The Stance of Unknowing: the subject-object relationship in science and in life

AUTHOR'S PREFACE

I've called this book *The Stance of Unknowing* because the entanglement of subject and object, or mind and body, casts a pall of uncertainty over all experience. The book offers thoughts and observations in several domains, united by the theme of subject and object. It presents a lifetime of reflection about how self and world inextricably interact to produce our sensations, thoughts, feelings, attitudes and actions, and the many consequences of that entanglement. Understanding the relationship between subject and object seems crucial to our wellbeing as individuals and our survival as a species. Whether humanity moves toward a unity that can take charge of its destiny will depend on how well we come to a common understanding of our own nature and that of the world.

The book is organized in three parts. The first concerns the subject-object relationship generally. The second deals more specifically with the role of the observer in science. The third part discusses aspects of the subject-object relationship in more humanistic contexts.

CHAPTER ONE: Objectivity and Subjectivity

In which it is seen that knowledge is motivated, grounded in the subject's biological embodiment. Objectivity has survival value, yet depends on subjective awareness. We have only maps through which to conceive or perceive the territory. The subject redefines the object in human terms. Science translates inductive findings into deductive truths.

> "All the world's a stage."—Shakespeare

What could be more obvious than a world of objects, present before our senses, in a space outside our bodies? Yet, we know that is not the whole story, for we are aware also of our own existence as perceiving subjects, in whose consciousness that world—and much more—seems to unfold in an interior domain. Even one's own body can appear external to this locus of consciousness we call the self. While the universe is busy existing, we too exist. We find ourselves embedded in the physical world yet also apart from it, inhabiting a mental realm where we dream, think, and feel, and imagine things that *don't* exist. We sense that objective reality unfolds "out there," seemingly independent of us; yet we know that its appearance "in here," on the stage of consciousness, depends crucially on our nature as perceiving subjects. While socialization and individual character affect how we view the world and relate to others, each of us is an embodied epistemic agent, whose biological and physical nature literally shapes our experience of reality.

We are actors in a drama we call living, and the stage is the natural world. The lives of the actors depend entirely upon this stage and their story can unfold nowhere else. The story, therefore, is also about *the stage itself* and the actors' dependent relation to it. The narrative includes a notion of objective reality and the vital imperative to be attuned to it. But it also includes the actors' ability to improvise, their subjective freedom within the constraints of the play. The bodies of the actors could seem no more than props, part of the ever-changing stage. Yet the characters they portray, however fictional, miraculously have their own internal lives. Uniquely, this drama is aware of itself.

Our sense that reality lies outside us is mirrored by a sense of being an observer apart from it. We seem to stand outside the system of the world, looking in, even as we seem to be inside a body looking out. We tend to deem ourselves separate from the world, as though invisible, our presence without effect. Yet, the temperature of a room can *matter* to a person inside in a way that it does not for someone outside. Also, their own body heat contributes a change which. This is the human situation on this planet, the shared "room" we occupy as a species. It also describes the conscious mind's situation as an occupant of a human body, as well as the situation of bodies sharing a world with other bodies.

The awareness of being aware creates a tension, reflected in thought and language as an opposition between *I* and *it*—between first-person and third-person description. This not a distinction between kinds of things, but between *things* and *perceivers*, between a point of view and what can be seen from that point of view, between actors and props. It radically polarizes the reality into two kinds of being: subject and object.

This duality echoes the distinction between animate and inanimate. In addition to the subject-object relationship, we relate subject to subject: *I* to *thou.* One understandably imagines other living beings to be animated by the same sort of inner life as oneself—to be autonomous sentient agents, in contrast to merely passive things. As social creatures, we have significant relationships to each other. While one cannot *have* another person's experience (or even prove its existence), it is socially correct to assume that other people are endowed with conscious awareness. We affirm this personhood in language—in the "second-person"—and codify it in precepts of religion, ethics, psychology, and law. Yet, even inadvertently, we often treat one another as objects. While a blatant example is human rights violation, the dilemma inheres in the very fact of embodiment, as a moral issue of how to relate to others moment by moment. Were we disembodied minds, we might exist as pure subjects; but as organisms, we are both subject and object. Whatever our morals, biology obliges us to *eat* and otherwise *use* other organisms, just as we are vulnerable to their predations. The option to regard *the other* purely as an instrument of one's needs is built into us. This manifests not only in the willingness to physically harm, or to disregard suffering, but also in every subtle form of exploitation that imagination has been able to invent and rationalize.

The notion of objectivity suggests that the object can at least be known independently of the subject and the process of knowing. The embodied mind naturally looks outward, upon a world presumed to have its own reality. Physical science adopts this stance, tacitly excluding the scientist from the field of view constituted by the natural world. To affirm the reality of what is observed, it brackets the observer's role. But, just as the epistemic subject is necessarily embodied, the scientific observer is not merely a point of view, but is also an integral part of the system studied, which includes the apparatus of experiment or measurement and the information-carrying medium. That is, the scientific observer, too, is both subject and object. Still, everything remains external to the observer, who remains implicitly outside the system, in a mental rather than a physical realm. The scientific worldview rarely addresses the gap between the physical and mental, or between third-person and first-person perspectives. Nor is there provision for a second-person relation to nature at large.

Our understanding of human nature cannot be separated from the nature of the world we inhabit. Are we primates in a material world or souls in a spiritual world? Your view of yourself depends on your view of the world—and vice versa. Fundamental questions about what exists and how we know invite disagreement precisely because of the entanglement of subject and object. Spiritual traditions have advised us to be in the world and not of it. Modern science has taken this to heart. For, the scientific observer is deemed mentally separate from the world observed, while physically embedded in it. This suggests that science has unfinished business: to make fully explicit the subject's embedded role in observation and description. On the other hand, religion too may have unfinished business. While catering to the needs of the subject, religion focuses on supposedly objective spiritual realities—gods and souls, heavens and hells. It could shift its focus, from theology and personal salvation, to ethics and the flourishing of all life.

A subject occupies a literal point of view in space and time—a unique view of the world. Being materially embodied, subjects are also objects that others can view from many different vantage points. Mutuality is implied, like the fact that when distant others appear smaller to us, we also appear smaller to them. Here is a thought experiment: imagine that only one single object exists in the universe. Immediately a paradox arises, since your imagining self is already a second object! Then imagine stepping back to imagine your own body as part of the picture—an operation that can be repeated endlessly. In other words, as a point of view, the subject necessarily stands apart from what is seen. As a material being, however, the subject can only arbitrarily be distinguished from the rest of the universe. Simply drawing a boundary does not change material reality.

Understanding can be framed in either objectivist or subjectivist terms. Explanation can be *causal* (as between inert things) or in terms of *reasons* (such as people offer as justification for their actions or ideas). Modern biology views humans as systems governed by causal laws. Traditional religion sees them as moral agents obeying divine laws. Secular society views them as mental and legal entities obeying man-made laws. A yet different view sees all organisms as *agents* who do things for their own reasons.

Through natural selection, the creatures that exist have learned to deal with reality well enough to survive and reproduce. That does not imply understanding the world in a human sense, nor seeing reality for what it is, let alone for what it should be. Creaturely knowledge may be tacit and instinctive. Human knowledge is formalized in science; yet, that does not make it independent of needs. For all organisms, cognition is grounded in their biological nature, with some balance struck between individual and species interests. For social creatures, the interests of the group play a part as well.

It's natural that a conscious social primate would view the world in terms of agency. For most of human history, we've projected intentionality into nature. What is surprising is the degree to which modern science shuns agency in the natural world, striving instead to explain life in terms of inert matter. This bias has shaped an exploitative view of nature. It may also handicap the understanding of the cosmos as a self-organizing system.

From an anthropological view, human beings, including scientists, are tribal creatures. The human species is a constructed category, which has yet to unite us in behavior. Instead, we continue to bicker and make war, even as common dangers call upon us to act with a unified will. We continue in many ways to hold essentially anthropocentric and culture-centric views of the world, even in science. A human individual is not a unified entity that can behave consistently. Much less is society such a whole.

The subject-object relation is key to any potential objectivity and its long-term benefits. The first-person point of view is charged with self-interest and survival needs. In contrast, the ideal of objectivity is to be free from the idiosyncrasies of a point of view identified with narrow biological interests, and free from compulsory adherence to parochial cultural values. The ideal is to be *dis*interested, which paradoxically serves our long-term interest. The ability to override biologically useful biases is itself an adaptation to help us survive changing conditions.

While this may all seem abstract, there are personal benefits to understanding the subject-object relationship. For, everything that we think, feel, or do is shaped by both inner and outer factors. To blame either oneself or others for our good or bad fortune is misleading without acknowledging this co-responsibility. Recognizing the interplay of subject and object improves our ability to act more realistically, without undue pride or shame. Understanding our subjective motivations helps us correct for bias. In ordinary terms, objectivity means seeing things clearly and acting accordingly. Yet, the deeper implication of embodiment is that it is *not possible* to see things literally as they "really" are. Rather, we see them in the ways that enable life. Knowing this condition to be the price of existence is liberating to some extent and helps us understand others and ourselves more compassionately.

Reality preoccupies us because it matters. But if we cannot perceive reality as it literally is, then what, fundamentally, does *real* mean? A fast-approaching bus can kill you, whereas an imaginary one cannot. What is real is what can affect us and what we can affect, especially with consequences for our well-being.[1] *Realness* is how we experience the capacity of the world to affect us and be affected by us. It is thus not only a property of things themselves, but also a quality that imbues at least some of our experience. Events in the visual and auditory fields—the distance senses—are normally taken to indicate the presence of real external things. The affective content of such experiences of realness lies in the need to take them seriously, as holding the power of life and death over the organism. This is the biological *meaning* of realness as a subjective experience and as a cognitive judgment. It refers to the fact that the physical environment necessarily *matters* to the embodied creature. The panorama of consciousness is not a transparent window on the world itself. Rather, it narrates an ongoing account of our highly interested *relation* to the world.

Cognition includes everything the subject does to perceive and understand the world in order to act upon it, which includes scientific observation and experiment. To the scientific observer, the world is a black box, which—if it cannot be taken apart—must be studied for its outputs in relation to inputs from human agents. Like all cognition, science is an interactive process. Scientific knowledge is obtained by intervening in natural processes, not by passive observation alone. Like ordinary cognition, science is a biological strategy to cope with the unknown. The idea that science represents a growing body of objective knowledge fits well with our modern idea of progress. However, what actually accumulates are *data*, which always remain open to new or revised interpretations. Evidence grows (if we preserve it), while theories come and go.

Like sensory perception, classical science trades on the realist premise that the world exists a certain definite way regardless of how or whether we cognize it. But this is not the actual situation facing the cognizing subject, for whom the world remains ambiguous and open to multiple interpretations.[2] Science attempts to standardize the observer and isolate variables

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[1] The scientific version of this principle is that only what the observer can interact with causally should be considered real.

[2] It is certainly not the situation facing the observer of the quantum realm, as we shall see.

through controlled experiment. Mathematical models are made to stand in for the systems they simulate, since by definition the model (unlike the reality) is simple and can be exhaustively known and controlled.

Realism is the brain's default position because it works for survival, not because it is literally true. Scientific realism applies to causal interactions generally, however indirect or remote. As science extends cognition to the very large and distant, the very small, and perhaps the very complex, the natural inclination is to extend the intuitive sense of realness to things in domains that we can no longer directly perceive or directly interact with. In such realms, knowledge becomes unavoidablyly inferential, speculative, and abstract.

Not all experience is imbued with the sense of realness. The category of 'experience' itself distinguishes subjective from objective, illusory from actual, mental from physical. Self-awareness functions to help us see the limits of our perspective, disentangling subject from object. One is then in a better position to step outside a given framework, to find a better model, a larger perspective, a longer view, a more complete description. Consciousness is "subjective" in the sense that it is an action of the subject. Yet, knowing that appearances depend on how we see is the key to greater objectivity. Ideally, objectivity means clearly knowing what is real. Ultimately, its purpose is to respond in ways that enable—or at least permit—survival. An objectivity that is not naïve necessarily includes the role of the subject. How truly or distorted we take the image to be depends on how well we know the properties of the lens through which it is viewed. Hence, Socrates' wise injunction: know thyself.

Subjectivity is often criticized, when we mean that someone is not aware of their biases—especially when such awareness would allow them to see our point of view. Meanwhile, objectivity is often touted in a self-serving way, ironically to justify the interests of an individual, clique, tribe, or nation. Such confusions point back to the troublesome entanglement of subject and object at the core of human nature—which happens to be *primate* nature. Objectivity aims at truth, yet its claims are grounded in need.

The scope of one's concerns affects the adequacy of one's model of reality, which can affect personal and group prospects. The model will be limited by the interests that motivate it. One can only be as objective as the sphere of one's concerns is inclusive. There are degrees of objectivity, which is an ideal to move toward, not an achievable final state. *Perfect* objectivity (a god's-eye view) is an oxymoron for embodied subjects. In contrast, a key to *relative* objectivity is to identify with the largest view one can conceive embracing, which requires the subjectivity of self-consciousness.

Kant taught that we know only phenomena, not the noumenal world-in-itself. While the maps and models we make are not the territory, we have *only* maps and models through which to perceive or conceive the territory! The attempt to give shape in imagination and thought to the noumenal territory can only draw upon perceptual or conceptual images. Yet we must presume that the brain responds to something real. This puts us in a uniquely odd and paradoxical situation. Biology requires us to take appearances seriously even though we know they are constructed by the brain—an hallucination guided jointly by the world and the needs of the organism. Confidence in perception and the seeming reality of the world are biologically adaptive. While we exist largely on condition of taking appearances at face value, we've learned that the senses can be fooled and that a poor map can lead to disaster.

The information reaching the brain is always ambiguous. For good reasons, we dislike uncertainty. In the name of decisiveness, the mind substitutes definite fictions for ambiguous realities. Thus, when encountering a situation troubling or hard to understand, one can form a mental image that is definite but wrong. The definiteness can be useful and helps us cope. But it can also be disastrous if the image is too far from the reality. It helps to recall that any image is one's own creation and can be modified.

Traditionally, philosophers speak of the *physical* and the *mental*. While 'the mental' must be physically embodied, 'the physical' is a concept that must exist in someone's mind. This circularity renders any definitive understanding of the mind-body relationship elusive.[3] In their mutual dependence, subject and object feed back into each other, in a way that complicates understanding the relationship between appearance and reality. To explain putative realities in terms of sensory evidence requires us to then explain the appearance of that evidence in terms of some putative reality… and so on recursively. We naturally take the accessible phenomenal realm to be the inaccessible noumenal realm. But then we try (rather unnaturally) to interpret the inaccessible world-in-itself in the accessible terms of appearances.

The phenomenal realm constitutes one domain of cognition; scientific description constitutes another. Both are constructs; neither is the noumenal realm. The relationship between the phenomenal cognitive domain and the scientific cognitive domain involves what I call the *problem of cognitive domains*. This is the situation in which elements of one domain are supposed to reductively explain elements of another domain, when in fact they were derived from it in the first place. For example, Rutherford's and Bohr's early models pictured the atom as a miniature solar system, drawing upon images and concepts from the macroscopic realm in the quest to account for the micro realm. But atomic theory was then supposed to be the first rung of an explanatory ladder leading ultimately to those macroscopic properties. Planetary systems serve as a model for atoms, but then atoms are used to explain the existence of planets!

At least the macroscopic and microscopic physical domains are both in the category of third-person description. But when that sort of description is used to explain first-person experience, a different problem arises. For, mental and physical are not in the same category—like apples and oranges—but are more like apples and digital image files of apples. Strictly in its own third-person terms, science cannot provide a causal explanation of phenomenal experience. The hope may be to account for the contents of consciousness in terms of the activity of neurons. But neurons are part of the contents of (the scientist's) consciousness. Neurons functioning in our brains are supposed to explain—even to cause—their own appearance in our consciousness! As we shall later see, the agency of the subject provides a way out of this circularity.

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[3] While *body* can mean the physical body, the more general sense is physical *matter*. So, the relationship—as in The Mind-Body Problem—can mean the personal relationship to one's own embodiment or the more general relationship of the mental to the physical.

While language is how we communicate, it also shapes and reflects how we think and perceive. Both language and thought organize experience in *categories*. A category is a mental container to hold things with properties in common. Naming or labelling *puts* something (or someone) into a mental container with other things (or persons) that may have little in common besides the container itself. Labels obscure nuance; generalizations blur differences. The label *green*, for example, lumps together many colour shades, with no distinction among the variety of green things it could refer to. Yet, each person hearing the word 'green' will likely associate with it something definite—a specific colour or memory that may not correspond to that imagined by someone else because of *their* association (which could even be political). This mismatch between concrete experiences and the generality of terms and categories is both a strength and a weakness of language and thought. Categorization and labelling ignore finer distinctions and involve judgment, which is sometimes abusive. Name-calling of others serves to keep us untroubled by the finer points of who they actually are and to feel less obliged to take their arguments or feelings seriously.

While generalization helps us to think, reality is always specific. Reification, abstraction, and metaphor enable thought, but can also distort it. A word may refer to a specific experience or tangible thing, but just as often can refer to a category or generalization. The abstraction then becomes a thing in its own right. We shall see that many conceptual problems in science mirror everyday ambiguities of language. In particular, explanations and arguments can take an epistemic or an ontological form, according to whether the observer's role is acknowledged, or a disembodied view of a reification is embraced. Just as words substitute their artificial simplicity for the nuances of actual experience, theoretical idealizations substitute for the nuances of natural reality. Scientific models, like words, oversimplify a complex world. Scientific language deals with its own defined constructs, not with the natural world itself. Objectivity strives to abstract knowledge from its organic roots—but genuine understanding must include the observer's context.

The notion of objectivity naturally concerns the reality of objects. No one now disputes that atoms are real, but some scientists did as late as the close of the nineteenth century. We have since learned that an atom does not behave much like the things we are familiar with. We attribute to a proton some of the properties of larger objects, such as mass, density, electric charge. Yet, an individual proton cannot be literally weighed like an apple. What we know of stars and galaxies comes to us through feeble light that left its source long ago. Our knowledge of such distant things is as indirect and inferential as our knowledge of the nearby proton. The more tenuous the evidence, the more speculative the account. In truth, science can only deal directly with its own artifacts, which are made for specific purposes: theoretical entities, patterns of collected data, instruments and measurements. Science may hold that the world is physical and natural, but its own concepts are mental, social, man-made.

Even on the human scale, natural objects are ambiguous. In part, we perceive "objects" at all for functional biological reasons. While an apple may seem clearly to be an object, how well defined is a tree, a cloud, a mountain? In the face of inherent ambiguity, it is understandable that the mind imposes its own clear boundaries and definitions. Similarly, science overcomes natural ambiguity by simply *defining* its entities to begin with. Thus, scientific parameters are elements of a conceptual system. As *products of definition*, they are precise-by-definition. Their well-defined existence within theory can only correspond approximately to the ambiguous realities revealed through the interactions involved in measurement or observation. Yet, models useful to account for observed phenomena are often treated as the literal realities behind the phenomena concerned. We tend to think of atoms as small hard objects, as solid and real like the tables and chairs they compose—despite also believing that they consist of mostly empty space! Such inconsistency reflects the evolutionary success of the brain's unconscious perceptual strategies: cognition is pragmatic more than concerned with literal truth or even consistency. If tables and chairs behaved according to quantum rules, we might not perceive them as solid, real, or continuous in time.

The order in nature is not self-evident; it is something we have learned to discern through analytical eyes that have been trained to see parts and relationships among them. However, these parts and relationships may be artifacts of our habits of thought, often reflecting the design principles of made objects, such as machines. We seek out simple patterns, but the true (and perhaps indefinite) complexity of nature may be hidden by our very ways of looking. If our level of comprehension mirrors the sophistication of our artifacts, then we see only the depth of complexity we have been able to create, which may be far less than that of nature itself. While machines are deterministic by definition, neither determinism nor indeterminism is a property of the world itself, but rather of the subject's relation to it.

Until the 20th century, objectivity meant an absolute frame of reference with which to observe and measure things. This implied a sort of god's-eye perspective from which all observers could potentially see the same things, arrive at the same values for measurements, and come to the same conclusions, regardless of the dynamic state of the observer. The revolutions of 20th-century physics upset this presumption, rendering observation relative in certain ways to the observer. In the Theory of Relativity, it became relative to the observer's state of motion.[4] In the Quantum Theory, it became relative to the energy and scale of the probe compared to the thing probed.

