to use these words." (Wittgenstein, *Philosophical Investigations*, § 410)

independent.[34,35] Precisely in the measurement of relative motion is the observer himself nothing but a perspective,[36] or vantage point,[37] and unable to affect the system accordingly.

34 "Tis utterly inconceivable, that inanimate brute matter, without the mediation of some immaterial being should operate upon and affect other matter without mutual contact; that distant bodies should act upon each other through a vacuum, without the intervention of something else, by and through which the action may be conveyed from one to the other." (Bentley, "A Confutation of Atheism from the Origin and Frame of the World, Part II," 162)

35 "However, if one abandons the assumption that what exists in different parts of space has its own, independent [from each other], real existence, then I simply cannot see what it is that physics is meant to describe. For what is thought to be a 'system' is, after all, just a convention, and I cannot see how one could divide the world objectively in such a way that one could make statements about parts of it." (Albert Einstein, quoted in Born, Born, and Einstein, *The Born-Einstein Letters*, remark within marginal comments attached to letter 86)

36 "The subject of optics, [was] known as 'perspective' in the Middle Ages [. . .] " (Hannam, *The Genesis of Science*, 145)

37 "A curious analogy could be based on the fact that the hugest telescope has to have an eye-piece no larger than the human eye." (Wittgenstein, *Culture and Value*, 17e)

4

GRAVITY AND INFINITE SPACE

> *Once again, therefore, there was an act like the act of Copernicus to be accomplished, an act of emancipation from the evident present in the name of infinity. This the Western soul achieved in the domain of Nature long ago, when it passed from the Ptolemaic world-system to that which is alone valid for it to-day, and treats the position of the observer on one particular planet as accidental instead of normative.*
>
> —*Oswald Spengler*[1]

In the development of the General Theory of Relativity, Albert Einstein broke with the Newtonian tradition and stopped referring to gravity as a force,[2] choosing to describe it instead as the very shape and form of space-time.[3] Why did he do that? What is it like being pulled by gravity as compared with being pulled by an electric charge? What is the grammar of gravitation?

Einstein's theory is based on the Equivalence Principle, which says that a body falling under gravity moves in the same way no matter how heavy it may be. Galileo proved this principle with the following thought experiment: Take two cannonballs, one heavier than the other, and then tie them together with a string and drop them from some height. Were the heavier cannonball to fall faster than the lighter one, then the lighter body would retard the motion of the heavier, and the composite body would fall slower than the heavier cannonball alone. But the composite body, as a unit, is even heavier than the heavy cannonball alone, and so it should fall faster. By contradiction, the two bodies must therefore fall at the same rate.[4] The grammar of gravitation specifically lets one describe the same falling object as a single object or as a set of independent smaller

1 Spengler, *The Decline of the West: Form and Actuality*, 94.

2 "But we have accumulated around the terms 'force' and 'electricity' more relations than can be completely reconciled amongst themselves. We have an obscure feeling of this and want to have things cleared up. Our confused wish finds expression in the confused question as to the nature of force and electricity. But the answer which we want is not really an answer to this question. It is not by finding out more and fresh relations and connections that it can be answered; but by removing the contradictions existing between those already known, and thus perhaps by reducing their number. When these painful contradictions are removed, the question as to the nature of force will not have been answered; but our minds, no longer vexed, will cease to ask illegitimate questions." (Hertz, *The Principles of Mechanics*, 7–8)

3 Wald, *General Relativity*, 9.

4 Galilei, *Discorsi e dimostrazioni matematiche intorno a due nuove scienze*, 73–77.

objects, no matter how those divisions are made.[5] (The same argument does not apply to the electrostatic force, because if an electrically charged cannonball were split in two while 'falling' in an electrostatic potential, then those two parts would not continue to fall adjacent to each other, but rather would repel each other strongly.)