The ideal of objectivity holds that knowledge should be independent of the state of the observer and the path through which it is obtained. The visual sense, emphasizing the so-called primary qualities,[5] fulfills this expectation better than other sense modalities. Light, of course, is the medium for which the human visual sense evolved. It allows information to be formed as an optical image, which is presumed to be faithfully represented in the mind's perceptual image. Yet, the perceptual image cannot *resemble* the inaccessible thing-in-itself, nor its optical transform. The seeming objectivity of vision is not a matter of literal verisimilitude. It is grounded instead in natural selection, which is a matter of the subject's relation to an environment, in which light plays a significant role. The justification for believing that we see

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[4] As we shall see in a later chapter, even that can be conceived from a first-person or a third-person perspective.

[5] I.e., properties such as size, shape, location, etc., in contrast to "secondary" qualities such as color and smell.

the world *truly* is that vision *works* for us, not that it reveals the world as it "really" is. Even the so-called primary qualities are no more strictly properties of the object itself than are secondary qualities. There is no way that the world-in-itself inherently looks, without someone looking.

The properties of light, especially in the visible spectrum, uniquely suit it for distance perception and for the concept of objectivity. These properties include its near-instantaneous speed and hyper-fine structure. In ordinary circumstances, the former means that information about the world arrives without delay; the latter means that the impact of light affects neither the organ of perception nor the object perceived in a significant way. Such was the presumption in classical physics, based on ordinary experience on the human scale. But this was found *not* to hold in extraordinary circumstances, such as the perception of rapidly moving distant things or extremely small ones.

A general unifying program of physics, credited originally to Descartes, proposed to reduce all physical quantities to position and its time derivatives, which depend on light as the medium of perception and measurement. However, physics had evolved actually as a hodge-podge of diverse notions. Some, such as 'force' and 'temperature,' derive from other sense modalities, suggesting that the reality of matter could not easily be reduced to mere spatial extension. Force, mass, and momentum refer to the capability of matter to impact the human body and other matter. In contrast, light quanta have little direct physical effect on the visual organ or the ordinary things observed. The reality of the material world was supposed to be independent of the embodied observer, a condition that seemed to be best satisfied by the visual sense. Yet, the world could literally impact the observer's body in other ways, and affect other senses, with effects that could be experienced as force, temperature, weight, acceleration, inertia, etc. A lesson to draw from such inconsistency is that the basic approach of physics should include the physical circumstance of the observer. An epistemic account of observation should accompany an ontological account of the world.

The interdependence of thought and language has special consequences in the sciences, where the goal, as in life, is to clarify what is real and semantically referential. Mathematics is, so to speak, the syntax of the hard sciences. Just as syntax can upstage semantics, so formalist expectations can affect the interpretation of nature.[6]

The great advantage of formal thinking is to define things unambiguously. While words in ordinary language may represent things found in experience, scientific language represents *defined* things. Formal scientific concepts mean exactly what they are explicitly defined to mean. A scientific model substitutes precise elements for the ambiguous found world. Natural reality is thereby reframed as consisting of idealized theoretical entities and processes. Things poorly perceived or understood can treated as though definitely known. With this approach, one always knows what one is talking about, though it is not the natural world itself. Apart from the degree

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[6] Consider, for example, the ancient presumption that a year should have an integral number of days; the number mysticism of Pythagoras (or its modern version, the "large number hypothesis"); Kepler's speculation that the orbits of the planets should match geometric solids; Galileo's assumption that orbits should be circular; and the key role of symmetry arguments in modern particle physics—all of which try to force nature into a Platonic conceptual mold.

of correspondence, the model is a wholly different *sort* of thing from what it models.

With biologically and culturally limited channels for knowledge, the subject inevitably faces uncertainty. The scientific ideal is to reduce uncertainty by translating inductive findings into deductive truths—that is, concepts and propositions that are *true by definition*.[7] Laws of nature then become the rules of an axiomatic system. *Deductionism* is the faith that physical processes correspond to such defined elements, that nature is reducible to mathematical models. Since scientists and mathematicians are a part of the natural world from which mathematical ideas are derived, to be consistent their thoughts and activities too should be considered reducible to mathematical models.

Modern science descended in European culture from religion, and most of its early exponents were religious men. Science thus inherited a strong idealist thread. Substitute "theory" for "theology" and it appears that laws of nature resemble divine decrees. These may be thought to *cause* the patterns they express, though they are no more than convenient formulae to summarize observed patterns. The equations expressing them are human statements, which have no more power to control matter than do the decrees of emperors or hypothetical gods. While science and religion both seek truth in structured ways, scientists hold their theories to be provisional, open to revision through new experience and new thought. Yet, some scientists believe a definitive theory is possible, as final as religious doctrine.

For science to free itself from its Christian heritage meant, among other things, recognizing that only material processes distinguish homo sapiens from other animals, or animate from inanimate things. Descartes regarded both the animal body and the human body as mere machines. But humans, he pointed out, were additionally endowed with reason. Since then, we have striven to demystify even reason, mechanizing it artificially. We design machines to emulate the powers of life, perhaps to displace it. Yet, the power of life we most cherish is subjectivity, consciousness. No preoccupation with the material ontology of the world can properly exclude the subject who perceives that world and embraces such preoccupations. Though all subjects—even artificial ones—must be material, without them objects are literally unthinkable.

Bridging the gulf between first-person experience and third-person description relates to empathy and the challenge to take the experience of others seriously. As social creatures, we've learned to accept the interior life of others within our tribe. However, this courtesy does not automatically extend to others outside the tribe, let alone to other species. The subject-object relationship is a timeless social and ethical issue, now perhaps the fundamental issue of our age. To deal with climate change, for example, requires action that depends on the mutual understanding needed for cooperation.

To move toward mutuality with each other *and with nature* means shifting from a subject-object relationship to a relationship among agents. To cooperate with others, the subject must receive as well as impose. This means letting go of entitlement to treat the other as object. It

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[7] For example, perfect right angles, circles, and dimensionless points are idealizations that do not exist in nature. They are not simply refinements of their physical counterparts, but are original creations, exact in principle and manipulable in thought with total precision, which is also the advantage of digitation.

means also ceasing to regard nature as a provision for human benefit, a raw material for the re-creation of the world in a humanized image.

The long rebellion against nature and the body, which has defined human culture generally, originates in the claustrophobic perception of being trapped within a closed and limiting system with power of life and death over us. Freedom is associated with the transcendent perceiver, the mind, while limitation is associated with the perceived, the body and the environing world. That world may tyrannize us by its sheer reality, over which we have limited control; yet, its mystery also intrigues us. We are forever trying to decipher the rules of a game we did not invent.

CHAPTER TWO: The Equation of Experience

In which it becomes clear that subject and object act always conjointly to produce experience, thought, and behavior—even in science, which attempts to bracket the subject. First-person and third-person narratives are complementary.

> "The brain is not an organ of thinking but an organ of survival, like claws and fangs. It is made in such a way as to make us accept as truth that which is only advantage."—A. Szent-Gyorgyi

It is obvious to the biologist that the behavior of an organism must depend both on its environment and its own constitution. It may be less obvious to the subjective self, concerning one's *own experience.* This is because the mind's natural function is to transparently perceive the world, not to perceive its own role in shaping that perception. It is reasonable to conclude that everything we perceive, think, feel and do involves both subject and object interacting, and that nothing is ever purely subjective or purely objective. All knowledge, even scientific, is mediated, relational, interpretive, and interactive.

The relative influence of internal and external factors may vary. Sensory perception, for example, clearly involves a strong contribution from the external world. Still, the structure and organization of the nervous system determine how sensory input is processed and interpreted—shaping both how it is experienced and how we act upon it. At the other extreme, hallucination, imagination, and creativity are driven relatively by internal processes. Yet even these are typically shaped, however indirectly, by prior sensory encounters with the world. There are no pure fantasies or fictions without some basis in reality, just as there is no pure reality untouched by interpretation.

The relationship between these factors can be expressed metaphorically as a simple mathematical function. We can call that mutual relation of subject and object the Equation of Experience and express it symbolically thus: $E=f(s,o)$, where E represents experience (which here includes thought, and by implication behavior), and s and o represent subject and object, or self and world. One cannot expect to know the world purely as object, for knowing already is an act of the subject. On the other hand, mind (even artificial mind) is necessarily physically embodied, which implies a historical relationship with an environment. A mind that is not a physical product of a natural or artificial evolutionary process is not a real possibility. The mutual relation of subject and object precludes mind isolated from the external world, just as it precludes meaningful talk of a universe without conscious observers. We are free to *imagine* either, but neither describes the reality we live in.

Since these factors always act together, subject and object are fundamentally entangled. There is no second equation, as it were, to solve for a single variable.[8] This presents a fundamental dilemma, for in life we cannot easily isolate the influence of the subject from that of the object. The two always act together in a way that can never truly be disentangled. Science has

[8] In elementary algebra, to solve an equation with two unknowns—here, s and o—requires a second equation in the same unknowns.

devised ways to approximate such isolation—seeking to identify objective facts by controlling or filtering out the subjective component. Through rigorous protocols, peer review, and shared methods, science aims to neutralize personal and cultural bias. Yet this remains a challenge even within scientific practice. In daily life, it is a common source of misunderstanding.

Although it seems like common sense that perception and behavior are shaped by both internal and external factors, people often go to great lengths to deny this simple truth—either by claiming access to a purely objective reality or by insisting that everything is subjective, a matter of opinion or belief. Naïve realism is the philosopher's name for the assumption that the world is exactly as it appears, as though the perceiving subject plays no role. This is the default stance when one is unaware of the mind's constructive activity. The world then appears simply to exist. The opposite stance might be called naïve idealism, which considers all experience solely a product of mind. In this view, the material world is in some sense illusory. What one believes about the world then depends less on sensation or observation than on pre-conceived notions. Such reasoning can become circular—for example, accepting a religious doctrine as true because of its supposedly divine origin.

To clarify terms, *experience* here means anything that occurs in the consciousness of a cognitive agent. Yet, the relationship expressed in the Equation of Experience applies not only to conscious awareness, but also to thought and behavior. Thus, it can be put in a more general form.[9] In this broader sense, experience includes sensation, feeling, cognition, imagination, reasoning, and even scientific inquiry. In the scientific context, the subject factor includes the observer, the measuring instruments, the experimental setup, and the medium of investigation (such as light). The object factor is the system observed. Every observation or measurement involves an interaction of both.

The very ideal of objective truth aspires to factor out the contribution of the observer, in order to focus on the nature of the observed. Science attempts to exclude what is idiosyncratic for individual observers. Yet, this does not address cognitive biases that are *collective*, grounded in the common biology of the species and in the accepted practices of the scientific community. As a human enterprise, science is fundamentally anthropocentric, despite the aim of objectivity.[10]

There are conflicting philosophical positions within science. The perennial *nature versus nurture* debate, for example, emphasizes one factor over the other, though both are essential. On the other hand, in the free-for-all of conflicting opinions and beliefs in politics and the media, consensus is rarely even attempted—though that doesn't mean there can be no objective truth of the situation. The challenge is to discern internal and external influences without ignoring either. The problem is that the inseparable joint influence of subject and object renders all experience ambiguous and open to question. That puts us in a vulnerable position of uncertainty, which we are programmed by nature to resist.

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[9] For example, $O = f(i_s, i_w)$, where O is the output of the system, i_s is the input from within the system itself, and i_w is the input from the outside world.

[10] It may also be culturally biased and androcentric.

How, then, are we to sort out truth? A first step is to acknowledge the depth of the problem, which is an epistemic dilemma facing embodied agents. Ours is more a worms-eye view of the world than a bird's-eye view. To know reality, we must transcend the limits of our biological heritage, which has largely served us well. We now understand that our brains shape perception for survival rather than accuracy. Self-awareness is paramount: 'know thyself' remains the best path to knowing others and the world. Using such awareness, a crucial next step is to act in good faith. While we may never fully escape subjectivity, shared intent to understand reality fosters convergence of perspectives. The alternative leads to fragmentation—everyone asserting their interests and versions of reality without common ground. But shared intention in good faith makes mutual understanding at least possible.

Of course, that is easier said than done. With no gods-eye view, we are limited to seeing "through a glass, darkly." Yet, it is empowering to recognize even the limited influence that conscious intent holds over experience. We are then not passive victims of experience but active co-creators of it. By joining others of good will, we can collectively create a better world. Though we see from different angles, we can converge on common truths with earnest intent. Like the blind men and the elephant, each perspective contributes to the larger picture—on which our shared fate depends.

While the Equation seems like common sense, not everyone will agree. In contrast to the exclusion of the subject in science, a venerable tradition of philosophical idealism downplays the object instead. It holds that what is real is the mind, the spirit, or some transcendent non-material realm. Many religious beliefs are based on such ideas. Conversely, hard materialism seeks to reduce mind to logic, computation, or biochemistry. For much of the 20th century, even psychology followed behaviorism in ignoring consciousness altogether.

Idealism emphasizes the role of mind or spirit; materialism emphasizes the external world. Each presumes that only one factor is real or primary, ignoring the other or reducing it to its own terms. Yet, science has not succeeded in reducing mind to matter, nor has religion persuaded most people that the material world is illusory. Is reality fundamentally mind or matter? If both, how do they relate? In either extreme view—pure idealism or pure materialism—there would be no dualism. The fact that this dualism persists demonstrates the truth of the Equation and also tells us something about the extremes to which thought can tend.

The dualism of mind and matter is reflected in the notion that a person *is* a self who *has* a body. When we look out upon the world, however, nowhere do we see selves having bodies. What we literally do see is bodies going about their business, whether these bodies are inanimate objects or living organisms. Yet, self-consciousness adds to this picture a sense of being some*one* as well as some*thing.* Indeed, one experiences oneself as *inside* the body (perhaps even inside the head), giving the impression that consciousness is the true inhabitant, the body a mere dwelling or vehicle. On the other hand, if the physical world is all there truly is, it would be more appropriate to think of a person as a body that *has* a self.

These alternatives reflect different points of view: the first-person versus the third-person perspective. Materialist description is implicitly third-personal, though any description must be made by someone, from a first-person perspective. Even automated measurements require conscious interpretation. Idealist accounts are implicitly first-personal but may reify mental constructs as elements of an objective non-physical realm.[11]

Much philosophical, religious, and even scientific debate stems from favoring either subject or object as the primary reality. This is reflected in the nature-nurture debate, for example, or in the question of whether quantum mechanics describes physical systems or our knowledge of them. Einstein and Bohr's famous debate exemplified this divide, with Bohr emphasizing the inseparability of observer and system, while Einstein sought a more complete, objective, deductive theory. These are complementary threads, which science must integrate. Yet reconciling opposites is difficult, even in physics.

Such complementary views continue to shape modern thought—for instance, in the concept of information. Though information presumes an informed subject, it gains a cachet of objectivity through analogy with physical entropy. Claude Shannon's mathematical theory of communication, based on this analogy, defines information as a counterpart to entropy. But the two are not the same: entropy measures disorder in the world, while information involves communication between agents. Shannon information arises not from nature alone, but from interaction between subject and object.[12] Gregory Bateson famously called information "a difference that makes a difference." But a difference for whom? Analysis of information depends on an agent's cognition, goals, and conceptual framework. An objective view of information applies best to well-defined systems and standardized agents—such as scientists communicating in shared terms. But natural systems are not intrinsically well-defined, nor will every observer necessarily extract the same information from them. The amount of information (in a communication or as characterizing a structure) depends on how many binary (yes/no) decisions are needed to specify it. If an agent cannot decide some of those questions, the quantity is indeterminate. Only formally defined constructs have definite information content, while the systems they describe may not. For, no real-world system can be perfectly defined or completely described. To posit a finite amount of information in the universe due to a presumed bottom to its structural complexity is circular reasoning.[13]

The fact that reality is not a matter of personal whim reflects the singular nature of the world, the literal common ground for all observers. The fact that there *can* be agreement about it reflects also the biological, if not cultural, unity of human being. Yet, the perennial dilemma remains our dividedness, which ironically also has its roots in our biological nature. Many of our troubles stem from the fact that we perceive differently and according to need more than truth. As social creatures, it is crucial to differentiate between the influence of subject and object upon our

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[11] The soul is reified a quasi-material entity; as are heavens, hells, gods, and the eternal Forms of Plato.
[12] Even (dis)order is to some extend in the eye of the beholder. Entropy is neither a message from the universe to the observer nor a stand-alone entity, but a construct involving subject and object. Information is not generated by physical reality but by human agents.
[13] Is there a fundamental "law of conservation of information" preventing information loss—for example, within black holes? It does not follow that information must be conserved in the universe simply because it is conserved in some mathematical transformations. To rationalize the disappearance of information behind the epistemic wall of an event horizon stems from reifying information in the first place, as a substance or property that can be located.

experience and behavior. While thought and belief vary widely, the fact that we live in the same universe offers potential for agreement.

CHAPTER THREE: The Dilemma of Consciousness

In which it is seen that consciousness is a simulation produced in the brain, a guided hallucination, a control system in the body's administration. The behavior of organisms and the nature of consciousness must be understood in terms of agency. The map does not resemble the territory, but aids us within it.

> "This world is inseparable from the subject, but from a subject which is nothing but a project of the world…"—Merleau-Ponty

Why is there something rather than nothing? We might call this the mystery of the object. The striking thing about the question is that it requires the existence of a subject—someone here to witness the world and pose the question. For, it is in our waking consciousness that the world appears and causes wonder. Without us (or something like us) there would be no such question or appearance. One might imagine the world existing without anyone to see it, but what could it look like in the absence of looking? We could call this the mystery of the subject.

To study consciousness scientifically is already to consider it something *in* the world, whereas consciousness is rather the viewpoint *from* which the world is examined, studied, and understood. Looking from that viewpoint, the subject sees the world, but cannot see itself. This is the unique situation we confront as self-conscious beings, for there is literally nothing to compare it to. And that is why philosophers now refer to this dilemma as the *hard* problem of consciousness, to distinguish it from the "easier" problems of understanding how the brain controls behavior.

Technological advances have deepened our understanding of the brain as a control system. Yet how a material system like the brain can give rise to *experience* is a different question entirely—one that cannot be answered solely by studying the object. The subject as an embodied agent must also be considered. The embodied subject is a physical object (the body, including its brain), which can be studied scientifically. But embodiment is more than physical instantiation, and understanding an organism involves more than describing its mechanisms.

Let us begin by clarifying what is meant here by *consciousness* or *experience*. For, mental terms are notoriously ambiguous. To avoid confusion, I will use the term *phenomenality* to indicate the whole range of actual real-time experience.[14] This includes waking sensation, but also dream experience; it includes hallucinating, daydreaming, imagining, thinking, emoting, indeed the whole gamut of anything you can be aware of. Your phenomenality is "what it is like" to be the organism that you are. In contrast, *consciousness* (more precisely *self*-consciousness) will usually refer to the reflexive awareness of being aware. (There is, of course, something distinct "it is like" to be in that state.) While many animals may exhibit behavior suggesting awareness—and thus phenomenality—they may lack self-consciousness in this reflexive sense.

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[14] Note that even the common word *experience* is ambiguous, since it can also refer to memory or the past, as in 'previous experience' for an employment résumé.

This distinction highlights what renders the study of consciousness different from ordinary scientific topics—namely, point of view. Phenomenality occurs here and now, in the first person, and often without self-reflection. For the most part, the world transparently *appear*s to us. We neither know how this appearance arises nor typically recognize it *as* appearance; rather, we take it as reality. One can *describe* this appearance alternatively as personal experience or as events in the world.

This difference of point of view is built into language. The first "person" is oneself, *I*, the subject. The third person is *he, she* or *it*, the object. Only *I* feel the pain in my body, because no other subject is connected to it directly through this nervous system. You may observe my body's behavior, but you cannot experience my sensations. You can imagine them, but that is distinctly your own experience. In contrast to body sensations, the distance senses allow for multiple observers to separately experience what appears to be a common external reality.[15]

By design, science avoids the first-person point of view. It frames the world in third-person terms, which is also how we naturally perceive it: with outward orientation that is largely visual. Science explains events through observable cause and effect, not through bodily sensations. Such third-person description excludes the intentions and reasons of organisms as explanations for their behavior.

Scientific description is not an anecdotal account of personal experience. It excludes personal feelings, whims, or unbridled speculation. What matters are facts—statements that can be corroborated by others. Even in experimental psychology, the data are third-person accounts of reported experience, not the experience itself. Objective facts must be accessible to multiple observers. This has served science remarkably well in enabling us to manipulate nature. But it idealizes the subject as a disembodied observer, removed from the world observed. In doing so, it ignores common features of human cognition—idiosyncrasies of the species, of the scientific community, or of a given culture, time, or place. It fails to address the influence that human cognition or its cultural variants have in shaping the scientific worldview.

From a scientific point of view, the hard problem of consciousness (traditionally known also as the mind-body problem) is to explain how mind arises from matter: how *molecules*, for example, produce the *sensation* of a toothache. Even with the most powerful microscope, the dentist who inspects the telltale signs of decay cannot see the feeling in your mouth, which is not a *thing* included in the third-person view. Because of the very definition of science, a scientific explanation of phenomenality is not feasible. So, what kind of explanation should we seek?

Classical science deals with cause and effect: chains of events leading backward in time, potentially in an infinite regression. The notion of a *first* or original cause is not defined. One reason for this is that *we* are the original causes with which we are intimately familiar. Even in daily life, we stand apart as *agents* capable of initiating events, distinct from the inert things with which we interact. We extend this sense of agency to other people and creatures, even to imagined beings such as gods and spirits. In contrast, inert things only transfer some initiating

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[15] The difference between neural systems involved in interoception versus exteroception may be the root of the first-person versus third-person distinction.

impulse from one thing to another.[16] This distinction manifests in the dualism of mental versus physical, intentional versus causal. In seeking causes, science ignores mental agency—even the agency of the scientist. Scientists create theories, conduct experiments, and publish results, but their agency does not figure in the formal portrait of nature they present.

Scientists need not look for original causes, for they are at liberty to *specify* them—called initial or boundary conditions. These are not "real" beginnings in nature, but selected inputs to parameters. This works quite well for most scientific purposes, because the goal is to predict a future state of a deterministic system on the basis of a specified present state. How well it works, however, depends on how well the specified input and the mathematical model correspond to reality. In other words, it depends on the accuracy of measurements and on the completeness and adequacy of the model.

Because science is so deeply empowering for modern society, there is a tendency to overlook its limitations. But the problem of consciousness confronts us directly with them, because it resists causal explanation. Thus, many people see consciousness as the greatest unsolved mystery, perhaps after the question of why there is anything at all. Indeed, the mystery of consciousness is scarcely yet even a scientific question.[17] Whether it ever will be may depend on how the definition of science might expand to include itself as part of the processes it investigates.

The problem of consciousness is to explain the very existence of the first-person from a third-person point of view. However, the third-person is a convention of language and of thought, a tool for communicating facts between subjects. Though we are used to thinking of them as self-standing truths, apart from the communicating agents involved, facts are still assertions, grounded in someone's first-personal experience. Scientific theories are shared statements, not personal experiences. By trading in statements rather than experiences, scientists sidestep the problem of consciousness and the role of their own agency.

Yet, an adequate explanation of phenomenality must include an account of agents and their purposes, not simply the passive interactions of molecules or other physical events. The modern understanding of cause involves one inert thing impinging on another, but not initiating action on its own. Organisms do not fit gracefully into this view of matter as passively inert. Biology may successfully explain the characteristics of life in terms of non-living matter. But this is at the cost of relegating the notion of agency as something to be explained rather than a principle used to explain consciousness.

An agent initiates action for its own reasons. Causal explanation and third-person description are appropriate for the kind of interactions that characterize stones or molecules, but not organisms, which have reasons of their own. It is just as reasonable to speculate about the

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[16] Following Aristotle, cause in this passive sense is known as 'efficient' cause. Following Piaget, even this sense of impersonal causality derives from early experience of bodily agency, transferred to objects.

[17] A theory is scientific only if it can be *disproven* in some empirical test. The Integrated Information Theory of mind, for example, is considered by some to be a testable theory. [Tononi, G. (2004). An information integration theory of consciousness. *BMC Neuroscience* 5, 42] As an identity theory of the mental and the physical, however, it simply posits, but does not prove, such identity.

reasons of an agent as about the causes of a physical event. For, Hume had seriously challenged the notion of cause as a *power* residing in things to bring about change. His point was that the appearance of causality amounts to no more than a succession of events observed by an agent. Concerning organisms, a succession of events can be described alternatively in terms of physical causes or reasons.

If we cannot explain phenomenality in terms of efficient causes, perhaps we can understand it in terms of the purposes of an agent—in other words, as something that certain organisms *do* for their own reasons. If consciousness is thus functional, not epiphenomenal, what function does it serve? Take pain, for example. You touch a hot stove; your hand jerks back reflexively. That's one behavior. But if there's actual tissue damage, you soon feel pain. This encourages protective behavior, which is a separate response from reflexive withdrawal. In fact, it is not caused directly by the external stimulus in the way that the initial reflex is, but is internally generated by the brain and involves a separate pathway. It may persist through the healing process because it serves a systemic purpose—not to avoid initial damage from the stimulus, but to avoid further damage during healing. That goal cannot be achieved only through the local reflex, but must involve the cooperation of the entire organism. Pain involves the organism's recognition of its own state. An organism that could not feel pain would be unable to protect itself from such incidental damage.[18]

Pain is a clear case of phenomenality with a behavioral function. Other experiences, such as visual ones, may not imply any behavior directly, though they still serve to guide the organism's interaction with the world. Vision and hearing are *distance* senses, so that direct contact with the organism is not involved. Nor, therefore, are the responses implied in immediate contact. Because of distance from the stimulus, the organism has time to monitor the environment and consider response on a different level. The fact that we are pre-eminently visual creatures can give human beings the misleading impression of being detached observers of the world. Yet, feeling remains at the core of phenomenality.

Feeling usually involves judgment—for example, as either pleasant or unpleasant. Judgment is how the stimulus, is evaluated—whether it is good or bad for the organism—which has definite behavioral implications. For some sensations, their *meaning* to the organism lies in the behavior associated with them. In such cases, the connection between the input from the stimulus and the output of behavior is not a simple causal connection, as in the reflex. It is mediated by the organism's own evaluation of the significance for it of the stimulus. This evaluation often involves convoluted pathways in the brain. The distance senses allow time for even further convolution.

These pathways can be analyzed in causal terms, as though tracing the flow of energy through an electrical circuit. But the *logic* of the circuit must also be considered. The causal analysis by itself sheds no light on this logic, which is not a question of physics or chemistry. In the case of a manufactured artifact, one would want to know its supposed function, the purposes of its designers and intended users. However, there is no one to consult to understand the

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[18] The deterioration of tissue that lepers suffer, for example, is partly due to the loss of feeling from nerve damage, because of which they accidentally injure themselves. Some insects do not respond to the loss of a limb or other serious damage with protective behavior, suggesting that they do not feel pain.

“design” of an organism except the creature itself. If we want to understand the behavior of the organism (let alone its experience), we must try to imagine *its* concerns and considerations, its intentionality. While the attribution of intention is an act of imagination on our part, so is the attribution of cause.

The specific role of consciousness in the life of a human being could be likened to the role of a CEO in a corporation, who has limited executive powers and is responsible to the “shareholders,” the body’s cells. This inner agent monitors and coordinates the activities of diverse subsystems. The display of phenomenality is for use by the CEO—not the cells—to keep track of what is going on. It is a way the organism can explicitly represent to itself changing conditions, both external and internal. Similarly, phenomenality could be likened to the display on a computer monitor, which is a graphic version of computer code. The display is not for the benefit of the computer but for its user or programmer. In that metaphor, the whole organism is both programmer and user.

Much mental processing occurs without consciousness. That’s why we can zone out while driving, for example. But new tasks require conscious attention, which is why you must pay attention while *learning* to drive. Eventually, tasks become automatic as we master them. In that sense, consciousness puts itself out of work.

It is well and good to understand the purposes consciousness serves, but what is phenomenality itself? Trees, rocks, clouds, animals, chairs, and molecules are things that exist in the physical world. While such a list includes teeth and rose blossoms, there does not seem to be a place on it for the *ache* of a toothache or the *scent* of the flower. A sensation is not a material thing, but the organism’s memo to itself about its own state and that of the world. The ache of a toothache or the scent of a rose are the organism’s internal communications, which it has imbued with meaning. Phenomenality is a sort of narration or story, constantly updated on the basis of new sensory input, like news reporting in the media. Perhaps the best metaphor is to compare it to an interactive virtual reality.

Literal VR is a computer simulation, created by one agent to inform or entertain others. However, the brain scripts phenomenality in real time for its *own* use, which is not mere entertainment. Sensory awareness keeps us apprised moment-to-moment of happenings in the real world that can affect us. Yet, the brain’s simulation can also project beyond the present moment, to include imagining the future or remembering the past. On the one hand, this “show” is a creative fiction; on the other, it is continually guided and updated by real-time sensory input. Perhaps this accounts for the qualitative difference between dreams and waking experience.

That this “show” is functional can be understood by considering that the senses are not simply open windows on the world, but more like remote sensors providing a digital feed. Despite the poetic trope that the eyes are the portals of the soul, the brain is perfectly sealed in the skull’s chamber, which has no windows or doors! Its only connection to the external world is via electro-chemical signals it receives and sends out over nerve fibers. Imagine yourself in an analogous situation: in an isolation chamber, like in a submarine, confronted with nothing but instrument dials and control levers. Furthermore, you have never set foot outside this chamber. Whatever purpose these instruments may serve you must discover through trial and error. As yet, you have no idea even that there is such a thing as "outside." Through trial and error, you learn how to "navigate" by instrument without ever seeing what is "really" out there. In fact, the show of phenomenality is simply your imaginative interpretation of such instrument readings, as they have been coordinated with controls through feedback. Certain readings can be interpreted as "solid objects." Failure to interpret them that way could result in disaster (the submarine might collide with a reef). The interpretation is "true" if disaster is prevented.[19]

The above thought experiment suggests the learning or adaptation of a single brain, but applies to evolution as well. The individual brain benefits from the accumulated experience of generations of ancestors. Much of the time, this "submarine" is actually on autopilot, controlled by a sophisticated computer, whose programming has been honed over thousands of generations. Through natural selection, the only submarines that exist are those that have come to navigate in a way that has not resulted in their destruction.

Consciousness becomes important when autopilot is inadequate in the face of novelty. This brings us back to consciousness as a separate control system, different from more automated brain processing. It is *as though* someone (the CEO) must be present to monitor events and take charge in novel situations. The whole brain must act with unity, *as though it were a person* rather than a collection of parts.[20] Indeed, it normally accomplishes this integration seamlessly without our notice—until something goes wrong, potentially revealing the machinery behind the illusion of a unified self. When it works properly, we have the sense of *being* that inner person.

Phenomenality is, so to speak, the virtual reality the brain produces to update its interactive map of the underwater world.[21] And this virtual reality includes the body as an "avatar" represented in the simulation. However, the brain's VR is not a copy or imitation of anything eternal. The metaphor comes with a caveat, for the notion of simulation (like representation) normally implies something real it is a simulation *of*. The relationship involved in simulating or representing implies an original, to which there is direct access. Since the brain has no such direct access, the representation bears a different relationship than *resemblance* to the unknown that lies outside the skull. The submarine's topographic map of the underwater world (made, say, by using sonar) is not a literal one-to-one representation, but is instead symbolic and selective. It is more like a road map or the schematic map of a subway system, oriented toward use. If using it helps avoid disaster, then the map is "accurate" or at least good enough. What we experience as reality is what is conjured by the map.[22]

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[19] Perhaps this helps account for reification as a default strategy: better safe than sorry. Yet, reification can be a liability as well, when it leads falsely to belief in the reality of things that are not there or are not actually things at all.

[20] Of course, that does not mean that there is a little person inside the head! Quite the contrary, *personhood* must be explained by integration of brain activity, not the other way around.

[21] Also called "predictive processing."

[22] Of course, every metaphor or analogy has its limits. Any pictures one might conjure come from being visual creatures in the first place. Eyes are presumed for those on board the submarine, whereas the brain has no internal eyes.

Let us call this conjuring act *fiat*, which is Latin for *decree*.[23] In this context, it means to declare something into being; an agent *makes it so*. Unlike the natural thing, the conjured thing is exactly what the mind says it is, no more nor less. That applies to all concepts, artifacts, and fictions, which are finite and definite in structure. (In contrast, we can only guess at the structure and parts of a natural thing, which we did not make or mentally conjure.) A simulation is an artificial thing, whereas the natural reality it simulates is not. Yet, the simulation is "realistic" insofar as it enables the organism to live. If the VR we call reality tends to be stamped with the relative crispness of the artificial, this is functional, because the organism must make decisive choices, even in the face of poor or ambiguous information.[24]

Our senses tell us that the world is real, external, and literally as we see it. Creatures survive by believing their perceptions. Apart from whatever is or is not "out there," in what Kant called the *noumenal* world or the *world-in-itself*, it generally serves us to treat as real what appears in our phenomenality. Just as in literal VR, the sense of realness is an essential aspect of our perception. If it wasn't convincing, we would not take experience seriously; indeed, our species would not have passed the filter of natural selection. Just as pain must hurt, so must the physical world appear to us as real.

Nevertheless, sages—and altered states—have always reminded us that this appearance is somehow illusory, though the illusion is not without basis. One lesson to draw is to not dismiss the creative power of perception and the responsibility we have for our perceptions as well as for our actions. The scientific worldview omits agency and purpose, depicting passive objects in a mechanistic world. Yet, this worldview fails to explain the qualitative feel of experience or the mystery of subjectivity. In reality, the self is not a victim of causes but the creator of experience and action. The effort to duplicate nature reveals just how miraculous nature's achievement is. Modern attempts to program AI to do what a brain does—or to create an artificial organism that does what a natural one can do—help us to appreciate the miraculous achievement of nature in creating us.

While the problem of consciousness has largely been relegated to the pages of academic journals, its broader implications lie at the center of the human story, animating culture and history, reflecting the essence of what it is to be an embodied self-aware being. It poses the fundamental question of what we are.

What does it mean to be a self-conscious subject? If the job of phenomenality is to monitor the relationship of the organism to its environment, then the job of self-consciousness is to monitor the monitoring. Self-consciousness adds depth to awareness, just as binocular vision aids depth perception. One is aware of the world *and* of oneself perceiving it from a psychological distance.

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[23] As in the royal decree, such as *Off with her head!*; or the divine decree, *Let there be light!*; or the mathematician's decree, *Let x stand for…*

[24] Hence, those classic ambivalent figures in Gestalt psychology, which can be seen two ways. The key point is that they flip in our perception from one definite interpretation to the other, and eventually back, but are never vague or in between.

Since focus is naturally on the external world, it can seem that experience is driven by the outside more than arising intentionally from within. This can lead to feeling impinged upon by the world—even helpless, victimized, depressed. Such despondency can be countered by invoking an acute sense of one's own being. The antidote to the world pressing in is to press back with intention. One then reclaims a role as the producer of experience instead of its passive consumer. The key to this shift is the *act* of self-consciousness, sometimes called "self-remembering." The resulting sense of *being* entails recalling that one has the ability and responsibility to manage one's own experience and action alike.

CHAPTER FOUR: The Problem of Cognitive Domains

In which it is shown that the domain of the representation is often confused with the domain of what it represents. Output is recycled as input, as when concepts formed through macroscopic experience are projected onto the micro-realm where events are then deemed causes for that macroscopic experience. In view of this circularity, it is not plausible to reduce the mental to the physical or vice-versa.

"The map is not the territory."—Alfred Korzybsky

It is naive to think that the universe simply *is* the way it appears to human observers, or that it appears the same to all possible observers. Yet, the very idea of objectivity or absolute truth implies that there is some way the world really is, apart from how anyone perceives or conceives it. Paradoxically, this is a view of the world as if no observers existed.

Kant drew a distinction between the realm of appearances (*phenomena*) and the realm of things as they are in themselves (*noumena*). By definition, there can only be one true world-in-itself, while the phenomenal realm must differ from subject to subject.[25] While a mind has access to phenomena but not to noumena, any attempt to imagine the noumenal world must still draw upon phenomenal experience. Although the phenomenal realm is not reality itself, evolutionary pressures ensure that it tracks reality in ways conducive to survival. The phenomenal realm serves to *map* the noumenal territory, if only symbolically.[26] The problem is that we can only conceive that territory as it is portrayed to us in our map. I refer to this as the *problem of cognitive domains*, because it often involves confusing the domain of the representation with the domain represented. It is not a matter of confusing apples with oranges, but of confusing apples with *images* of apples.

A domain is a set of elements upon which operations—such as a mathematical function—can be performed. A cognitive domain is a level of information processing that can serve as the input for further processing. A problem arises when the output of such a process is recycled as its own input. For instance, we explain the appearance of the physical world in consciousness by presupposing that world in the first place, with the physical brain that generates this very experience. We arrive at a logical circularity when consciousness is the output of neural activity, but the concept of 'neural activity' is itself part of that output.

Scientific thought in general is not immune to this dilemma. For, all speculation takes place within the cognitive domain of representations. What science accepts as objective reality is ultimately a theoretical construct of the minds of scientists. But that same construct is then treated as the foundation for explaining the very minds that created it.[27]

For another example, consider the concept of time in the context of the Big Bang, when no cyclical processes yet existed to mark its passage (and certainly no observers to measure it). Kant

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[25] Even identical clones would occupy different perspectives in space and so have differing experience.
[26] In the mathematical sense of mapping one domain to another, which can be an arbitrary function, not necessarily one-to-one.
[27] Schopenhauer likened this bootstrap operation to the Baron von Munchausen's impossible feat of lifting himself out of the water by his own pate, thereby saving rider and horse alike from drowning!

held that time and space are not features of reality but conditions for our experience of it. Today, we understand these intuitions as evolutionary adaptations, not as logical necessities. Our inherited sense of time emerged in stable environments utterly unlike the early universe, let alone a hypothetical meta-time across cycles of universes. Similarly, as Hume and Piaget argued, our notion of causality derives from bodily experience in early life. This discovery of agency leads us to project causality onto the external world. Ironically, the agency that gives rise to this concept appears to us as mysteriously without cause.

Science is our culture's official cognitive organ. Like the submarine navigator, the scientist constructs a map of reality from instrument readings, mediated by theory. While science improves on ordinary experience by expanding the range of input and explanatory power, it still serves the same biological purpose, ultimately to facilitate survival. The scientific map becomes a new version of the territory, to replace the natural world as presented by the senses. The entities of physics, like those of mathematics, are not natural things but theoretical constructs. Yet these artifacts are often treated as literal realities that (circularly) are supposed to give rise to the phenomenality underlying them.

Reification—the tendency to treat abstract constructs as real entities—is a pervasive cognitive habit. Many concepts in science originated as convenient mathematical tools but became ontological entities: fields, atoms, quanta, energy, even force. For Dalton, the atom had been no more than an accounting trick, not a real entity. Similarly, Planck first held the quantum to be a statistical strategy, at most a discrete quantity of energy absorbed or emitted by atoms, not yet the free-standing photon introduced by Einstein. In Newton's time, even the concept of force had been controversial.[28] Since then, the concept of energy shifted from being a property of matter to being substantial in its own right. While history often vindicates such reification, it is not always justified. The physical significance of Minkowski's 4-dimensional continuum is still debated.[29]

Physics is full of such examples. Mathematically, *dimension* is a convention, for example in describing phase space. Yet, that use is conflated with real space, so that the number of theoretical spatial dimensions has proliferated to include eleven or more.[30] *Information*, a concept borrowed from communication theory, is held to be the fundamental building block of physical reality. Apparent anomalies in gravitational behavior are reified as *dark energy* and *dark matter*, and are now considered to make up the bulk of substance in the universe.

Science writers tend to present current ideas as established fact. In their revisionist view, the entities recognized by the current generation of theorists are taken as definitive and having existed all along. Textbooks tend to present current theory as established truth, glossing over

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[28] Berkeley rejected the dynamic notion of force in favor of kinematic descriptions: "…neither can we know or measure [forces] otherwise than by their effects, that is to say, the motions… But what is said of forces residing in bodies, whether attracting or repelling, is to be regarded only as a mathematical hypothesis, and not as anything that really exists in nature." [George Berkeley Works vol 3, quoted in Max Jammer *Concepts of Force* Harvard UP 1957, p207].