Einstein restated the Equivalence Principle in the following more general terms: "[T]he acceleration imparted to a body by a gravitational field is independent of the nature of the body."[6] That is, every atom of a falling object is moved the same way, and the mutual relations of all of the parts of any composite body remain unaltered. Each body is accelerated as a unit—as a simple whole—and every body moves the same in a given gravitational field. Employing the terminology established above, we may say that *gravity describes only translational motion and no internal motion*. Einstein realized that person floating in a gravitational field doesn't feel any forces: an object in free fall isn't compressed under its own weight, and a person enclosed in an elevator is therefore unable to say whether he is floating in outer space far away from everything or accelerating rapidly toward the Earth and about to crash into the ground.[7] In Relativity, one describes such a frame of reference—where there is no internal motion—as 'locally inertial'.[8] However, the word 'local' here does not refer properly to what is a *finite* distance away, as one might think, but rather to what is *zero* distance away. Accordingly, in Einstein's Elevator,[9] one distinguishes between objects that are *inside* the falling body ('local') and those that are *outside* the elevator ('non-local'—say, a nearby aeronaut that it flies past).

What about the 'force of gravity' acting on a person that is standing on the surface of the Earth? A body might experience the same force in an upward-accelerating elevator out in space. One might say that gravity doesn't *pull* rocks toward the Earth any more than gravity *pushes* balloons upward. (How would Newton have seen gravity in the falling of an apple had he lived underwater?) I cannot experience 'zero-g' in a swimming pool only insofar as I have internal organs, as it were; but those internal organs are another matter entirely. (If I drop a hammer inside of an underwater habitat, then the hammer will fall downward; the

5 "For my part I believe that gravity is nothing but a certain natural desire [...] to gather as a unity and a whole by combining in the form of a globe." (Copernicus, *Nicholas Copernicus on the Revolutions*, book 1, chap. 9)

6 Einstein, *The Meaning of Relativity*, 63.

7 "When I was busy (in 1907) writing a summary of my work on the theory of special relativity [...] I also had to try to modify the Newtonian theory of gravitation such as to fit its laws into the theory [...] At that moment I got the happiest thought of my life [...] Because for an observer in free-fall from the roof of a house there is during the fall—at least in his immediate vicinity—no gravitational field. That is, if the observer lets go of any bodies, they remain relative to him, in a state of rest or uniform motion, independent of their particular chemical or physical nature." (Einstein, "Fundamental Ideas and Methods of the Theory of Relativity, Present in their Development," § II.15)

8 "Therefore we formulate the equivalence principle as the statement that *at every space-time point in an arbitrary gravitational field it is possible to choose a 'locally inertial coordinate system' such that, within a sufficiently small region of the point in question, the laws of nature take the same form as in unaccelerated Cartesian coordinate systems in the absence of gravitation*." (Weinberg, *Gravitation and Cosmology*, 68; italics original)

9 Einstein, *Relativity*, 78.

hammer isn't underwater—the chamber is. I am not in outer space right now; the Earth is.) The *force* of gravity is a *buoyant* force.[10] That is, the motion of a body in a fluid such as our atmosphere may be described as a rearrangement of the internal elements of the Earth *qua* complex body.

This raises the question, what does it mean to travel through outer space? How is that different from, say, running through a field of grass on Earth? I can measure how fast I'm moving through a field by counting my strides. I wouldn't call that 'my speed relative to the field,' however—which part of the field? The field is not a body, and my distance to the field isn't changing.[11] Imagine that you're in the void of space: there are no longer any strides for you to count, nor could you measure your speed through the air with a pitot tube, say, the way you might in an atmosphere—you can only measure your speed relative to other moving bodies. A small asteroid, say 10 meters across, passes right next to you... you should be able to measure your speed relative to it as if it were a simple object. But what if the asteroid were 10,000,000 meters across (the size of the Earth)? You would no longer be able to say that the asteroid is 'passing you by'—you would be traveling across its surface, or perhaps through its atmosphere, and all nearby objects would be doing the same[12]—as you would not say that the Earth itself is 'passing you by' while you sit in a moving train.[13] When the asteroid is *very* large, then one speaks of motion *within* that much larger system, and that motion then has the grammar of running through the field rather than that of floating in space.[14]

Newtonian gravitation is a picture of the universe at a large scale, depicting even the most massive bodies, along with all others, as mere points in a coördinate system.[15,16] In this picture, there is no motion