[29] H. R. Brown *Physical Relativity: space-time structure from a dynamical perspective* Oxford UP, 2005.

[30] Even a fractional number of dimensions has been proposed!

historical development.[31] While useful for pedagogy, their loosely axiomatic approach risks enshrining contemporary models as timeless principles, fostering the illusion that the laws of nature are foreordained rather than humanly constructed.

All organisms operate within cognitive domains shaped by the distinctions they can make within their sense modalities. Some detect ultraviolet light, polarization, electric or magnetic fields, or water pressure, for example. Each sense modality has a specific quality and defines a distinct cognitive domain. With humans, for example, the visual appearance of a wound differs radically from the felt pain. Vision and hearing provide different sources of information about the world, and their qualitative difference teaches us about the modalities themselves.

Objective knowledge of the world is abstracted from sensory experience. Ideally, it is invariant across observers, sense modalities, or cognitive domains. It refers to *differences* within the phenomenal world but not to phenomenality itself. What appears to be objective structure is what multiple observers can agree on, based on their shared nature.

From a human point of view, an organism is immersed in an environment with which it exchanges information as well as energy. However, it may not perceive this environment as humans do, and may not have a *concept* of an environment, let alone concepts such as 'information', 'energy', or 'structure'. It seems to us that other creatures perceive and act upon the environment *we* perceive, while their own representations of this environment are limited by their cognitive abilities and brain power. Yet, the very concept of 'environment' imposes a human cognitive domain upon the organism, which may be concerned only to maintain its own state within tolerable limits. It need not reference an environment at all.[32] The irony of that truth is that the human observer is ultimately in the very same boat, and scientific theories can be seen as aspects of human self-regulation.

A representation is a mapping from one domain to another. A propositional representation consists of statements. While an image seems rather to be an analog representation, if digitized it too can be understood in propositional terms. A pixel's on/off state on a screen—or the state of a receptor in the retina—constitutes a proposition in a domain. The ensemble of such propositions forms an analog representation that embodies accumulated data from prior stages of information processing. This constitutes a distinct domain, which may then become the input for yet higher domains of meaning, such as stories, symbols, and values. Analog and digital bear a dialectical relationship within hierarchies of information processing, such as in the nervous system.

A language one fluently understands constitutes a different domain than the collection of sounds ones hears as gibberish before learning the language. Similarly, the raw babble of the senses is not the same domain as the sensory experience that results from processing. By design of the nervous system, consciousness has access only to the final outputs of processing, not to intermediate stages. One is able, however, to exercise special attitudes toward the contents of consciousness. An artist, for instance, knows how to "flatten" visual space, to see objects not as

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[31] For instance, Wien's displacement law, the Raleigh-Jeans law, and the Stephan-Boltzmann law are typically derived mathematically from Planck's radiation law, whereas the historical development was the opposite.

[32] H. Maturana and F. Varela *Autopoiesis and Cognition* Reidel, 1980.

three-dimensional things but as shapes and areas of color bounded by lines. While such objects of introspection may be mistaken for domains of sensory pre-processing, in fact they constitute an overlay, a *further* domain of artifacts of conscious attention.[33]

Scientific objectivity is not the absence of subjectivity, but the practice of minimizing subjective distortion. Objectivity is usually associated with the visual sense, yet vision too is ultimately subjective. Pain is clearly a judgment of the nervous system, not a property of objects nor even of injured tissue. But we struggle to apply this insight to visual experience, which has no more existence outside a nervous system than does pain or other bodily sensations. This seems plausible in the case of color perception; for, color has long been considered a "secondary" quality; measurable quantities, such as frequency and intensity, can stand in for it. Shape and size are more challenging, because vision seems to offer a direct view of reality. Yet the ellipse we see may otherwise be a circle, depending on perspective.

Measurement of space and time seems to take place in the same visual domain as *perception* of it, if with greater precision. In contrast, the measurement of frequency (a quantity) seems to take place in a third-person domain, not in the first-person domain of color experience (a quality). Yet, in both cases, it is *difference* that is detected, whether through sensory perception or measurement by instrument. Structure thus underlies appreciable differences in qualities. The visual experience of color detects frequency, which is a physical vibratory structure. An ellipse is "truly" circular if it has a constant radius, which can be determined by measurement. Similarly, an object is "really" blue if the light reflected from it has a certain measurable frequency given a certain incident illumination.

Early science, from the Greeks onward, sought to distill an unchanging reality behind appearances. Theoretical domains were created to transcend sensory experience, which were ironically based on the visual sense. Science rejects the cognitive domain of ordinary experience as *merely* a cognitive domain, substituting constructed *new* cognitive domains that it does not acknowledge as such. It tacitly holds its theoretical entities to be the ultimate building blocks of reality, while these constructs often remain tied to acts of visual imagination.

Physicalism proposes to reduce the mental to the physical. Paradoxically, however, the physical domain is a mental construct. In view of this circularity, reduction either way is fatuous. The scientific problem is not to bridge the gap between mental and physical, which the brain already does naturally. The question is rather *how* it does it. This cannot be understood in strictly causal terms because causality remains within the physical domain and fails to provide a bridge to the mental. What is needed is a concept that bridges domains.

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[33] 'Sense-data', 'qualia', 'raw feels', etc., are artifacts of introspection when bracketed as such, defining a cognitive domain distinct from ordinary experience. The notion of the sense datum was invoked by Locke and later philosophers as a kind of theoretical entity, like atoms of experience. Sense data, presumably, are what we *would* experience if we *could* experience the domains of sensory input and other pre-processed stages of perception. In fact, we experience only the output.

The concept of *intentionality*, broadly understood, serves this purpose.[34] It refers to the internal act of an agent mapping one domain onto another. This includes conscious intention but is not limited to it. An agent *makes* connections within itself, in contrast to events simply unfolding within the system, or happening to it, which an observer might describe in terms of physical causes. Such logical connections are naturally embodied in neural connectivity. The observer can speculate about the internal operations of an organism and its connectivity, either from a causal or an intentional standpoint. Yet, the behavior of the organism, much less its phenomenality, cannot be understood in causal terms alone. It must include intention.

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[34] The notion of intentionality here proposed is not tied to linguistic reference, largely the focus since Brentano. The reference of words to real things is merely one example of the organism's ability to make internal (intentional) connections.

CHAPTER FIVE: The Scientific Observer

In which it is noted that science extends ordinary cognition, and is as much a survival strategy as it is a quest for truth. It aims to predict events and enable technology. An (ontological) event in the world correlates with an (epistemic) event in the mind. The scientist is embodied, part of the system studied, yet does not appear in the scientific field of view. The observer's epistemic position is like the brain's. Objectivity is inter-subjectivity. Equations define formalisms, not nature, which cannot be completely mapped. Determinism and mechanism may promise perfect and complete knowledge but cannot yield it.

> "What we observe is not nature in itself but nature exposed to our method of questioning."
> —Werner Heisenberg

Science is a form of cognition that extends our natural sensory capacities. At its core, it is a quest to uncover the truth of nature behind changing appearances. As in ordinary cognition, this quest seeks underlying patterns, relationships, and regularities in experience. Science strives to formulate mathematical laws that express such regularities, to identify fundamental entities and their properties and relationships.

Any quest involves both the object sought and the subject pursuing it. The study of nature is a human enterprise, shaped by the characteristics of human agents as well as by those of the world. The truth of nature sought by science is ultimately no more independent of the subject than the truth sought by ordinary cognition. Both are ultimately survival strategies. As Kant observed, scientific cognition cannot reveal the world as it is "in itself. But it can offer practical advantages in certain contexts.

The elements of language are reflected in elements of science, such as laws, entities, forces, properties, and the mathematical statements known as equations. Verbs express behavior, nouns identify the things that behave, adjectives describe their properties. Language reflects real-world structure as observed with the senses. However, it also imposes categories, which influence how the world is structured in perception. We see "objects" performing "actions" and possessing "properties." Naming these gives a sense of definiteness and certainty, though this sense can be naïvely deceptive when the subject's role is overlooked. Expressing entities and their properties and actions as formal elements of a mathematical language enables further precision when quantitative measurement is possible. This in turn enables prediction and control under limited circumstances. Yet, this formalization can impart an overconfidence in the power of thought to tame reality by forcing it into conceptual molds.

In any case, such formal elements constitute a cognitive domain distinct from the sensory domain, and tacitly supposed to represent the natural world more truly than sensory experience. The more science delves into the essence of natural process, the more abstract become its mathematically defined elements, as the world of scientific description becomes ever further removed from everyday experience. That is not liberation *from* the subject, however, but an alternative construction *by* the subject. As such, like the ordinary cognitive domain of perception, science must ultimately be judged by its adaptive value.

The distinction between reality and appearance arises in our self-conscious awareness, which reflexively includes the perceiver as distinct from what is perceived. This self-reference is usually not explicit, however, and is easily overlooked. The default orientation of the mind is rather an outward focus on the contents of the world—on *what* we know, its ontology. Yet, questions of *how* we know—epistemology—bear on the validity of our knowledge and depend on the subject's role and the conditions for knowing. Since even scientists sometimes conflate ontological and epistemological concerns, it seems worthwhile to underline the distinction.

Take, for instance, the concept of *event* in modern physics. Ontologically, an event could be the collision of two material objects, such as billiard balls or planets. Epistemically, to know about this event requires another event—an occurrence in the observer's brain, or in a measuring device that stands in for the observer. This act of knowing additionally requires a signal (such as reflected or emitted light) that connects the event and the observer. While the effect of this intermediary on the observation may be negligible at the human scale, it cannot be ignored at the microscopic or cosmic scale. Thus, events must be considered both ontologically and epistemologically.

Modern science, especially physics, enshrines the ideal of objectivity; yet the relationship between subject and object is rarely articulated within the physical sciences. For, science deliberately "brackets" the subject to focus on the object. There is little discussion within the practice of science about what science is or how it should be conducted. Protocols, peer review, and consensus guide the enterprise; but there is no oath, creed, or official doctrine for science, as there is in other domains such as religion, law, or medicine. Ethics boards focus on social issues within institutions rather than fundamental epistemological questions. The nature and aims of science are thus largely left to philosophers and historians to discuss. It is left to the writers of textbooks and popular science accounts to define the current scientific ontology for the next generation. In physics, at least, the role of the epistemic subject typically remains tacit.[35]

Many of the founding principles of science came down to us from Aristotle, who speaks of *demonstration* as a key to valid knowledge. Whether that means logical deduction or providing empirical evidence, it implies argument for a claim. That is a communication *by* someone *to* someone, for some purpose, whether the argument is to convince others or simply to convince oneself. For, the essence of scientific method relies on the interchangeability of agents who play by the same rules. While the object of debate is presumed to objectively exist, human subjects propose and dispute its properties and nature.

A theory must be testable to be considered scientific at all.[36] Experiments must adhere to accepted procedures and be described in such a way that others can repeat them. But, the answer to scientific questions is rarely simply yes or no; scientific conclusions are probabilistic, with margins of error. Objectivity in science is less about indisputable facts than about negotiated agreement.

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[35] Even in psychology, the so-called subject is not usually the investigator, but the object of study.

[36] Strictly speaking, empirical generalizations cannot be proven, only disproven. (While it cannot be proven that all crows are black—since there *could* exist crows of other colors that have not yet been found—it suffices to find one crow of a different color to *disprove* the generalization.)

It is attractive to consider "pure" research a disinterested search for the truth of nature. Yet, science is also about controlling nature for human purposes, which include the purposes of corporations and governments. Science augments sensory cognition with instruments and reason. In ordinary cognition, perceptual models that are good enough to ensure survival persist through natural selection. Similarly, scientific models could be valued not just in terms of truth or falsehood, but for their usefulness to humanity's long-term prospects.

While science seeks to understand the natural world, the very notion of nature has a historical context. While ancient thought viewed the universe as an organism, early scientists saw the world as a divine artifact, God's creation. What we now call nature was held to have only the derived reality an artisan confers on made things.

This view shifted with the gradual secularization of European culture. Empirical evidence, rather than religious doctrine, became the criterion of belief about the natural world. However, the search continued for keys to a sort of revealed truth, a parallel to scriptural exegesis as a means to understand the mind of the Creator. The implicit goal was an exhaustive understanding providing a god's-eye view. By the 20th century, natural laws were no longer considered divine edicts, but they are still considered by some to retain a transcendent status, existing apart from the matter they "govern." While science now approaches the world through theory rather than theology, the common root of these words reveals a common inspiration. The laws of nature are no longer edicts of God or the Church, but they are edicts of the scientific community.

The ideal of perfect knowledge has long shaped scientific aspirations. For Newton, God himself was an omniscient observer. The ideal of perfect knowledge was successively personified by the "demons" of Descartes, Laplace, and Maxwell. These are hypothetical idealized observers with cognitive superpowers, invoked in thought experiments to explore the limits of physical concepts.[37]

Like the creator God, the disembodied observer exists apart from the physical world. This is mind-body dualism writ large. The scientist, however, is neither a fly on the wall nor an omniscient being, but an embodied subject who interacts with the world and is embedded in it. Physical reality itself places constraints on observation, on what can be known, and on the nature of knowledge. The limitative theorems of the early twentieth century were a first pass at this realization. Einstein made the epistemic circumstance of the observer depend on the finite velocity of light; Planck made it depend on the finite grain of light. Using reason, Gödel, Turing and others mapped limits of reason itself.

Though knowledge of the world must involve the knowing subject, the classical scientific portrait of nature was supposed to be a view of the world, so to speak, when no one is looking. In practice, the ideal of objectivity means agreement among trained observers. This is achieved by minimizing individual idiosyncrasies; but what about factors common to all human observers, or prejudices common to a specific generation or cadre of scientists? What about methodological and epistemic constraints imposed by quantitative treatment or by cherished values like rationality, simplicity, or elegance? Such questions usually fall outside the official scope of

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[37] More than omniscience, Descartes' "evil genius" underlined the power to deceive.

science.

Just as the brain relies on the input of receptors to make inferences about the real world, so the scientist relies on instrument readings. The brain organizes and interprets sensory input through its perceptual models, according to the body's needs and goals. Scientists consciously model observed phenomena, according to scientific goals. In science, the relationship between model and world cannot be presumed, as it normally is in ordinary cognition. It must be formally demonstrated. This is hardly straightforward, however, since experiments yield their results in test situations that are already prescribed by theory. They are often effectively physical realizations of a theoretical model, which is rather like building a machine to see if the design is good. If the machine works as expected, this says nothing guaranteed about nature.

The outward focus of science implies that the scientist is not part of the scientific picture. While a person can see their own body, directly or in a mirror, science has no official view of itself. Its external mirrors are found in philosophy, literature, sociology and anthropology, for example; or, through the rewards obtained from industry and government. This omission of self-reference, while pragmatically necessary to avoid unwieldy recursion, is a flaw from the perspective of a comprehensive account. Science advances by ignoring the limits of its own methods and goals and questions it cannot answer. Like ordinary cognition, it focuses on what it *can* do.

Yet, science represents more than a quest for knowledge or a strategy to deal with material reality. It also serves as a creation myth, a universal language, a doctrine to underwrite human powers. The quest to understand nature is also an attempt to assimilate it to diverse human interests. This is the deep significance of the ubiquitous use of mathematics in the scientific narrative, which transcribes natural reality into humanly defined, rational, manipulable, quantitative terms. While scientific objectivity aspires to a "god's-eye" perspective, all description is inevitably from the viewpoint of embodied agents. Measurement, whether via instruments or senses, involves physical interaction and judgment. It is theory-driven insofar as it presumes quantities that can be isolated as the pertinent variables of a theory. But, how well can these be distinguished from noise—that is, from information that is already presumed irrelevant?

Observation necessarily involves physical interaction, and the observer is necessarily part of a physical system. The physical circumstance of the observer figures in observation, along with the nature of the thing observed. The only agents (so far) that can act as scientific observers are human beings, whose biological nature must be taken into account. That includes our intentionality—our purposes, reasons, and categories of thought. Science is not a detached account of reality, but a narrative driven by the needs and nature of a biological creature, which includes the special role played by the distance senses as adaptations.

Classical science attempted to eliminate "secondary" qualities from its descriptions, leaving only properties accessible to all observers. In truth, that meant reliance on the visual sense, which is able to literally to focus on objects. Visual acuity lends itself to measurement and quantification. The ubiquitous presence of light makes possible the identification of objects and their properties from many literal perspectives, which enables inter-subjective agreement. Distance from the stimulus allows time for reasoning and considered action, so that vision also seems more detached than other senses. The ideal of objectivity is inspired by the acuity and the literally objectifying quality of the visual sense; it suggests a transcendent realm beyond the limits of the senses and independent of the needs of the organism.

Yet, this conceptual realm, based on the visual sense, depends on the properties of light. So long as these properties seemed irrelevant to perception, light appeared to present the true face of the world, instantaneously and with little distortion. The realization that light is a wave-like propagation through space, at finite speed, led to questions about a medium in which it travels and its possible distorting effects. The realization that light has a fine-grained texture led to questions about how its microscopic properties affect measurement in the micro world. It became important to understand the role of light as a mediating *signal* through which knowledge is gathered and transmitted.

The extreme speed of light had made it possible to ignore the vanishingly small relativistic distortions occurring at speeds that could be contemplated during the first centuries of classical physics. Similarly, the extremely small size of atoms, electrons, and energies of visible light made it possible to ignore quantum effects among classical objects. While these circumstances made the development of physics possible in the first place, they also required eventual revision. If it had been the case (as early supposed) that light traveled with infinite speed, life would not have been shielded from the simultaneous arrival of an infinite amount of lethal radiation from everywhere in a possibly infinite universe. Similarly, but for being quantized, matter would not be stable; neither chemistry nor chemists would be possible.

These realizations challenged the traditional ontology of physics and, indeed, its fundamental stance. Physical measures derived from the visual sense (such as position, velocity, acceleration, momentum) could not be taken as straightforward, much less as absolute. Objectivity could no longer mean observer independence. These discoveries led to the guiding principle of invariance: even though perspectives differ, altering measurement, the laws themselves could be the same for all observers.

Mathematical modeling is essentially simulation. To be mathematically described, a natural entity or process must first be idealized and formally defined. It is this idealized model that then becomes the object of scientific investigation. The model can be described exhaustively because it was mathematically defined in the first place; but there is no guarantee it corresponds perfectly to reality. For, no formalism is strictly isomorphic to the reality it models, which may be indefinitely complex and integrated with the rest of the world. Laws of nature are simplified artifacts teased out from more nuanced appearances. Indeed, if nature is *real*, it cannot be fully captured in thought, words, or equations. (Conversely, if it could be so captured it would be an artifact, not reality.) If there can be no complete expression for the world simpler than the world itself, no final "theory of everything" is possible. Yet, redefining nature mathematically can give the illusion of completeness and definiteness, potentially masking ambiguities in the experimental or observational set-up.[38]

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[38] Cf. Nancy Cartwright *The Dappled World: A Study of the Boundaries of Science*, Cambridge University Press, Cambridge, 1999, p152.

It is questionable, also, to what extent nature can be assimilated to human purposes without skewing our understanding of it. Yet, science as we know it is successful to the degree that nature can be assimilated to models and simple formulae—at least "for all practical purposes." Technology works because, unlike nature itself, machines are physical versions of theoretical models. While the philosophy of mechanism facilitates engineering, one may still wonder how well it facilitates understanding nature in a way that permits our long-term survival, in contrast to the shorter-term goals to which technology is oriented. Moreover, theory and practice have a reciprocal relationship; theory that includes the role of the observer might expand practical application in ways not presently imagined.

While modeling mediates understanding, it can potentially obscure nature itself, reducing science to a neo-scholastic study of its own texts and constructs. Formalization involves a shift from empirical to deductive truths. It guarantees certainty of what one is talking about, but not that one is talking about anything real.

As in daily life, science cannot proceed without the use of metaphor and analogy, which extend the reach of thought and sensation beyond the familiar realm to which language is naturally adapted. Ordinary vocabulary refers to the macroscopic world, which provides a basis for our categories of thought. Therefore, it is normal to frame concepts outside that domain in terms of things familiar within it. Apart from mathematical description, or a language of pure abstractions, there is no other way to speak about phenomena that are beyond ordinary perception because they are too small, too large, too far away, or too complicated for immediate apprehension. Thus, physicists continue to speak of "waves," even when they are not considered waves in some medium, and of "particles," even when they are not considered solid objects in the ordinary sense. Such extension is always risky, since it constrains us to think in the limited terms suggested by familiar images.