10 "Before Einstein, we thought that what we felt all day, every day, was gravity pulling us down. Einstein realized we were mistaken. What we feel is the floor pushing up on us." (Smolin, *Time Reborn*, 68)

11 Edmund Husserl wrote, "The earth does not move—perhaps I may even say that it is at rest. But that can only mean that each earth-piece, which I or someone else separates off or is broken off by itself and which is at rest or in motion, is a body. The earth as a whole whose parts—if conceived by themselves as they can be separated off, as separable—are bodies; but as a 'whole' the earth is not a body." ("Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 225) This line of thought was so controversial, however, that it necessitated such apologies as this by Alfred Schütz which states, "One of the most serious misinterpretations of Husserl's attempt at an analysis of space, for instance, would be the supposition that this philosopher ever had the intention of substituting constructions of a primitive speculation for the accomplishments of modern science and mathematics, which he knew as thoroughly as anyone." ("Notizen Zur Raumkonstitution," 22)

12 "For all the earth is the same earth—on it, in it, over it, the same bodies hold sway. 'On it,' etc., the same organismal subjects, subjects of animate organisms, which, in an altered sense, are the bodies for all. For all of us, however, the earth is the basis and not a body in the complete sense." (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 226)

13 "Thus the earth has deformation and continual inner motion, etc. But how can it move as a 'whole,' how is that conceivable?" (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 225)

14 Precisely when the cannonballs in Galileo's thought experiment are much smaller than the Earth are there no gravitational tidal forces that would differentially affect the two components of the cannonballs *qua* composite body. (Wald, *General Relativity*, 73–74)

15 "[I]t is by this argument that Newton concludes *all* gravitation to be mutual; concludes, therefore, that every particle of matter, having weight proportional (at a given place) to its mass, is also a center of gravitational force, with a strength proportional to its mass." (Stein, "Newtonian Space-Time," 180)

16 " [...] Leibniz and Mach suggest that if we want to get a true idea of what a point of space-time is like we should look outward at the universe, not inward [...] The complete notion of a point of space-time in fact consists of the appearance of the entire universe as seen from that point. Copernicus did not convince people that the earth was

'within' or 'through'—there is only motion in outer space,[17] an infinite void dotted with points of mass,[18] where the motion of a falling body is the same phenomenon as the orbit of a planet around the Sun, and where Jupiter is the same kind of object as the apple on Earth.[19,20,21] And it is thus that Newton's inverse-square law of gravitation is equivalent to Gauss's Law of Gravity, which says simply that (as far as gravity is concerned) every body is nothing more than a point at its center of mass with a mass equal to that of the whole.[22,23]

In Newton's theory, where all bodies are point masses in outer space, there is no 'up' nor 'down'. Every location in space is the same.[24,25] And yet, on Earth, when I drop a hammer from my hand, it does fall *down*, toward the ground. So, in Aristotle, light objects rise (e.g., balloons) while heavy objects fall (e.g., rocks).[26] Now, a balloon flies up, toward the sky. Could one say that the hammer falls 'away from the sky'? When the hammer falls to the ground, or even into the deepest ocean trench, eventually it'll get there... to the bottom. What is the balloon's destination?[27] The falling hammer gets farther away from some things, but also closer to others—to other particular parts of the Earth. If I launch a rocket upward,

moving by getting them to examine the earth but rather the heavens. Similarly, the reality of different points of space-time rests ultimately on the existence of different (coherently related) viewpoints of the universe as a whole." (H. R. Brown, *Physical Relativity*, 14)

17 "[R]ectilinear, uniform motion is utterly impossible, and can take place only in a vacuum." (Koyré, *Metaphysics and Measurement*, 34)

18 "But now it was Space that ruled the universe. 'World' signifies space, and the stars are hardly more than mathematical points, tiny balls in the immense, that as material no longer affect the world-feeling." (Spengler, *The Decline of the West: Form and Actuality*, 329)