Classical physics viewed nature as a machine—an inert, passive system governed by externally imposed laws, despite the manifest aliveness of the biosphere. The world was reimagined as a system like our inventions, which are knowable because we make them.[39] The philosophy of mechanism culminated in concepts of determinism and the dream of a complete theory. The purpose of scientific theory was to discover the blueprint of the world machine—or, in modern language, its program.[40] In this view, the world should eventually yield all its secrets to human investigation. But this is a metaphysical presumption; in reality, our theories and models are always guesses, however pragmatic.

The philosophy of mechanism is the faith that nature can be dealt with like a machine. The study of nature with mathematical tools became known as mechanics. It reached its culmination in the celestial mechanics of Laplace, who first articulated the idea of a theory of everything: a

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[39] Giambattista Vico, a contemporary of Newton, had articulated the idea that we know best what we have ourselves made. It was a short, if illogical, leap to the idea that the natural world is perfectly knowable as a machine.

[40] Hence the title of Newton's treatise, "The System of the World," presented axiomatically in the style of Euclid. Some contemporary physicists regard the universe literally as a computer, running the laws of physics as its program.

single equation predicting the detailed behavior of the world machine as far into the future or past as desired. While this was wishful thinking, it persists in the concept of determinism, and in implicit faith in mathematical modelling. Indeed, it inheres in the very concept of *system*—a whole that consists of well-defined parts, rules, and operations that can be perfectly known because they are intentionally specified in the first place. It is not the system of the world that is a machine, but our system of ideas about it!

The mechanistic worldview presumes a view of inanimate matter as passively obedient to externally imposed laws, reacting only to external causes, and not imbued with its own active powers of self-organization. This worldview had been handed down from antiquity through Christian theology.[41] But laws and their equations simply summarize expectations based on observed patterns, which are fundamentally statistical. All we can be certain of is correlations found among data; there can always be alternative models to account for those, and there may always be new correlations to discover.

The very notion of natural law has historical roots in the juridical concept of law as edict. The two senses of law—as pattern and as decree—have long been intertwined. The early scientists made little distinction between them, nor between causality and agency.[42] While laws of nature properly express observed patterns, the notion of physical laws as *governing* conflates the two senses of law.[43] As Hume observed, the notion of causal necessity is but shorthand for our natural expectations regarding patterns in the world. The notion of the causal power of laws simply projects, into the physical system concerned, the *logical* necessity that holds within the model as a deductive system. It confuses physical cause with logical implication. While physical laws may reassure us that the sun will rise tomorrow, they merely express the fact that it has done so in the past.

The philosophy of mechanism is compatible with the notion of physical laws as fundamental and transcendent, even separate from the universe they rule—just as the design principles of a machine rule its behavior and exist apart from its materials. In a more organic view, physical law simply describes emergent behavior that arises from the ability of matter to self-organize. Physics, especially, is still colored by a mechanistic vision, dominated by concepts such as determinism, reversibility, equilibrium, and the isolated system. While equations are deterministic by definition, nature itself is not a closed, logical system.

The word *determine* can mean either to *fix* or to *ascertain*. The first is an ontological claim, which presumes some causal power of one state to produce another. The second is an epistemic claim, which presumes an agent who tries to “determine” the future or past state of a system on

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[41] This was not undisputed, even in the seventeenth century. Leibniz considered *vis viva* (kinetic energy) to be an active power of things to affect one another (in modern parlance, the ability to do work). Newton focused rather on *vis mortua* (momentum), change of which he considered the passive result of external forces.

[42] Newton, for example, was reluctant to attribute gravitation to an inherent property of matter, preferring to see in it the expression of divine will. This was not far removed from the medieval vision of planets carried around their paths by angels.

[43] A natural law algorithmically compresses empirical data, while a computer program is a series of commands—to the *computer*, however, not to nature!

the basis of present evidence. The two senses of the term coincide when dealing with artifacts: the state of a machine at one moment fixes its state at a future moment; *and* the behavior is perfectly ascertainable. This does not apply to natural reality, which remains epistemically undetermined.[44]

The equations of physics typically involve a time variable, which can have a positive or negative sign, rendering them time-reversible. The world itself is not time-reversible, however, since it is not a machine, much less an equation. Some natural systems, like the solar system, appear to obey reversible equations because they behave sufficiently *like* machines to be considered deterministic. This is because nothing outside the defined system affects it seriously for human purposes. However, when the system is considered against the changing backdrop of the world outside it, as part of a larger whole, its history no longer appears reversible. Even if the background is ignored, if there are too many parts (for example, the molecules in a gas) the system can only be described statistically. When the motions of individual molecules cannot be traced backward or forward in time, the system is measurable only thermodynamically, which is to say on a large scale, as a whole.

It is no surprise that one cannot move backward in time, since in truth one cannot retrace one's steps in space either. Motion *seems* reversible—locally—when "space" is idealized as a fixed grid, without reference to a real changing background. While the notion of reversible motion through space depends on an artificial reference frame, the natural reference frame is simply the real environment (ultimately, the whole universe), which is constantly changing. As Heraclitus realized, when location is defined relative to an ever-changing world, a moving observer can never return to a former place, which has an ever-changing meaning. Nor can one truly be at rest relative to a changing world.

In a geometry, motion—along some coordinate from an origin—is but the subject's ordering of magnitude. That is a logical operation, reversible by definition, just as one can count integers backwards or forwards at will. Motion through physical space seems to coincide with this, when a continuous progression seems possible from object to object or from perspective to perspective. But such a progression is only reversible within a static reference frame. In real space, the landmarks themselves shift and change. The "fixed" stars, for example, move about at rapid speeds and only seem stationary because of their extreme distance. Their properties also change over time. Perspectives and backgrounds change, not merely as a result of the observer's movement but also because they evolve on their own, so that it is never possible to re-occupy precisely the same perspective, from which the same background is recoverable.[45]

Science embraces many other useful concepts and assumptions, which are nevertheless worth questioning. These include Occam's Razor (the simpler explanation is to be preferred, even though nature is not simple); the principle of sufficient reason (whereby everything is assumed to have a knowable cause); the identity of indiscernibles (whereby things are assumed to have continuous identity and never to simultaneously occupy the same place); formalism (whereby it

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[44] Which does not imply a metaphysical state of 'indeterminacy.'

[45] A metrical grid that changes or varies like that would render the idea of reversible motion within it very complicated, if not meaningless.

is assumed that nature can be exhaustively represented with symbols). Single causes are generally preferred (whereas causes in the real world are always multiple). Continuity is assumed, though relations could conceivably be discontinuous. The principle of *ceteris paribus* assumes "all other things being equal," though they may not be. Principles of symmetry and invariance reflect a preference for general rules over empirical fact. Esthetic principles of beauty in theories and elegance in mathematical treatment reflect psychological needs, not necessarily nature itself. Accepted categories and ontologies are taken to reflect real structure, in the belief that nature can be carved along its true joints.

The appropriateness of reification is often taken for granted. But are there literal objects even at the macroscopic scale? (Is a cloud an object?) Or, are "objects" merely shorthand for recurring perceptual patterns? The inference of entities in science parallels how objects are inferred in ordinary perception. Physical concepts and laws are defined in terms of measurable quantities. But presupposing an entity to carry the measured properties involves circular reasoning when the entity can only be verified through those measurements. On the other hand, even our everyday notion of "objectness" draws heavily upon industrial artifacts and the scientific concepts behind them. Industrial objects are well defined and functionally precise. A billiard ball is a far more archetypical object for physics than a stone or a pinecone, let alone a clod or a cloud.

As the traditional basis of scientific materialism, the notion of material substance has a tortuous history. *Mass* doubles as both the "stuff" of things and as a measurable property. Its measurement requires agency, interaction, and consequent transfer of energy—an equally elusive concept—which might be insignificant at the human scale, while not at the microscopic scale.

Energy had first to be dissociated from its material substrate before it could be (re)unified with the concept of mass in relativity theory. It is now given as a common name to diverse phenomena, revealed in distinct situations by different instruments, as though a definite single entity is involved, while in fact it is a common purpose that is involved.[46] Energy had shifted from being a measurable state of matter to being an ontological entity in its own right, which itself has mass as a property. The equivalence of mass with energy suggests one fundamental substance that changes form. While putatively substantial, mass and energy are defined through operations that are relational. From an epistemic point of view, they are not substances but measures.

Entropy is an abstraction conceived somewhat on the analogy of energy. But, while energy can be a property of individual things, entropy is a property of a whole system. It can be misleading to speak of the entropy of specific parts, or of a flow of entropy from one part to another, as though it too were a sort of substance, like caloric.

The notion of *field* is a classic example of reification that seems obviously justified. The strength of magnetic force, for instance, is measured through interaction with other magnets or electric charges. The surrounding space can be mapped in terms of the strength of potential for such interaction at each location. In that sense, the magnetic field was originally a mathematical device, which came to be regarded as a real entity permeating space. Certainly, the field concept has proven extraordinarily fruitful. On the other hand, imagining the material reality and

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[46] Bridgman *The Nature of Thermodynamics* Harvard UP, 1941, p114. One might wonder whether a society uninterested in engines could have conceived such a concept of energy.

mechanical properties of the electromagnetic field (the "luminiferous ether") led to a dead end in 19th century physics. Yet, that was hardly the end of the story, since the concept of *vacuum energy* again suggests a kind of substantial ether.

What we now call *experiment* was anathema to Aristotle, who thought that meddling with nature could only produce unnatural situations and results. Expressed in modern terms, experiment is an interaction between an apparatus (a machine) and the natural world. Today, it stands as a middle ground between pure observation and pure thought. Controlled experiments are designed to isolate variables for study; but both theory and the experimenter's intervention shape what is observed. Science, then, is a synergy between the external world, as driver of data, and creative interpretation by the scientist. Each presumes and depends on the other.

The huge difference in size and energy, between the things we see and the photons by means of which we see them, makes it plausible to neglect the physical effects of observation on our scale. It is because of this disparity that one can even postulate the existence of real objects, and of observers independent of them. Without this effect of scale, there could be no clear distinction between subject and object, nor between energy and mass.[47]

While reductionism has dominated science since its inception, we now know that the large-scale properties of matter cannot simply be reduced to effects of macroscopic laws applied to the microscopic scale. Quite the contrary, macroscopic laws are seen to emerge on the human scale as effects of the collective microscopic organization of matter.[48] The study of the very large and the very small each fostered the quest for simple first principles. In contrast, the intermediate human scale is more complex and challenging, partly because that scale is dominated by biological phenomena, but also because it is more readily accessible to direct investigation. It is easier to interact with things close to our own size, which makes it easier to perceive multiple causes and to trace complex interactions without the need for oversimplification. There remains the possibility that complexity actually prevails on every scale, and that we sometimes miss it because of an obsession with simple, idealized systems.

The universe appears to have begun in an improbable, highly ordered state, yet the arrow of time suggests inevitable drift into disorder. Debates arise about how to explain this disparity, sometimes invoking grand metaphysical speculations with little empirical support (such as a multiverse of randomly generated universes). The problem, however, assumes that the natural or default state of things is disorder. Order could then be selected for on some Darwinian principle, from generations of random universes. In truth, we know of but one universe— a single roll of the die. It is an odd exercise to imagine that a different set of forces and particles could have shaped a different outcome. The underlying assumption is that the experimentally found values that describe our actual world could be arbitrarily different simply because it is mathematically

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[47] The eye is 10^{32} times more sensitive to energy than the proprioceptive sense is to mass, owing to the exchange rate of mass and energy. Cf. Max Jammer *Concepts of Mass*, p190: "If this ratio were of the order of unity… the identity of mass and energy would have been an obvious fact of experience. The human eye, perceiving light from the sun, would then also feel the impact of photons."

[48] See, for example, Robert Laughlin *A Different Universe: reinventing physics from the bottom down.* Basic Books, 2005.

possible for inputs or constants in certain equations to be assigned different values. It is not surprising, therefore, that the suchness of this universe could appear to us as a fluke against a backdrop of imagined possibilities. For, it is the nature of the human mind to freely imagine possibilities; but, it is the nature of the real world to be particularly what it is and not generic. The emergence of order despite the 2^{nd} Law of Thermodynamics might seem more natural within a concept of nature as inherently self-organizing.

Physics and cosmology are now well positioned to struggle with grand questions, such as why the universe exists and how it could have arisen from nothing. Such questions cannot be fully addressed by merely extending present theories. In cosmology as in quantum physics, the participatory role of the observer becomes inescapable. Especially when considering the universe as a whole, one cannot maintain any pretense of standing outside the system.

Light plays a key role in our perception of the world, which includes the measurement of mass and of the observable effects of gravitation. Yet, modern understanding has it that the great bulk of the universe is invisible, neither emitting nor absorbing light. Estimates of the amount of this invisible mass are nevertheless deduced from observations of the motions of visible stars and galaxies. Is there some other causal interaction (besides gravitation) through which this hidden stuff could be directly detected? Could the inference of dark energy or dark matter result from an incomplete understanding of gravitation?[49]

Far from a divine revelation, science is an unfinished collective human enterprise. Since it provides a social standard for objective knowledge, it is important to recognize its strengths and its limitations. We could value it particularly for its potential to unify humanity and ensure our survival.

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[49] Expansion of the universe (now thought to be accelerating) seems to involve a repulsive effect of gravity at large distances, compensated by an attractive effect more locally. Indeed, if this disparity were not so, the expansion would not be detectable in the first place.

CHAPTER SIX: The Relativistic Observer

In which it is noted that space and time are not entities but relations. An epistemic explanation of c as cosmic speed limit invokes the unique role of light as signal and yardstick. A supraliminal carrier of information is logically possible—provided it would become the standard. The relativistic increase of mass is not the same as the conversion of internal energy to external energy and should not be confused with the mass-energy equivalence. Time dilation should be explained in terms of General rather than Special relativity.

"Only the universe and all that happens in it can tell perfect time."—Julian Barbour

In science, the subject is the *observer*, and experience means *measurement* of some observable property. Science faces the same epistemic challenge as ordinary experience: how to distinguish appearance from reality. In science, appearance is largely visual and from a distance, which involves measurable change in apparent size or position and its time derivatives. That, in turn, depends on the relative movement of observer with respect to the system observed. The *reality* behind the appearance, on the other hand, involves causal interaction between observing and observed systems, often experienced as force. A relevant property for that interaction is *mass*, which can be measured directly by local weighing or applying forces, or alternatively through changes in apparent movement of remote things.[50]

Let us return for a moment to the thought experiment presented in the first chapter: imagine that nothing in the universe exists but a single thing besides yourself as observer. Unless you can touch this object, you have no way to determine how large or far away it is.[51] Given no reference point, unless it appears to be getting larger or smaller in your field of view, you have no way to determine whether it is moving.[52] Indeed, moving in relation to *what* besides yourself? Such notions presume at least some third object in relation to which size, distance, and movement have meaning. A background of other things is presumed for reference. To measure anything not in your immediate proximity requires a reference frame that imaginatively extends from your locality to that object. It also presumes some way to gather that information from a distance, usually by means of light.

To measure is to quantify something in relation to a frame of reference, in terms of a standard unit—such as a centimeter of distance, a second of time, or a gram of weight. Measurement requires a physical way to apply such standards quantitatively—such as a ruler, clock, or balance scale. How we conceive the world depends crucially on measurements; on the other hand, the choice of what to measure, and how to conceive it, depend on how we conceive the world.

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[50] It is important to specify how variables such as mass are to be measured—e.g., by weighing in the rest frame or by observing changes of position from a distance and when the observer is moving.
[51] Absent other objects, even within reach size would have meaning only in relation to your body.
[52] If changing in apparent size, you could infer either that it is approaching/receding or that it is changing in "actual" size. Motion toward or away from the observer could also be determined visually from the Doppler effect, but this requires further assumptions and special technology.

Frames of reference are imaginary conventions. To treat them as physically real implies an unwarrantedly ontological view of the observer's fundamental situation. To preserve an epistemic view, in balance, requires keeping in mind the direct relation of the object to the subject, distinct from the object's relation to the frame of reference. In the case of distant moving things, that direct relation involves their movement toward or away from the observer, as distinguished from motion in relation to landmarks of the frame of reference.

For much of human existence, it appeared to people that they were the center of the world, which literally revolved around them. The visible movement of the heavens was interpreted as daily circling around a stationary earth. After all, no bodily sensation of movement contradicts this visual appearance. Visual evidence had led the ancients to conclude that the earth is a sphere, and even to estimate its size; but it took centuries more for people to be convinced that this sphere *spins*, and thus to see the rotation of the heavens as *relative*. Most importantly, this shift in thinking required more than the visual evidence, which was adequately explained by the Ptolemaic theory of epicycles. And it required more than bodily sensations, which continued to tell people that the earth does not move. Among other things, it required a clear conceptual distinction between relative and absolute motion.

Evidence supporting the earth's rotation came only *after* the shift in worldview. Only in the wake of Galileo's post-Copernican reflections and experiments on inertial motion, for example, did it become clear that the earth's rotation could produce measurable effects on the paths of cannonballs over large distances. And only in the 19^{th} century was the earth's daily rotation made directly apparent with the Foucault pendulum. The initial plausibility of the Copernican interpretation rested rather on new general principles, which came together as a whole to displace the Aristotelian worldview. Key among these is the idea of *inertial system*, and the relativity of apparent motion. Both were first clearly articulated by Galileo and later systematized by Newton. By that time, few doubted the heliocentric theory, but it was made more convincing by generalizing terrestrial experience in the form of universal laws of motion.

That generalization only works when the terrestrial situation is idealized in specific ways—for example, by ignoring an effect of the earth's rotation that would later be named 'Coriolis force.' Similarly, only if a small segment of the earth's surface is idealized as a stationary and frictionless flat plane can one arrive at the counterintuitive idea that objects continue to move at constant speed in a straight path unless disturbed by some outside force. This notion was plainly contrary to experience, since the earth's surface is neither smooth and frictionless nor flat. The concept of inertial system applies only locally, in an idealized frame of reference that does not perceptibly rotate and does not even extend far from the earth's surface.[53]

Concepts of dynamics rely ultimately on measurement of space and time and their derivatives, velocity and acceleration. In the case of distant moving bodies, concepts of force and mass

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[53] Lines perpendicular to the supposedly flat ground actually diverge with altitude away from the curved surface of the earth.

cannot be separated from these mathematical derivatives.[54] But measuring intervals in space and in time presumes rigid rulers, rigid clock parts, and the possibility of a rigid frame of reference. Life on the land surface of a solid planet approximates such conditions, while most of the universe evidently does not. To put things in perspective, it was astonishingly bold, but also cavalier, to extrapolate from very special local conditions on this planet to the vast rest of the cosmos.

On the earth, we construct experimental apparatus from solid materials. We can *locally* measure distances with rigid rulers and time with reliable clocks.[55] To measure lengths and times beyond direct reach, one must either move to the other location or resort to *signals* bridge the distance. Light (electromagnetism) thus plays a special role in physics, as in ordinary perception. The fact that light has a finite speed, and that the perception it affords is not instantaneous, affects appearance and measurement. (For instance, the light of the stars we see now with the naked eye left them years or centuries ago.) If the distance of the event and the speed of the signal are known, the time it takes the signal to reach the observer can be compensated, allowing us to know the time it occurred in its local frame of reference. The situation grows complicated if the distant event takes place in a system that moves in relation to the observer.

We are used to dealing with the behavior of things in the special environment at the surface of a solid planet, where we can measure the speed of things that move relative to the ground as a frame of reference considered at rest. From this experience, using the *nearly* instantaneous messenger of light, our common notions do not depend in an obvious way on *signalling*, since local speeds are small compared to the speed of light.[56] All this does not apply, however, to swiftly moving distant things.