19 "For the attractive force of all parts of the earth can affect us, neither more nor otherwise, than if it were wholly concentrated in its central point, and it were this alone that influenced our sense; similarly with the attraction of a mountain, and of every stone, &c." (Kant, *Kant's Prolegomena and Metaphysical Foundations of Natural Science*, 184)

20 "He regarded every heavenly body as a mathematical point, as fixed stars indeed appear to be at a first approximation of observation. Between each two of these points there was to be a force of attraction along the line joining them and inversely proportional to the square of their distance. By conceiving a similar force to be acting between any two material particles of any body whatsoever and by applying the laws of motion obtained from observations on terrestrial bodies, he succeeded in deriving from the one law the motions of all celestial bodies, gravity, the tides and all connected phenomena." (Boltzmann, "On the Development of the Methods of Theoretical Physics in Recent Times," 80)

21 "*[T]his* kind of a conception of space is always, under the influence of science, becoming smaller and smaller: in the same way as science has taught us, and is still teaching us, to look upon the earth as small—yea, to look upon the entire solar system as a mere point." (Nietzsche, *Dawn of the Day*, book I, § 7)

22 "In his demonstration Maupertuis refers to a theorem from Newtonian potential theory that states that only spherical bodies exert equal forces in all directions. The only definite point of reference for the determination of distance in this case is the center of the sphere. If, now, the Creator aimed at a uniformity of action in matter, the law should apply equally for a mass point as well as for an extended sphere." (Jammer, *Concepts of Force*, 157)

23 The inverse-square relation is therefore knowable *a priori* as a logical feature of such a picture of the world. Indeed, "textbooks commonly derive the form of the force law from the assumption of Gauss' law [...] " (Callender, "Answers in Search of a Question: 'Proofs' of the Tri-Dimensionality of Space," 118)

24 "The difference between one event and another does not depend on the mere difference of the times or the places at which they occur, but only on differences in the nature, configuration or motion of the bodies concerned." (J. C. Maxwell, *Matter and Motion*, 21)

25 "The general validity of the principle that the universe presents the same aspect from every point (and according to a modern school of cosmologists also at every time), except for local irregularities, is accepted in modern science as a necessary condition for the repeatability of experiments, since space and time are the only parameters which, at least in principle, are beyond the control of the experimenter and cannot be reproduced at his will." (Jammer, *Concepts of Space*, 84)

26 Aristotle, *Aristotelis Opera*, 214.

27 "*Philotheus:* Shoot up an Arrow perpendicular from the Earth; the Arrow you know, will return to your foot again.¶ *Hylobares:* If the wind hinder not. But what does this Arrow aim at?" (More, *Divine Dialogues Containing Disquisitions & Instructions Concerning the Attributes and Providence of God*, first dialogue, § XXVI)

no matter which way it flies, it will only get farther and farther away from everything else. (It is "Up, up and away!"[28] but "down down to Goblin-town."[29]) How is it that when 'everything' falls, it all falls down, toward the Earth?[30] If the Earth began spinning around much more quickly, then everything would be flung away from it—as though the Earth were a giant slingshot—and yet if the Sun did the same, one would hardly notice. It was such considerations that led Ptolemy to call the Earth the center of the universe:

> Hence I think it is idle to seek for causes for the motion of objects toward the centre, once it has been so clearly established from the actual phenomena that the earth occupies the middle place of the universe, and that all heavy objects are carried towards the earth. —Ptolemy[31]

Ptolemy's geocentric world-view, originating in the Arabian culture[32] and having persisted through the Renaissance, was eventually rejected and replaced by the heliocentric paradigm of Copernicus, in which the Earth is just another body, like the Sun.[33] The Copernican theory, in turn, was succeeded by Newton's theory of universal gravity, which treats all bodies—the Earth and sun included—as mere points in absolute space.[34,35,36] Finally, Newton's theory was overturned by Einstein's General Relativity, wherein even locations in space cannot be distinguished.[37] The coördinate system itself is now completely arbitrary and there are no

28 Webb, *Up, Up and Away*.

29 Tolkien, *The Hobbit, or, There And Back Again*, 56.

30 One says all the time, "Everything is falling down." But what could "everything is flying up" mean? (One wants to say here, instead, "Everything is flying *away*.")