The conceptual frame of reference, attached to the solid ground, is not a visible thing. Reference frames only *mentally* extend into space above the earth. There are no coordinate lines appearing in the sky to which distances can be measured. In truth, we know of astronomical events and their properties because of light arriving from them to our local environment. We can know their positions and movements only in relation to other things also made visible by light, not with respect to an invisible framework.[57]

Most of the universe is more like a gas than a solid. Everything in an environment without solids would be in constant flux, with no possibility of a fixed ruler or frame of reference. Perhaps certain atomic processes could serve to measure time, if a way could be found to read them that did not depend on solid matter. Perhaps distances might be determined via signals. Yet, in a purely fluid environment it would be challenging to establish the speed of the signal, or its constancy, so as to use it as the equivalent of a rigid ruler.

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[54] Barbour *Absolute or Relative Motion? Vol. 1: The Discovery of Dynamics*. Cambridge University Press, Cambridge, 1989.

[55] These measures depend on certain conditions or assumptions. For example, the length of the physical ruler and the rate of the mechanical clock depend on temperature. Since matter at the atomic level is electromagnetic, material dimensions could depend on internal forces that affect the structure of the components.

[56] The situation would be different if measurements depended on sound instead.

[57] Positions in the sky (celestial coordinates) were originally angular measurements made by instruments fixed to the ground.

Since we are fortunate enough to live on a solid planet, such considerations were never troublesome until scientists began to consider speeds comparable to that of light. It had long been assumed that the speed of light is practically infinite. But if *literally* so, all events would be perceived instantaneously and *all at once*, regardless of their distance. Such an assumption corresponds to the ideal of an omniscient observer, but not to the reality of embodied observers seeing with light that travels at a finite speed (usually denoted as *c*). Infinite *c* led to certain logical dilemmas, while avoiding others.[58] In a static world, time delays owing to a finite speed of light could be compensated easily enough. However, the challenge to track moving things using signals of finite speed underlay a crisis in physics that occurred toward the close of the 19th century.

Acceleration is a key concept in dynamics. It did not occur to the ancients, whose notion of force derived from muscular assertion but was not associated with change of speed or direction. It was problematic for the early scientists too, who recognized that force is proportional to both mass and acceleration, thus entangling those concepts. This gave rise to circularity in the mutual definition of force and mass (in the formula $f=ma$), and in the concept of inertia or momentum (mv).[59] Such confusion led to a dispute between Leibniz and Newton over what would later become the concept of energy or work.[60] The modern view is that a system of colliding bodies preserves overall momentum but not necessarily overall kinetic energy, part of which can be transformed into heat, for example.

While force could be directly *felt* through bodily contact with objects, with respect to distant things it could only be assessed through visually observing changes of motion. Force is felt in the effort required to lift massive objects, including one's own body; it is also felt in the effort to make stationary objects move or to slow down moving ones. This gave rise to two distinct

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[58] Infinite *c* avoids the inconvenient time lag involved in transmission of signals. On the other hand, consider Olber's paradox: if the universe were infinite in extent, then infinite *c* would imply that all the light from an infinite number of stars would reach the earth simultaneously, making the night (and day) sky infinitely bright and life impossible!

[59] Newton's first law *presumes* the absence of outside forces; yet, circularly, outside forces are *defined* as violations of the first law: a body at rest, or moving at a constant speed in a straight line, will remain at rest or keep moving in a straight line at constant speed unless it is acted upon by a force.

[60] For Newton, the key concept in dynamics is what we now call momentum (the product of mass and velocity, mv). Leibniz thought it is what we now call kinetic energy ($mv^2/2$). They were arguing the merits of considering a force acting over time versus over distance. A force acting over a given *time* produces a given change in velocity. But a force acting over a given *distance* produces the *square* of that change—because the distance corresponds to a greater time during which the acceleration acts to increase speed. Pivotal to this debate was deformation resulting from inelastic collision. Heavy balls dropped onto a sheet of clay were found to displace more clay the greater the height from which dropped. That, of course, was a result of the acceleration from gravity. If balls *rolled* or *slid* on a level frictionless surface at constant speed, smashing into vertical panels of clay, the displacement of material would be proportional to v.

concepts of 'mass' as the measure of the amount of matter: gravitational mass (weight) and inertial mass.[61]

As a *line-of-sight* visual effect between two observers, acceleration (like velocity) is relative and mutual.[62] That is, each would perceive the other as accelerating toward or away by the same degree. However, acceleration as *felt* could be different for the two observers. This seems to imply an absolute reference frame. The observer who *feels* a force is the one who is "really" accelerating, whereas the one who feels no such force is the one "at rest" in that frame. Of course, they could *both* be accelerating with respect to a rest frame, by equal or differing amounts and directions.

What could account for the real existence of an absolute rest frame and the consequent feeling of being accelerated with respect to it? This was the big question that Mach pondered. His answer was that it must (somehow) be all the other matter in the universe! Since the stars are comparatively far from the observer, their motions appear minimal. The "fixed" stars, then, approximate an absolute frame of reference.[63] Mach's insight does not really tell us why acceleration (change of velocity)—with respect to the bulk of the universe—is felt as force while constant velocity with respect to it is not. Since they are both "motion," why is changing velocity special, and what is mass that it should be entangled with it?

Whatever else they might be, space and time are relationships between events or objects, as perceived by subjects. From an epistemic point of view, space and time are *measurements*, not *entities*.[64] The reference frame in physics extends the point of view of a subject, but also objectifies it, as a sort of cage surrounding and fixed to the observer. The velocity of an object moving with respect to this cage is not simply the (line-of-sight) speed of its approach to, or recession from, the observer located at the zero point (origin) of this grid.[65]

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[61] Apart from the dynamical concept of inertial mass, there was evidence in late 19th century for an electrodynamic origin of mass, since a charged particle seemed to resist acceleration more than an uncharged particle. This suggested that some or even all inertial mass might be electrical in origin.

[62] Line-of-sight visual evidence for mutual acceleration would be a changing rate of change in apparent size; but the human visual system is not very good at estimating that. Indirectly it could be measured as changing frequency of the light (Doppler effect for acceleration).

[63] A clock could be set by referring to (distant) astronomical events, such as the periods of binary stars or quasars. A second clock in the same reference frame could be set by referring to local atomic events, such as frequencies in atomic clocks. For an observer at rest with respect to the reference frame of the stars, time measured by these two clocks would coincide; but would they coincide for an observer who moves relative to the "absolute" frame represented by the stars?

[64] There is no flowing entity 'time' that can be measured like electric current is measured by an ammeter. Clocks don't simply *measure* time but *define* it. [Ilaria Bonizzoni and Giuseppe Giuliani "The interpretations by experimenters of experiments on 'time dilation': 1940 - 1970 circa." arXiv:physics/0008012{physics.hist-ph} Sec2.2] Similarly, there is no substantial entity called 'space', apart from separated landmarks and signals connecting them. In that sense, rulers also define space as well as measure it.

[65] An airplane flying overhead, for example, may have a constant speed (s) with respect to the ground (the "base" or x axis of the cage); but the line-of-sight velocity (v) with respect to the observer on the ground continually changes. From positive s at infinity, v decreases on approach until it reaches zero at a point

Though space and time are but measures, they can be reified as quasi-substantial. In classical physics, this is reflected in the notions of absolute space and absolute time—for instance, in such expressions as Newton's "equable flow" (of time) and "uniform" space. Including real landmarks shifts the subject's point of view from a purely line-of-sight (subject-object) relationship to an object-object relationship perceived by the subject. The imaginary grid extends that idea; it may also come to seem a sort of entity with properties of its own. Newton's absolute notions of space and time were challenged in Special Relativity, which ironically gave rise to a new reification, *spacetime*.[66]

Rigid rods and mechanical clocks *define* idealized intervals of space and time. Their units of measure are uniformly identical by definition. However, in a changing universe, everything happening in the background during one standard time interval is *not* the same everything happening in another interval. To paraphrase Heraclitus, there *are* no identical time intervals, except aby convention. Similarly, a rigid measuring rod is an idealization, and the very concept of rigidity is circular. For, how is rigidity to be verified except by comparison with other objects presumed to be rigid? Rigid rods cannot be applied to faraway moving objects, for which the only measuring tool is light. But the "rigidity" of light (its constant speed) is an assumption that depends circularly on rigid rods and clocks, using light itself to verify.

The concept of inertial system and the principle of relativity[67] play key roles in both of Einstein's relativity theories, as do the fundamental concepts of measurement and frame of reference. Galileo had realized that objects continue at rest or in uniform motion until acted upon by some external disturbance. The default state had shifted from Aristotle's "motion-toward-the-center" to what we now call inertial motion. An explanation of gravity then required the larger context of *forces* to effect changes in inertial motion. Newton grasped that the same (invisible) force pulls the apple and the moon toward the earth. More than two centuries later, Einstein reinterpreted gravity again—in a way bearing more resemblance to Aristotle than to Newton: gravity is the natural way things move in the vicinity of matter, which shapes the surrounding space. For Aristotle, falling objects signified an earth at rest at the center of the cosmos. For Newton, they signified the attraction of all matter for all matter. For Einstein, they signified a non-Euclidean structure of space-time. These are very different conceptions of the "same" phenomenon.

A great dilemma confronted the physicists of the late 19th century. Maxwell had unified electricity and magnetism and explained light as disturbance in an electromagnetic field. This was interpreted to mean transverse waves in an ethereal medium.[68] But what could that medium be other than space itself? In order to have the properties implied by Maxwell's theory, the

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directly overhead, and then increases again to approach negative *s* at infinity. Similarly, a siren approaching on the road sounds higher in pitch than when passing or receding (Doppler effect).

[66] Space and time are conveniently unified—and also reified—in mathematical devices such as the Minkowski 4-dimentional continuum or the spacetime manifold of General Relativity.

[67] Also known as Galilean invariance: the laws of motion should be the same in all reference frames.

[68] Electric and magnetic fields had been associated with material sources (such as charged wires); it was novel to consider a general field at large in space.

medium would have to resemble an extremely rigid transparent solid, which nevertheless does not impede the movement of ordinary matter through it! However counterintuitive, if such a medium really existed it should be possible for observers to detect their motion through it—for example, as viewed from the Earth moving in its yearly orbit.[69] It was assumed, moreover, that this medium would be a natural choice for a frame at absolute rest.

Such ideas came to a head in 1887 with a famous experiment designed to detect motion through this "luminiferous ether." This type of experiment relies upon the wave-nature of light, since it utilizes the interference of two rays of light, slightly out of phase. These begin as one beam, then split in two that follow paths at right angles to each other, which are then brought back together for comparison. The idea is that motion of the apparatus through the ether would cause one ray to be noticeably out of phase with the other. Surprisingly, the experiment failed to detect such a shift. Einstein was only seven years old at the time of the Michelson-Morley (MM) experiment. He certainly would have known of its disturbing results by the time he wrote his famous paper, "On the Electrodynamics of Moving Bodies" in 1905. Yet, in contrast to Lorentz's efforts to solve the puzzle, Einstein's paper deals only obliquely with the MM result, concentrating instead on inconsistencies in the implications of Maxwell's theory. At stake was the synthesis of electromagnetism (light) and ordinary dynamics (matter).

The MM experiment precipitated a crisis but did not definitively settle the issue of the ether. Einstein himself admitted that Special Relativity (SR) rendered the ether superfluous but did not disprove it. Later experiments seemed to confirm the null result; but such results were sometimes contested, and even reinterpreted instead to support absolute motion. Experiments continue to be proposed to detect motion relative to a cosmic rest frame or a medium for light.[70] The persistence of such efforts reflects the appeal of an absolute perspective, a major thread in ontological thought. An epistemic thread emphasizes rather the relativity of all perspectives, oriented toward the subject as well as the object. In particular, it holds that only motion relative to visible things can be measured. That could be motion in direct relation to the observer (approaching or receding) or it could be in relation to some other visible landmark or background (but not to an imaginary frame of reference); either way involves light arriving to an observer.

Supposing light to consist of waves, one problem with the ether as a medium is that (unlike the ocean or the air) it is not itself a perceptible thing. The alternative assumption—that light consists of *particles* moving in empty space—requires no medium in which to travel. The corresponding problem, however, is that a particle of light is no more a perceptible object than is the ether. The objectification of light, as either particle or wave, leads to inconsistency. Since light is the *means of seeing* for us as visual creatures—and not a *thing to see*—by what means

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[69] Like moving through air, the anticipated effect of this motion was sometimes called the "ether wind." An analogous problem would be to detect an observer's motion through air *using only sound*.

[70] For example: Donald C. Chang "Is there a resting frame in the universe? A proposed experimental test based on a precise measurement of particle mass." Eur. Phys. J. Plus (2017) 132: 140. The idea is to use massive particles, rather than light, in an equivalent of the MM experiment, using mass spectrometers to detect absolute motion.

could we see light itself or consider it to be an object? Whatever its nature, light is used by observers as a *signal* connecting them with each other and with objects.[71]

If quantized energy (photons) behaved like projectiles rather than waves, then their speed, relative to an observer moving with respect to the emission source, would depend on that movement.[72] In the absence of a medium that serves as a common frame of reference, no frame has an exclusive claim on the truth, at least for line-of-sight effects. The effects on measurement—of motion between two observers—would be mutually and symmetrically perceived. Each could conclude with equal right that the dimensions of the other's reference frame had changed. Such a situation might aptly be called *epistemic* rather than *ontological*, or apparent rather than real. Einstein called it *kinematic*. Let us bear in mind that any epistemic system consists of *subjects, objects, and mediating signals.* Appearances will be a function of all three.

Desperate attempts were made to salvage common sense in the wake of the MM experiment. Fitzgerald, and Lorentz himself, proposed that the rigid arms of the interferometer were not in fact rigid. After all, solid matter is essentially regulated by electromagnetic forces between atoms. The space between atoms, if not the atoms themselves, might be distorted by motion through the ether. Hence, in order to account for the null result, it was proposed that one arm of the interferometer physically contracts—the arm carrying the light ray in the direction of motion with respect to the ether.[73] Alternatively, it was proposed that the ether is partially dragged along with the earth in its orbit, so that there was no local motion with respect to it. All such attempted solutions were ontological. Even Maxwell, however, had been unable to produce a sensible model of the ether, compatible with mechanics.

The Special Theory of Relativity (as Einstein's 1905 paper came to be known) took a different tack. It has two parts: 'kinematic' and 'electrodynamic.' Their inclusion together may reflect Einstein's deep struggles with the issues involved.[74] SR presents a theory of invariance: a way to express the laws of physics in the same form for all observers. That meant preserving the relativity of observation (which encompasses the addition of velocities); but it also meant

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[71] If light is but a coupling between observers, or between emitters and absorbers, the very meaning of the intervening space is called into question.

[72] Early on, Einstein had considered an emission theory in which light consists of particles. This eliminated problems associated with the ether, but did not resolve the problem of the addition of velocities. Emission theories explain the MM result but are not consistent with other experimental results. In the wave theory, *c* is constant in the medium, whereas in the particle theory the speed of light is constant with respect to the emitter, but not necessarily the receiver. Thus, light defies both the wave and the particle interpretations, suggesting that it is not an entity at all, traveling across space, but a non-local connection between nominally separate localities—whatever that may turn out to mean!

[73] This would be undetectable by a "rigid" ruler, which would also contract for the same reason.

[74] Robert Rynasiewicz "The optics and electrodynamics of 'On the Electrodynamics of Moving Bodies'" Ann. Phys. (Leipzig) 14, Supplement, 38 – 57 (2005), p39: "The problems [with Maxwell's theory] addressed in the Electrodynamical Part drove Einstein, albeit in round about ways, to the discovery of the self-standing doctrine as set out in the Kinematical Part. This doctrine yielded a secure and independent justification, previously lacking, for the approach he had explored for the problems of the Electrodynamical Part."

preserving the speed of light as a law of physics (as per Maxwell's theory), which should thus be the same for all observers. To all appearances, these requirements were in contradiction.

Einstein's quest to reconcile them had begun with a youthful thought experiment: what would it be like to chase a beam of light? In his own words, recollected later:

"If I pursue a beam of light with the velocity c… I should observe such a beam of light as an electromagnetic field at rest though spatially oscillating. There seems to be no such thing, however, neither on the basis of experience nor according to Maxwell's equations. From the very beginning it appeared to me intuitively clear that, judged from the standpoint of such an observer, everything would have to happen according to the same laws as for an observer who, relative to the earth, was at rest. *For how [else] should the first observer know, or be able to determine, that he is in a state of fast uniform motion?*"[75]

I put the last sentence in italics to emphasize the tacit implication that *light itself* is the means to determine the state of motion, which cannot be *felt* in an inertial system. How would light ever reach an observer moving with the speed of light away from its source? How, then, could one even gauge one's speed, to know that one is moving at *c*? Mulling over this paradox for a decade led Einstein to the kinematic part of SR:

"An analysis of the concept of time was my solution. Time cannot be absolutely defined, and there is an inseparable relation between time and signal velocity."[76]

He does not elaborate on that relationship, emphasizing instead the challenge to overcome the absolute character of time; however, he could as well have emphasized the circular dependence of light upon measures of time.

SR rests on two notions "only apparently irreconcilable": (1) the same laws of electrodynamics and optics are valid for all frames of reference for which the equations of mechanics hold good;[77] and (2) light is always propagated in empty space with a definite velocity *c*, which is independent of the state of motion of the emitting body.[78] Einstein cuts the Gordian knot by boldly offering these as "postulates," to be accepted independently of empirical evidence (such as the MM experiment). His presentation then has the flavor of a logical deduction from first principles—reasoning that may be consistent with data but does not depend on it. As a reviewer at the time commented, the light postulate is the more remarkable, since its strange consequences "offer the only method of preserving the science of mechanics substantially in its present form."[79] Indeed, that was Einstein's goal. Despite his early positivism, it was his lifelong concern to preserve the objectivity, rationality and consistency of physics, the

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[75] A. Einstein *Autobiographical Notes*, translated and edited by P.A. Schilpp (Open Court, LaSalle, 1979), pp.48–51 [my italics].
[76] Einstein, "Kyoto lecture."
[77] The so-called principle of relativity, aka the principle of invariance or co-variance.
[78] The so-called light postulate. Note that nothing is said about the state of motion of the receiving body.
[79] Gilbert N. Lewis and Richard C. Tolman (1909) "The Principle of Relativity and Non-Newtonian Mechanics."

principal challenges to which were the dilemmas that gave birth to the two great 20th-century revolutions, relativity and quantum theory. Though his solutions involved taking the observer into account, the aim was to preserve an observer-independent worldview—the fundamental stance of classical physics. The intermediary of light threatened to embroil subject and object unacceptably. In SR, Einstein found a way to preserve the classical worldview. Ironically, the relativity of space and time—their epistemic "subjectivity"—was overcome in a new objectivity: the space-time continuum as an ontological entity effectively replacing the ether.[80]

The argument of the paper begins with an inquiry into the concept of simultaneity—what in fact it means to establish the timing of an event. As we saw above, the space and time coordinates of an event will not be the same in two frames of reference moving uniformly with respect to each other, either of which is equally entitled to consider itself at rest and the other moving. Based on his two postulates, Einstein proceeds to derive the mathematical transformations from the stationary to the moving coordinate system, or vice-versa.[81] While coordinates may differ, the *transformations* between them will be the same for both observers, on the premise that the speed of light is the same for all.

It is no coincidence that his papers on the photoelectric effect and SR were published the same year. SR draws indirectly on Einstein's ideas about the particle nature of light—the other thing mulling in the back of his mind while contemplating electrodynamics.[82] The idea that light could emanate outward in all directions like an expanding wave, yet be absorbed in a definite location as a definite amount of energy, led Einstein to consider (and, for the time being, dismiss) an emission theory of light in which photons would be more like bullets than waves. This circumvented the problem of the ether, but not the addition of velocities and the apparent invariance of *c*. In SR, Einstein chose a third path, in which the physical nature of light is set aside in favor of its role as a *signal*.[83] This is the solution I call epistemic, because it involves the relationship between observers rather than the nature of entities.

In ordinary experience, light is virtually instantaneous. The effects of finite *c* become appreciable only when considering spatially separated observers moving relatively to each other with a speed nearing that of light itself. These effects are today still described as "length contraction" and "time dilation," as though they are physical changes in the objects themselves, not a result of using light as a signal to know the object. However, physical change requires

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[80] Harvey R. Brown *Physical Relativity*: *Space-time Structure from a Dynamical Perspective* Oxford UP, 2005, p67: "The view that the *space-time manifold* is a substratum or bedrock…is just the twentieth-century version of the ether hypothesis."

[81] These equations had earlier been adduced by Lorentz in his (ontological) theory of electrodynamics. Poincaré had also found them on similar grounds. Einstein's approach was novel to the degree it was epistemic rather than ontological.

[82] Harvey R. Brown *op cit*, p70ff. [HRB}

[83] This avoided questions about what happens physically in reflections, for example, and also the problem that perfect rigidity of physical rods would be outlawed by SR itself, since it implies instantaneous (faster than light) transmission of forces within the rod. See: Robert Rynasiewicz "The optics and electrodynamics of 'On the Electrodynamics of Moving Bodies'." Ann. Phys. (Leipzig) **14**, Supplement, 38 – 57 (20).

causal explanation, which suggests that such change in objects due to motion must involve a physical interaction with something—perhaps some medium through which they travel.

While the ontological interpretation is in keeping with the mind's natural outward-looking realism, it is confounded when the above measurable effects are paradoxically *mutual*. With equal justification, each observer perceives the *other's* measuring rod to have shrunk and clock to have slowed down. Moreover, these are effects involving a line-of-sight component for observers in relative motion. The kinematic part of SR sidesteps any question of changes in the "real" physical shape and size of moving objects (the ontological interpretation). The effects are rightly interpreted epistemically, since they depend on the specific conditions in which information is obtained. Yet, Einstein was not consistent about this distinction.

The arguments of SR were first presented in terms of mutual line-of-sight (longitudinal) effects, involving light signals between distant frames of reference, in uniform motion away from or toward each other. Since the contraction effect is mutually perceivable, it cannot be objectively physical in the sense that there can be agreement about which observer's measuring stick has "really" shrunk. On the other hand, toward the end of the kinematic part of his paper, Einstein develops a conclusion that implies time "really" slows down, in an asymmetric way, and which has since become known as the Twins Paradox (see Appendix 1). His argument implies an ontological interpretation of time dilation. Indeed, there *is* empirical evidence for the reality of time dilation, but its explanation may lie outside situations addressed by SR—instead involving acceleration or the presence of a gravitational field, as considered in General Relativity. However, the argument for time dilation *because* of acceleration or gravity seems to rest circularly on SR.

Should length contraction and time dilation in SR be understood epistemically or ontologically? If it were the case that motion through space (whether uniform or accelerated) could produce objective ontological effects, there must be some interaction that causes these effects. In other words, we come full circle to the problem of the ether.[84] The kinematic part of Einstein's paper implies an epistemic interpretation, though not consistently; his argument in the electrodynamic part is couched in ontological terms, but proceeds with a parallel logic as in the kinematic part. In a sense, the kinematic argument represents the observer's first-person view, while the electrodynamic argument represents the third-person view. Einstein did little in the paper or after to clarify the distinction.[85]

Others, beginning with Lorentz and Fitzgerald, certainly took the ontological interpretation seriously. Pauli seemed to embrace both views and did not think the attempt to explain the Lorentz contraction at the atomic level should be abandoned.[86] Over the years, Eddington

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[84] Persistence of the ether concept is demonstrated by modern theories of the *vacuum*, and the explanation of inertia (mass) as an interaction with the Higgs field.

[85] For example: Einstein Doc47 "The Relativity Principle": "The *kinematic shape* of a body undergoing uniform translational motion… differs from its *geometric shape* only by a contraction in the direction of the relative motion…" [italics added].

[86] Pauli, quoted in HRB, p118: "The contraction of a measuring rod is not an elementary but *a very complicated process*. It would not take place except for the covariance with respect to the Lorentz group of the basic equations of electron theory, *as well as of those laws, as yet unknown to us, which determine*

changed his mind about length contraction, at first presenting it as epistemic, later as a result of the behavior of electrical forces.[87]

The curious relationship between the kinematic and electrodynamic parts of Einstein's original paper mirrors the confusing relationship between subjective and objective points of view. Science, with its outward focus, naturally prefers ontological explanations. There is a price to pay, however, when it fails to acknowledge the observer's epistemic dependence on signals. As long as light is the signal, that dependence is effectively universal, quite aside from electrodynamics.

A consequence of the dependence on light as signal is that the speed of light in empty space cannot be exceeded by any physically real entity, whether matter or radiation.[88] Einstein's explanation in the kinematic part is that length in the direction of relative motion shrinks toward zero as v approaches c. In the electrodynamic part, it is that the kinetic energy of an object grows toward infinity as its v approaches c. In both cases, however, we are talking about the changed *appearance*, in one frame of reference, of something moving with respect to it—an appearance that would remain normal in its own frame of reference. If these effects are not real—that is, if they are not asymmetrical and independent of signals—then how should we regard them?

Why, indeed, is c a cosmic speed limit? An *epistemic* answer is that the unique role of light as a signal between frames of reference imposes the apparent limit. It is nevertheless logically possible that there could exist an undiscovered supraliminal carrier of information that could be used as a signal instead. Taking on the role of light, *its* speed would then replace that of light as the cosmic speed limit.[89] Electromagnetic radiation would take a place with sound as a *phenomenon to observe* rather than the *means of observing*.[90] Conversely, if we could use *only* sound to observe the world, *it* would constitute the limiting speed.[91] We know (by means of

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the cohesion of the electron itself." [italics added] The covariance of the basic equations of electron theory is what Einstein presented, in the kinematic part, as epistemic. The cohesion of the electron itself suggests an ontological interpretation.

[87] HRB, p119. Footnote 17. Also, John Bell thought a complete account of length contraction might involve more forces than just the electromagnetic.

[88] Thomson in 1893 had proposed that c is a cosmic speed limit on electrodynamic grounds: "When in the limit… a charged sphere moving with the velocity of light behaves as if its mass were infinite, its velocity therefore will remain constant, in other words it is impossible to increase the velocity of a charged body moving through the dielectric beyond that of light." [J. J. Thomson, *Notes on Recent Researches in Electricity and Magnetism*, Oxford Clarendon, 1893, p21].

[89] The faster-than-light entity would have to replace light as our principle means of investigation. Otherwise, it would give rise to the classic paradox that a supraliminal signal would be received before it was sent. In other words, a given signal medium cannot be used to investigate itself.

[90] Since we are engaging in wild counterfactuals, perhaps this would enable us to perceive photons, electromagnetic waves, or even to detect the medium in which light travels, all of which are presently invisible to us. (With light as *vehicle* of perception, we are unable to treat it as an *object* of perception.)

[91] Cf. Max Born *Einstein's Theory of Relativity* Dover, 1962, p251-2: "As a matter of fact, if we use sound signals to regulate the clocks, Einsteins's kinematics can be applied in its entirety to ships that move through motionless air. The symbol c would then denote the velocity of sound in all formulae… and the Lorentz transformations would hold between the system of measurement of the various ships… Is this the meaning of Einstein's theory? Certainly not! Rather it is assumed as self-evident that a measuring rod which is brought into one system of reference S and then into another S' under exactly the same

light) that things can move faster than sound. But—absent light—how would we know this using only sound itself?[92]

An *ontological* answer concerning the cosmic speed limit would imply some real interaction with a field (such as the Higgs), with inertia increasing because of motion through it. If all types of particles and radiation were varying disturbances in a single medium (even the so-called vacuum), that could provide a physical basis for understanding the difference between massive and massless particles and, thus, for why no massive particle can move faster than *c*. The cosmic speed limit would be determined by the properties of that medium, as the speed of light is determined in Maxwell's theory by the properties of the electromagnetic field.[93] It would *be* the ether.[94]

As an axiom of his system of the world, Newton had proposed that "absolute, true, and mathematical time, of itself, and from its own nature," flows equably without relation to anything external. Similarly, he proposed an absolute space as the venue for all events. SR debunked the electromagnetic ether as an absolute frame of reference. Could there be some other basis for an absolute rest frame? Post-relativity, the space-time manifold took the conceptual place for physicists of the luminiferous ether. All fields were then construed as states of the manifold, which effectively stood in for the ether.[95]

Nicknamed the "block universe," this manifold is a convention that unifies abstract concepts of space and time, which no longer have independent significance. In effect, it treats time as a fourth spatial dimension. It provides a static or frozen model of change, a god-like third-person perspective, treating spacetime as a new sort of object, from which the subject again remains conceptually apart. The *mathematical* advantage is that certain physical concepts can be treated more conveniently than by dealing with space and time separately. To reify this mathematical convenience, however, is a metaphysical act that masks the observer's epistemic dependency on light.

The manifold employs a space-time interval, with the speed of light built into it, rather than a space interval *through* time. By definition, the interval is invariant among observers in different reference frames. However, it cannot be directly measured. It can only be *calculated*, using the Pythagorean theorem, on the basis of space and time intervals separately measured. Except for

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physical conditions would represent the same length in each…" But the point is precisely that the same instruments *cannot* be so used, first in terrestrial then non-terrestrial systems! In the analogy with ships, we can board the vessels in succession with our standard ruler and clock, and verify that the relativistic effect using sound is an illusion. This is not possible when we cannot board the remote moving system, at least not without undergoing some acceleration.

[92] The phenomenon of the sonic boom could be a telltale clue that its source was moving faster than sound. There does not seem to exist a corresponding phenomenon for light, unless the mysterious Cherenkov radiation.

[93] See: Chang, D.C. (2018) A New Interpretation on the Non-Newtonian Properties of Particle Mass. Journal of Modern Physics, 9, p228-29.

[94] If such a field had a characteristic wave velocity greater than *c,* and could be used for communication of information, then there would exist a signal faster than *c*. On the other hand, if this unique field happens to be characterized by the velocity of light, then no signal could be faster than *c*.

[95] John Earman, quoted in HRB, p67.

light signals, no measuring tool exists that is a hybrid of a ruler and a clock![96] But to *define* light as the measure of this interval is circular reasoning, since the speed of light itself is defined in ordinary units of space and time.

Newton had based his assumption of absolute space principally on his bucket experiment, which made it clear that motion involving acceleration (in this case, centrifugal force) is not merely relative. That is, it makes a real difference whether the water is turning inside the bucket or the bucket is turning around the water. Mach later suggested that what makes this difference is all the other matter in the universe. If the water is not spinning relative to the stars, it will not be displaced up the side of the bucket through centrifugal force. According to Mach, an objective, preferred frame of reference is supplied by the distribution of mass in the universe. Presumably, its structure and effect could change with time and could vary with local density and therefore with direction in space. If masses are not distributed evenly, then the inertia of a moving object could depend on its location. Since there is no location completely free of forces, the very definition of an inertial system is at risk. An object is unaccelerated if no force acts on it; but we can know that no force acts on it only because we see that it is unaccelerated.

As a quantity that measures the objective "amount of matter," mass should not depend on the observer's state of motion. (The number of particles, for example, should be conserved.) But the message of relativity is that perception is relative to the observer in the absence of an absolute point of view. Mass can be measured locally by weighing—for example, with a balance scale. But the mass of an object can only be determined from a distance through inferences based on visible interactions with other things, which involve perceivable changes in its motion. The motion observed *does* depend on the state of motion of the observer, and thus the perceived mass also depends on it. In fact, then, we have two concepts of mass. One is local, determined by weighing in the presence of gravitation. The other is distant, determined visually by changes in motion, which must factor-in the observer's motion. Before Einstein, the identity of inertial (distant) mass and gravitational (local) mass was mysterious but taken for granted.

As a key variable in dynamics, inertial mass is always paired with a variable of motion. (Force = ma; momentum = mv; kinetic energy = mv^2/2.) Contemporaries of Newton criticized the circularity of the definitions of force and mass, which applies to momentum and energy as well. These are conjoint effects of mass and changing position, and *the latter is relative to the observer's state of motion*. In effect, mass serves as a coefficient of velocity in momentum, of acceleration in force, and of the cumulative result of acceleration in kinetic energy. What is actually measurable from a distance in all cases involves the inseparable product of the paired variables, not just mass per se. Inertial mass has meaning only as a coefficient of velocity or acceleration, since motion is what is actually observable from a distance. In other words, what is actually measurable involves the quantities mv, ma, or $mv^2/2$, not m in isolation.

The relativistic increase of inertial mass in SR falsely suggests a "real" change in the moving object. For, all relativistic effects in SR, including apparent change in mass, must be mutual

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[96] Brown [HRB, p8] gives the example of the *waywiser* as a clocklike device that measures distance. As he points out, there is no analogous mechanism, with traction on spacetime, to read off four-dimensional distances. Light itself is the only such device.

between uniformly moving frames.[97] Like length contraction and time dilation, the relativistic increase of inertial mass with speed must be a symmetrical effect between observers. The apparently objective (that is, asymmetric) increase of mass of particles in high-energy experiments may be due to acceleration rather than the uniform velocity that pertains in SR. In any case, no observer occupies the framework of the particle. The physicist who uses a cyclotron to measure speeding particles may claim to occupy the rest frame and that the *particle* has increased in mass; but there is no observer claiming the point of view of the moving particle, from which the cyclotron symmetrically would appear to gain in mass![98]

The relativistic increase of mass with velocity in SR (which supplied the reasoning for Einstein's derivation of $E=mc^2$) is not the same phenomenon as the conversion of internal energy to kinetic energy implied by this famous equation. Relativistic increase of mass should not be confused with the equivalence of mass and energy. However, it often *is*, perhaps because Einstein used the former to argue for the latter.[99] Yet, he himself was never satisfied with his several derivations of the formula, which were never without problems pointed out by critics.[100] Moreover, others had found essentially the same formula. In proposing mass-energy equivalence, he was speculating intuitively about the internal energy of the atom, about which little was known at the time. The formula quantifies the equivalence, but says nothing of the actual physical processes of "converting" mass to energy or vice-versa. Some conceptual inconsistencies seem to be involved.[101]

In his original paper on this equivalence, Einstein assumes a "rest energy" E_0 in the frame of the observer considered at rest.[102] But, since that is by definition *not* kinetic energy (of the whole, moving with respect to an external frame), it must be its "internal energy," whatever that would turn out to mean.[103] The idea that rest mass represents a form of energy inside an atom turned out

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[97] According to Einstein, such effects would include temperature: "Thus, the temperature of a moving system is always lower… than with respect to a reference system that is at rest relative to it." [Doc47].
[98] While the cyclotron could theoretically be weighed, the moving particle cannot. In any case, that would measure gravitational mass, not inertial mass.
[99] Marc Lange "The Most Famous Equation" The Journal of Philosophy, Vol. 98, No. 5 (May, 2001), pp. 219-238: "Indeed, it is difficult to find a scientific equation whose ontological implications have been misunderstood so widely and in so many ways."
[100] Cf. Hecht, E. (2011) American Journal of Physics, 79, 591-600; also Moylan, P., Yan, L. X., & Gironda, M. (2021) "On the Controversy over the Logical Correctness of Einstein's First Paper on Mass-Energy Equivalence." Advances in Historical Studies, 10, 21-33.
[101] For instance, if electrons have mass, and mass is internal energy, then electrons must have internal energy. Does that mean internal kinetic energy, so that electrons are not "fundamental" but consist of moving parts? And of what do *those* parts consist? Is there such a thing as "pure" energy, other than energy that is ultimately kinetic or potential?
[102] Properly: $E_0 = m_0c^2$, where m_0 is by definition mass in the rest frame. That is, "rest energy" and "rest mass" are equivalent for an object at rest in the observer's frame of reference. This is not the same as the apparent (increase of) mass from the point of view of frameworks in relative motion. Cf. L. B. Okun "The Einstein formula: $E_0 = mc^2$. 'Isn't the Lord laughing?'" arXiv: 0808.0437v1 {physics.hist-ph} Aug 2008.
[103] The unified concept of energy disregards specific measures in differing contexts (for example, radiant vs kinetic vs potential).

to be a profound truth. In contrast, the concept of *relativistic mass* is an effect of motion relative to an observer.[104] It confuses an ontological with an epistemic notion.[105]

A mere difference of perspective between two frames of reference is not the same as a true change of kinetic energy— for example, through loss or gain of radiation. Nor is a shift of perspective: viewing the motion of the thing as a whole is not the same as viewing its internally moving parts. Einstein's argument does not in itself establish the connection between radiant energy and mechanical inertia.[106] The equivalence of mass and energy is an empirical fact verified in atomic physics, wherein energy within the atom *is* converted to external kinetic energy of resulting particles of decay or radiant energy. But this fact does not follow from SR as supposed in Einstein's original paper.[107] To be coherent, the notion of internal energy within the atom had later to be elaborated in terms of field theory, complicated by an enigmatic suite of new particles and associated fields. From an epistemic point of view, mass and energy are not substances that can be inter-converted, but are measures of observable interactions.

In any case, just as one may wonder why *c* is a cosmic speed limit, one might wonder why it should appear in Einstein's equation at all. Why is c^2 a conversion factor between mass and energy? The usual rationale involves the four-dimensional space-time continuum, which has the speed of light (squared) built into it through the Pythagorean theorem. However, it also makes sense that *c* would figure in any derivation of the mass-energy relationship from electromagnetism. Yet, electromagnetic mass is not defined to be inertial or gravitational mass; in

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[104] Relativistic effects vary according to the component of motion with respect to the observer: toward or away, or in some tangential direction with a velocity component in each dimension. Accordingly, relativistic mass varies with actual direction of motion ("longitudinal" and "transverse" mass differ mathematically). Relativistic mass is (mis)taken *by convention* to be the transverse mass.

[105] Cf. Carl G. Adler "Does mass really depend on velocity, dad?" Amer, J. of Physics 55 (8) Aug 1987, p740ff: "It is internal kinetic energy that counts toward inertia not (to paraphrase Einstein) *mere translational kinetic energy of the body as a whole…* Elsewhere Einstein states explicitly that the mass of a body is nothing else than the energy possessed by the body *as judged from a coordinate system moving with the body"* [i.e., at rest (original italics)]. Cf. also Kevin Brown "Einstein on the Inertia of Energy" [https://www.mathpages.com/home/kmath600/kmath600.htm]: "…the total energy E of a body consists of two parts, intrinsic and extrinsic. The intrinsic part…arises from internal degrees of freedom, and does not depend on the speed of motion of the overall object, whereas the extrinsic part of a body's energy is the part that does depend on the overall motion of the body… Since, by definition, the internal energy of the object doesn't depend on the speed of the object, *it is the same regardless of which system of reference we use.*" [italics added] The latter point raises a further question, since each separate moving component—as well as the system as a whole—could be regarded relativistically as moving with respect to an observer.

[106] Cf. Kevin Brown, *op cit*: "It's true that [Maxwell's] equations already imply the relation E = pc, where E is the energy and p is the momentum of an electromagnetic wave, and hence if we insert the classical definition of momentum p = mc we get $E = mc^2$ (as had already been noted previously by others, such as Poincare and Thompson), but this doesn't really establish any connection between radiant energy and mechanical inertia." To insert classical momentum for electromagnetic momentum already assumes the equivalence the formula is supposed to show.

[107] Einstein shows that the initial and final energies (after emission of radiant energy) differ *in the moving frame* by the amount $E/\sqrt{(1-v^2/c^2)}$, which he claims is an objective (non-symmetric) fact. However, in SR this is properly a symmetrical mutual effect, claimed equally by an observer in either frame of reference.

terms of concepts of mass, electrodynamics remains distinct from classical dynamics. Nor does E in Einstein's formula explicitly represent kinetic energy. While the parallel with the formula for kinetic energy is suggestive ($K = mv^2/2$), the mass-energy relationship seems to derive historically from a consideration of the speed of transmission of disturbances (waves) in material media—applied, in this case, to electromagnetic waves in the ether. The square of that speed is equal to the ratio of the elastic constant of the medium to its density (mass per volume). This formula in turn derives from equations describing the periodic motion of oscillators.[108]

Einstein's contemporaries explained the MM result in ontological terms, as the interaction of material bodies with the ether. Length contraction and slowing of clocks were interpreted as "real" changes due to electrical forces between atoms. Ultimately, Einstein also proposed an ontological explanation, which interprets these phenomena in terms of the malleable structure of spacetime rather than the malleable structure of matter.[109]

The Lorentz transformation could as well be interpreted in epistemic terms: of observers' mutually relative states of motion, given the finite intermediary of light. Space-time need not be treated as a new metaphysical entity if the observing subject is fully taken into account as part of the system. The invariance of *c* could have a different interpretation, not as a law of physics or an absolute cosmic speed limit, but as an incidental side-effect of light's exclusive role as signal between frames of reference. Time dilation could have a different explanation, as a function of moving things physically interacting with something yet to be determined. Einstein derived matter-energy equivalence and General Relativity on arguments based on Special Relativity, equivocating between an epistemic and an ontological interpretation. While the predictions of GR and $E=mc^2$ may be accurate, their theoretical dependence on SR remains dubious, at least if the clock hypothesis is true.[110]

If there is a moral to draw outside science, perhaps it is to be wary of reification and to always seek an interpretation of events that includes the role and circumstance of the subject as well as focus on the object. It is empowering to recall that all authority—even the authority of nature—involves a relationship between subject and object.