31 Ptolemy, *Almagest*, 43.

32 "The sacred book, the Canon is, scientifically as in other respects, Arabian—the scientific canon of Ptolemy (Almagest), the medical of Ibn Sina (Avicenna), and the philosophical corpus designated 'Aristotle,' but so largely spurious—so also the (mostly unwritten) laws and methods of quotation [...] " (Spengler, *The Decline of the West: Perspectives of World History*, 346)

33 "The earth is [...] one of the stars in the infinite world-space. The earth is a globe-shaped body [...] [The] earth is a huge block on which smaller bodies exist and on the basis of which they also always have become, and could have become, for us by division into pieces or by separating them off from the whole." (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 222)

34 "A material particle is a characteristic by which we associate without ambiguity a given point in space at a given time with a given point in space at any other time." (Hertz, *The Principles of Mechanics*, 45–46)

35 "In the infinite universe of Bruno [...] all 'places' are perfectly equivalent and therefore perfectly natural for all bodies." (Koyré, *Metaphysics and Measurement*, 9)

36 "All the mathematical ideas that the West found for itself or borrowed from others were automatically subjected to the form-language of the Infinitesimal—and that long before the actual Differential Calculus was discovered." (Spengler, *The Decline of the West: Form and Actuality*, 84)

37 "Aristotle is once more perfectly right. An empty space (the space of geometry) is utterly destructive of the conception of a cosmic order: in an empty space there are not only no natural places, there are no *places* at all." (Koyré, *Metaphysics and Measurement*, 28)

preferred frames of reference, even as General Relativity failed to abolish the notion of absolute space[38] and in fact reaffirmed the aether theory.[39,40]

After all of these developments, physicists cannot resist talking about the Copernican theory as if it were perhaps *half* true.[41,42,43] It's not so much that what Copernicus said was *correct*, but rather that he took the critical step in the abrogation of the idea that the philosophical Subject (the observer) enjoys a privileged position in the natural world, an idea that today seems naïve and provincial in its anthropocentrism and unimaginitiveness.[44] And yet, is the difference between a geocentric and heliocentric model mere convention?[45] Should we all stop using the word 'down' because we might instead be living on the surface of the Sun, where it would mean something different?[46]

The rejection of geocentrism was part-and-parcel with the historical development of the Mechanical world-view,[47] because in the examination of a Mechanical system, every observation is objective, reproducible, and

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38 "It required a severe struggle to arrive at the concept of independent and absolute space, indispensable for the development of theory. It has required no less strenuous exertions subsequently to overcome [the concept of independent and absolute space]—a process which is probably by no means as yet completed." (Albert Einstein, quoted in Jammer, *Concepts of Space*, xvi)

39 "We may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists an Aether. According to the general theory of relativity space without Aether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this Aether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it." (Einstein, "Ether and the Theory of Relativity," 23–24)

40 "If one accepts the general theory of relativity as giving a literally correct picture of the physical world, one must stand with the Newtonian tradition and regard space-time as a substance." (Maudlin, "Buckets of Water and Waves of Space: Why Spacetime Is Probably a Substance," 561)

41 "[An inertial system] is a [coördinate system] in which the laws of mechanics are valid. [...] The [coördinate system] connected with the sun resembles an inertial system more than that connected with the earth. The physical laws should be applied to Copernicus' [coördinate system] rather than to Ptolemy's." (Einstein and Infield, *The Evolution of Physics*, 209–11)

42 "As regards the question of whether the Earth or the heavens rotates, the difference between Copernicus and Ptolemy is indeed convention as long as we take no account of the *dynamical* discoveries that completed the Copernican revolution. However, as regards the second motion that Copernicus proposed (the annual as opposed to the diurnal motion) there is an unambiguous difference between Ptolemy and Copernicus, for Ptolemy taught that the Earth is at rest relative to the stars, i.e., the distance from the centre of the Earth to the stars does not change. Thus, if motion is defined as motion relative to the matter of the universe as a whole, Copernicus is without doubt correct about his second motion and Ptolemy simply wrong. The question of the diurnal motion remains tantalizingly open." (Barbour, *The Discovery of Dynamics*, 694)

43 "The sun appears to go around the Earth, but it's the other way around—and when you get right down to it, it turns out that everything moves relative to everything else." (Smolin, *Time Reborn*, xi)

44 Cf. "Two things fill the mind with ever new and increasing admiration and awe, the more often and steadily we reflect upon them: *the starry heavens above me and the moral law within me.*" (Kant, *Kant's Critique of Practical Reason and Other Works on the Theory of Ethics*, 260)

45 "[If we can develop a general relativity theory, t]he struggle, so violent in the early days of science, between the views of Ptolemy and Copernicus would then be quite meaningless. Either [coördinate system] could be used with equal justification. The two sentences, 'the sun is at rest and the earth moves,' or 'the sun moves and the earth is at rest,' would simply mean two different conventions concerning two different [coördinate systems]." (Einstein and Infield, *The Evolution of Physics*, 212)

46 "But a still better example would be that of the application of 'above' and 'below' to the earth. Here we all have a quite clear idea of what 'above' and 'below' mean. I see well enough that I am on top; the earth is surely beneath me! (And don't smile at this example. We are indeed all taught at school that it is stupid to talk like that. But it is much easier to bury a problem than to solve it.) And it is only reflection that shews us that in this case 'above' and 'below' cannot be used in the ordinary way. (That we might, for instance, say that the people at the antipodes are 'below' our part of the earth, but it must also be recognized as right for them to use the same expression about us.)" (Wittgenstein, *Philosophical Investigations*, § 351)

47 "But rest and motion cease to be absolute as soon as the earth becomes a world-body in the open plurality of surrounding bodies. Motion and rest necessarily become relative." (Husserl, "Foundational Investigations of the Phenomenological Origin of the Spatiality of Nature," 224)

predetermined; every perspective is equally valid.[48] I am merely one passive observer of the natural world, physically removed from my object of study,[49,50] and my body is an infinitesimal point in infinite space just like all others.[51] The "dead Nature of Newton"[52] (and of his successors) specifically deals only in the dynamics of the relative[53] and objective[54,55] translational[56] motion of the featureless masses[57] into which complex bodies may be divided. Indeed, it is precisely when a model describes exclusively the relationships between simple bodies that the dynamics of that model must then be found in the properties of the very space

48 "We are here faced with an epistemological problem quite new in natural philosophy, where all description of experiences has so far been based upon the assumption, already inherent in ordinary conventions of language, that it is possible to distinguish sharply between the behaviour of objects and the means of observation. This assumption is not only fully justified by all everyday experience but even constitutes the whole basis of classical physics, which, just through the theory of relativity, has received such a wonderful completion. As soon as we are dealing, however, with phenomena like individual atomic processes which, due to their very nature, are essentially determined by the interaction between the objects in question and the measuring instruments necessary for the definition of the experimental arrangements, we are, therefore, forced to examine more closely the question of what kind of knowledge can be obtained concerning the objects." (Bohr, *Atomic Physics and Human Knowledge*, 25)

49 "If one asks what, irrespective of quantum mechanics, is characteristic of the world of ideas of physics, one is first of all struck by the following: the concepts of physics relate to a real outside world, that is, ideas are established relating to things such as bodies, fields, etc., which claim a 'real existence' that is independent of the perceiving subject—ideas which, on the other hand, have been brought into as secure a relationship as possible with the sense-data. It is further characteristic of these physical objects that they are thought of as arranged in a spacetime continuum. An essential aspect of this arrangement of things in physics is that they lay claim, at a certain time, to an existence independent of one another, provided these objects 'are situated in different parts of space'. Unless one makes this kind of assumption about the independence of the existence (the 'being-thus') of objects which are far apart from one another in space—which stems in the first place from everyday thinking—physical thinking in the familiar sense would not be possible. It is also hard to see any way of formulating and testing the laws of physics unless one makes a clear distinction of this kind. This principle has been carried to extremes in the field theory by localising the elementary objects on which it is based and which exist independently of each other, as well as the elementary laws which have been postulated for it, in the infinitely small (four-dimensional) elements of space." (Albert Einstein, quoted in Born, Born, and Einstein, *The Born-Einstein Letters*, 170)

50 "Consider, now, Western painting as it was after Leonardo, fully conscious of its mission: How does it deal with infinite space as something *singular* which comprehends both picture and spectator as mere centres of gravity of a spatial dynamic?" (Spengler, *The Decline of the West: Form and Actuality*, 329)

51 "We, on the other hand, at bottom know only the abstract space-element of the point, which can neither be seen, nor measured, nor yet named, but represents simply a centre of reference." (Spengler, *The Decline of the West: Form and Actuality*, 81)

52 Spengler, *The Decline of the West: Form and Actuality*, 21.

53 "That this requirement of general covariance, which takes away from space and time the last vestige of physical objectivity, is a natural one, will be seen from the following reflection. All our space-time verifications invariably amount to a determination of space-time coincidences. If, for example, events consisted merely in the motion of material points, then ultimately nothing would be observable but the meeting of the material points of our measuring instruments with other material points, coincidences between the hands of a clock and points on the clock dial, and observed point-events happening at the same place at the same time. The introduction of a system of reference serves no other purpose than to facilitate the description of the totality of such coincidences." (Einstein, "The Foundation of the General Theory of Relativity," 117)

54 "Absolute [and infinite] space is then necessary, not as a mere idea which is to serve as a rule, for considering all motion therein as merely relative, and all motion and rest must be reduced to absolute space if the phenomenon of the same is to be transformed into a definite conception of experience (which combines all phenomena)." (Kant, *Kant's Prolegomena and Metaphysical Foundations of Natural Science*, 239)

55 "Just as the invariance with respect to the transformations characterizes the objective nature of reality, the structure of reason expresses itself in the arbitrariness of admissible systems. Thus it is obviously not inherent in the nature of reality that we describe it by means of coordinates; this is the subjective form that enables our reason to carry through the description [...] Kant's assertion of the ideality of space and time has been precisely formulated only in terms of the relativity of the coordinates." (Reichenbach, *The Theory of Relativity and A Priori Knowledge*, 90)

56 "The circular motion is (like every non-rectilinear [motion]) a continuous change of the rectilinear, and as this is itself a continuous change of relation in respect of external space, the circular motion is a change of these external relations in space, and consequently a continuous arising of new motions." (Kant, *Kant's Prolegomena and Metaphysical Foundations of Natural Science*, 236)

57 "The division of the body into *material points*, as we have it in physics, is nothing more than analysis into *simple components*." (Wittgenstein, *Notebooks 1914–1916*, 67e)

separating them.[58] Then, all that is left to describe is the shape and form of *infinite space*,[59] the prime symbol of Faustian culture.[60]

58 "The specifically Western symbol resides not in the reality of one or of another [geometries], but in the true plurality of equally possible geometries. It is the group of space-structures—in the abundance of which the classical system is a mere particular case—that has dissolved the last residuum of the corporeal into the pure space-feeling." (Spengler, *The Decline of the West: Form and Actuality*, 176)

59 "And so ends the metaphysical doctrine of body with *emptiness* and therefore incomprehensibility, and the reason has the same fortune in all other attempts, where it strives to reach principles of the ultimate grounds of things, inasmuch as its nature is such, that it can never comprehend anything except in so far as it is determined under given conditions; consequently, since it can neither rest at the conditioned nor can make the unconditioned comprehensible, when thirst for knowledge stimulates it, to grasp the absolute totality of all conditions, nothing remains for it but to turn back from objects, upon itself, in order that instead of the ultimate boundaries of things, it may investigate and determine the ultimate boundaries of the capacity pertaining to itself." (Kant, *Kant's Prolegomena and Metaphysical Foundations of Natural Science*, 244–45)

60 "The Western, Gothic, form-feeling [...] is that of an unrestrained, strong-willed far-ranging soul, and its chosen badge is pure, imperceptible, unlimited space." (Spengler, *The Decline of the West: Form and Actuality*, 81)

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