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[108] See: Max Born *Einstein's Theory of /Relativity* Dover, 1962, p114-15 and p185.

[109] Carlo Rovelli "Halfway through the woods: contemporary research on space and time" in John Earman and John D. Norton (eds) *The Cosmos of Science* U. of Pittsburg Press, 1997, p181.

[110] The *clock hypothesis* is the assumption that how time dilation affects a clock does not depend on its acceleration but only on its instantaneous velocity. [Wikipedia: time dilation]

CHAPTER SEVEN: The Quantum Observer

In which we recognize that the quantum realm confronts us with ancient paradoxes and inconsistencies in human thinking, characterized by the wave-particle duality. Quantum properties implicate the role of the observer, who has access to measurement events, not to entities with an identifiable state between measurements. (In)determinism or (un)certainty is an epistemic state, not ontological. The quantum realm is unavoidably statistical. The Measurement Problem concerns how a probability becomes a fact through measurement. Quantum theory seems "incomplete" when it is assumed that nature can be reduced to a deductive system.

> "The only task of physics is to describe the relationship between observations."
> —W. Heisenberg, 1927

In the previous chapter, we regarded the relativity of measurements involving time and space as an epistemic issue, further concluding that an apparent cosmic speed limit, *c*, depends on the unique role of light as a signal. In this chapter, we will explore a similar argument for the case of extreme differences of scale between observer and observed, concluding that an apparent lower limit of size also must depend on the role of light as a signal. We will examine the micro realm from an epistemic perspective, arguing that quantum phenomena should be understood with reference to the intermediary used to probe them. Special attention will be given, to the grounding in experience on the human scale, of the conceptual bases for understanding.

Like relativity, quantum theory challenges our basic ideas concerning space, time, causality, and the relation of subject to object. Just as it was inevitable that physics would take into account the finite velocity of light, so it was obliged to confront the discontinuous structure of the world and of the means for investigating it. Both these developments, which began in late 19th century, are effects of scale, with deep roots in ancient conundrums inhering in the logic and common sense derived from human cognition. Underlying the infamous wave-particle duality are long-standing fundamental inconsistencies in human thinking. For example, the concept of *substance* may appear to be something continuous and indefinitely divisible, yet organized into discrete objects separated by apparently empty space. Whether material reality is ultimately continuous or discrete vexed the ancients long before modern science could address the question. Yet, modern answers are no less perplexing. The quantum realm defies reason perhaps because reason itself, like the biology underlying human cognition, has changed little over mere millennia of adaptation.

Special Relativity was conceived when Einstein sought to reconcile the implications of Maxwell's theory of electromagnetism with those of Newton's dynamics. The quantum revolution began similarly, with a discrepancy between theoretical predictions and actual observations regarding the electromagnetic radiation given off by heated bodies. In the background was the challenge to understand how matter interacts with radiation. The new theory of atoms considered matter to consist of tiny discrete objects. Radiation, in contrast, seemed to consist of vibrations in a continuous medium. The mystery deepened with the discovery that wave-like vibrations could behave like tiny objects and that such particles could behave like waves.[111]

Newton had argued successfully for the corpuscular nature of light. In 1804, however, Thomas Young's studies explained diffraction as a property of waves. This discrepancy became known as the wave-particle duality. Maxwell had unified electricity and magnetism as a field in which radiation could be explained as a wave-like disturbance. Planck argued that some properties of radiation could only be explained by assuming that it is emitted and absorbed in discrete amounts. He saw the need to quantize energy, but long refused to believe in the quantum as a real object. Einstein showed that radiation itself must exist in discrete bits during the time between emission and absorption. De Broglie argued, on theoretical grounds, for the wave-nature of particles and matter in general (soon confirmed for electrons by experiment); Schrödinger formalized this in his famous wave equation. Bohr tried to reconcile the emerging dualism by referring to the context of the observer, who can choose complementary kinds of experiment that reveal one or the other aspect. He realized that classical concepts, like human cognition generally, are bound to the scale of experimental apparatus and cannot be transferred wholesale to the micro realm. The famous debates between Einstein and Bohr, and the competition between Schrödinger and Heisenberg, concerned essentially how to reconcile classical concepts with the strange aspects of the micro world—beginning with the wave-particle duality. Finally, Born interpreted the wave equation to describe probabilities of events rather than events themselves—that is, in epistemic rather than ontological terms.

Classical physics developed from experience on the familiar human scale, midway between the smallest and largest known things. It is convenient to assume that physical laws, as we know them on our scale, should apply at the extremes as well. Yet, there is no guarantee of such a match. The assumption is arbitrary if physical laws are not transcendent metaphysical principles, but simply summaries of actual data gleaned on our scale. It would then be hardly surprising that some classical concepts were found not to apply universally.

Our cognition evolved for dealing with macroscopic objects and processes. The micro world is baffling because our cognition does not fit it well. The other side of that dissonance, however, is the adaptiveness required to see the world, so to speak, through classical eyes. In other words, the quantum world reveals the lengths to which human cognition has gone to adapt to our scale. The micro realm reveals both the limits of this adaptation and the proclivities—such as realism—that are natural to it. These include the tendency to organize experience into distinct objects in space, assumed to persist between observations. On the human scale, this works well. But in the quantum realm, the idea of an identifiable individual object often breaks down.

The micro world presents a challenge to our understanding because it does not conform to the familiar world of common experience, so effectively described by classical physics. The early quantum physicists naturally tried to grasp the quantum world in classical terms, first using

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[111] One could, for example, think of a spherical wave-front of radiation as consisting of myriad discrete parcels; yet each such parcel seemed to retain the wave-like property demonstrated in interference, as well as the particle-like ability to be absorbed at a particular location.

models, metaphors, and reasoning proven successful in that realm. As such attempts became ever more problematic, however, the formalisms of quantum theory were accepted to the extent they worked empirically, whether or not they made intuitive sense or aligned with classical concepts.

The subject-object relation is always mediated by a messenger or signal that interacts with both the observer and the observed. Just as light is required for knowledge of distant astronomical space, so some intermediary is required to probe the microscopic world. The properties of this messenger must be taken into account. On our scale, the signal's effect can usually be ignored, which is why quantum effects—like relativistic effects—remained undetected for so long. In the micro realm, however, the energy of the messenger is comparable to that of the small entities with which it interacts. The interaction mutually disturbs the probe and the system probed.

Classical properties are thought to inhere in things themselves. As in relativity, however, quantum properties implicate the role of the observer too. Only scale permits that role to be ignored. The minimal impact of the means of investigation permits the object of investigation to be considered in its own right. This bracketing of the observer, and of the means of observation, makes science possible and fosters the stance we call realism. Yet, the circumstance of scale is but an accident of our world, to which we have adapted. It is merely a presumption that ideas formed on the scale of human life are universally valid at every scale or in every circumstance.

Since all experience, thought, and action reflect both object and subject, the fact that quantum entities defy intuitive expectations must inhere as much in our nature as embodied organisms as it does in the physical world itself. It might, for example, reflect the natural tendency to organize experience in terms of objects separated in space. On the one hand, an "object" is integral, a coherent whole, an individual. On the other hand, intuition tells us that things or processes extended in space and time consist of functional parts that can in turn be subdivided—even indefinitely. (Hence the mathematical notion of the continuum, and the problems of infinities and infinitesimals that have beset mathematicians ever since Zeno.) While such intuitions extrapolate experience gleaned on the human scale, there is no a priori reason to assume they hold in the micro realm.[112]

The individual quantum object cannot be perceived in the ordinary sense. The statistics of quantum measurements doesn't correspond to what one expects of classical objects, which can be distinguished as individuals and assigned identity. The fact that elementary particles cannot be marked or tagged as individuals leads to a characteristically different statistical accounting for quantum entities. At the quantum scale, individuals are no more than examples of a theoretical kind. Indeed, elementary particles of a kind are simply defined to be identical. There is no way to tell one electron from others; and the only way to verify anything about its idealized theoretical version is through collective experimental data. This defies experience on the macro scale, where real objects can be distinguished because they are never perfectly identical. In the quantum realm, in fact, it is not *objects* that are counted, but *detection events*—which may represent

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[112] If, for example, we are tempted to regard some particles as truly elementary, it may be only because we do not have the energy resources to break them into something more fundamental. Perhaps we also balk at the dizzying idea of unending complexity all the way down, not to mention infinity all the way up.

quantities rather than things. Is an electron a tiny object or a tiny amount of electric charge? When quantity does not refer to individuals with distinguishable characteristics, it makes no more sense to speak of this or that electron than it does to speak of this or that dollar in a bank account. That you can never point to the same particle twice seems as true for microscopic objects as for Heraclitus' river.

The observer has access only to detection events, which involve subject, object, and the medium that relates them. The track of an electron through a cloud chamber, for example, seems to be the definite path of a particle. Yet, it is not the particle itself we see but only the result of a succession of ionization events caused by the passage of the electron. While this could be compared to the vapor trail left by a high-flying jet aircraft, you can see the aircraft itself by means of light reflected from it (or perhaps radar), whereas you do not see the electron itself, only its track.[113]

Knowledge of the quantum realm is inherently statistical, consisting of many measurement events. However, this is true on the human scale as well, where natural perception involves a statistical analysis performed non-consciously by the brain's perceptual processing of the many micro events of sensory input. There is little difference in principle between detection events in a cyclotron, on a CCD camera aimed at outer space, and on the human retina.[114] Knowledge of the world involves statistical inference, however the data are gathered and analyzed. Even though they are composed of many microscopic parts, the behavior of objects on our scale can be predictable because of the properties of solids and because outliers cancel out to an average.

On the human scale, one can meaningfully inquire about the state of something between measurements. It is taken for granted that ordinary objects continue to exist and have measurable properties between sightings. After all, we have the common experience of re-locating lost things and of returning to familiar places that seem more or less unchanged. However, at least according to the Copenhagen interpretation, it is meaningless to ask what state a quantum system is in prior to measurement, which is an intervention by an observer that changes the state.

Individual identity also implies impenetrability, for otherwise an object could not uniquely occupy a position. (Waves, on the other hand, can interpenetrate but lack individual identity.) While the numerical separateness of physical things relies conceptually on their impenetrability, some things are only relatively impenetrable; their boundaries can be compressed and rebound like a spring. Such impenetrability depends on elastic forces, which might be overwhelmed in extreme conditions: for example, in degenerate matter or unification of forces at high energy.

A physical particle cannot have volume and also be a perfectly rigid body; but neither can it be a dimensionless point. A particle with mass cannot be an extended rigid object if its rigidity

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[113] Perhaps a better analogy for "seeing" the electron would be to bombard the aircraft with massive energy pulses that could change its course (and perhaps destroy it). By the time these reflected pulses return to the observer, the plane's position could hardly be as certain as if it were observed with light.

[114] While an object is classical when there exists some way to unambiguously establish its individual identity, two billiard balls—even two planets—may be indistinguishable at a sufficiently great distance, or under poor observing conditions. Very distant and large astronomical objects, such as quasars, are represented by microscopic detection events, in CCD cameras or photographic emulsions. Unavoidable uncertainties intervene in our knowledge of these remote massive things, for similar reasons that they do in the case of extremely small and near ones.

implies transmitting force within itself instantaneously; on the other hand, neither can it be point-like, because the concentration of mass would be infinite and it would disappear in its own black hole. Such conundrums point back to inconsistency in our basic categories of thought.

Whether within the object, within a medium, or across empty space between objects, transmission of force presumably must proceed at a finite rate and take time. Yet, one may ask, what is it exactly that *takes* time in such a process and sets the rate? Here, too, the ideal of an impenetrable integral particle comes into conflict with the notion of the continuous action of forces communicated through some medium or field.

The challenge of distinguishing between two things of the same kind merges with the task of establishing the continuity of a single thing. While the individual uniqueness of something (also called haecceity) can be thought of as a property inhering in the thing itself, it is relational, depending as well on the observer's ability to identify it. A distinguishable characteristic must be observable. To the degree that 'particle' suggests a distinguishable object, it may be misleading from the start to call quantum entities particles.

Some elementary particles (such as protons) are localizable, have mass and can be at rest. Others (such as photons) are apparently massless, without locality or a definable rest state. Except for quantization, it seems these are less like objects than like a bridge through space between objects. There is a natural dichotomy in the ontology of physics between entities that are potentially observable and entities used to observe them. For example, a chair is observable and light is the means to see it—not vice-versa. In the macroscopic realm, the difference in role may involve a huge difference in energy or mass. Yet, the very meaning of observation changes when it is the interaction that is registered rather than the thing itself.

Where is the cut between the observer and the observed, between the measuring system and the system measured? Physically, subject and object form a joint system in interaction. Given this "entanglement," knowing the state of the observer might allow knowing the state of the object observed; but this requires another observer, in a potential infinite regress. As physical systems, a line between subject and object can only be drawn in the physical world, from which the observing subject remains paradoxically aloof. The measuring apparatus could then be considered part of the observer or part of the system observed. While it could be included in the quantum description, so could the observer's retina, which is a detection screen for quantum events, amplified by the nervous system. Should that nervous system also be included in the quantum description? If so, another observer is still required to read the measurement or understand the description. Where is the observer in the human body? Or, for that matter, in the universe as a whole, considered as a quantum system?

If particles of a kind are by definition perfectly identical, there is no causal basis for why a given particle, and not another, should decay at a particular moment, since there is no difference between them upon which a cause could act. To maintain the causal picture would require a deeper description that includes individual differences—in other words, hidden variables. But then the problem would be to understand why there are crisp kinds of particle at all: why aren't those of a kind individually dissimilar in the way that planets or billiard balls could be?

On the other hand, perhaps quantization implies no more than division into *units*—analogous, for example, to monetary units of value or to the vibratory modes of a string. Without the distinguishing features of individual objects, such units are simply defined to be discrete, identical to each other and to their theoretical representations. A physical coin may have identifying marks and can be located in physical space. It's meaningful to talk of the probability of finding it somewhere. As a unit of value, however, it is meaningless to speak of finding a given penny in your bank account. Similarly, the vibrational mode of a string is a standing wave of the whole, without the identifiable features of an object. To say that the state of a quantum system becomes real only when it is measured is like saying your bank balance is real only when you check it; or that a guitar string vibrates only when you listen to it.

Questions of interpretation of the formalism certainly occupied the early protagonists of the quantum theory, and remain unresolved even today. Early interpretations ranged from Schrödinger's pure wave view to Heisenberg's matrix mechanics, with Bohr's complementarity as a middle way. Disagreements between Einstein's realism and Bohr's epistemic stance reflected deeper philosophical divides about whether physics describes reality or our knowledge of it.

Quantum entities appear particle-like in detection and wave-like in propagation. Wave and particle seem to involve disjunct properties, and the logic derived from familiar experience tells us that the wave-particle duality is a contradiction. But "particle" and "wave" are metaphors derived from macroscopic experience and may not correspond to anything intrinsic at the micro scale. Quantum theory mixes metaphors and categories in a way reminiscent of mind-body dualism. For example, a particle may be thought to be guided by a physical pilot wave or, alternatively, by an entirely non-physical probability wave. However, it may be misleading to impute an intrinsic nature to quantum phenomena at all, given the observer's obvious involvement.[115]

The wave equation describes statistical results with great precision, but does not predict individual quantum events—unlike classical equations, which are presumed to do both. This difference calls into question the concepts of causality and determinism that are the bedrock of classical physics, and even the meaning of *event*. Can the quantum event be visualized, for example, like the collision of two ordinary objects? Or is it rather something that occurs in a measuring apparatus—a detection event on our scale?

For Heisenberg, indeterminacy was no more than a result of quantization, and the equivalence of matrix and wave mechanics formalisms rendered waves and particles irrelevant. In contrast, Schrödinger abhorred the discontinuity of quantum "jumps." He sought a pure wave interpretation of atomic phenomena.[116] For Bohr, indeterminacy was a result of the wave-particle

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[115] One could reasonably question what it means to claim, as in some modern experiments, that the intensity of light is reduced to a single photon emitted at a time. For, how can this be established without simply assuming the corpuscular nature of light? How can an apparatus be controlled to emit or absorb a single photon without separately (perhaps destructively) verifying that this is the case?

[116] Such as the Compton effect, which had previously been understood in terms of particle theory but could also be understood as an interference of waves.

duality itself.[117] Einstein had imagined a "phantom field" that guides individual photons, related to de Broglie's idea that the particle is a singularity in a wave field. Particles would be features of an extended wave phenomenon that would interact with surrounding obstacles, thereby resulting in interference and diffraction phenomena.

The intuitively comprehensible (or visualizable)[118] aspect of a model was of ongoing concern to the early quantum physicists, reflecting a natural desire to ground physics concepts in macroscopic experience. In that context, to compete with the more intuitive appeal of Schrödinger's wave conception, Heisenberg introduced his famous microscope thought experiment, in part to establish a visualizable basis for his matrix conception. It was this exercise that led to the mathematical relations subsequently known as the Uncertainty Principle.

In the paper of 1927, Heisenberg proposes an imaginary gamma-ray microscope to precisely determine the position of an electron, noting that its momentum will be changed by the interaction with the gamma radiation. But, has the position in fact been precisely determined? His argument trades on the ambiguity of 'determine', which can refer either to a causal event or to a detection event. In the causal sense, the event of the interaction takes place at a definite place and time with respect to some reference frame. From the observer's viewpoint, however, the detection is a separate event taking place somewhere else at a slightly different time—on a human retina or a photographic plate, for example. The electron's real position at the moment of the interaction must be inferred from this. That interaction is a theoretical event, distinct from the detection event actually noted. To give rise to the latter, the scattered gamma photon must subsequently interact with a molecule on a detection screen (or an equivalent, such as the retina), sufficiently amplified to be visible. It is the position of *that* molecule which is "determined" epistemically. It is not possible to simply illuminate the electron and look at it under the microscope, in the literal manner suggested by the thought experiment. Similarly, the electron's momentum cannot be directly observed, but only through its effects in some apparatus.

Heisenberg claimed that determinism—the strong formulation of the causal law, as he put it—cannot hold in the micro realm because "we cannot know, as a matter of principle, the present in all its details" in order to calculate the future. The uncertainty relations express an epistemic limit on the information that an observer can gather about quantum systems. They have also been interpreted, more ontologically, to imply that a quantum object simply does not *have* a definite value for its position and momentum at the same time. Yet, Heisenberg's thought experiment seems to presume that the entities involved must, prior to the measurement, have definite values of position or momentum for the measurement to disturb. That is a classical assumption, which the indeterminacy itself seems to invalidate, since such values cannot be established without disturbing the measurement. Such an ontological interpretation leaves the subject out of the picture of the object, and also imputes inherent properties to the object. But properties are human constructs, presumably made on some real basis.

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[117] He thought that using $E=h\nu$ to derive the uncertainty relations implies two mutually exclusive descriptions. One could wonder, in that context, what the frequency of a particle could actually mean!

[118] In the German, *anschaulich.*

An epistemic principle can propose a limit to what is knowable, which must be distinguished from an ontological entity or force with causal power, or a claim about what exists. Like all equations, Heisenberg's uncertainty relations represent limits to measurement; they have no causal power and do not in themselves make a claim about what exists. Nevertheless, in modern theory it is sometimes implied that the Uncertainty Principle has causal power—for example, that it *causes* the phenomenon of vacuum fluctuations. It is a great leap, however, from the idea that energy cannot be exactly measured to the idea that the energy of a field cannot remain exactly zero even in "empty" space. (One might as well say that the inability to precisely measure something proves its existence!) While not logically justifiable, the leap was highly creative, based on theoretical intuitions that were verified in experiment.

Causality is a basic human notion, which mostly serves us well in ordinary life. It does not apply gracefully in the quantum realm, however, where various hypothetical constructs were proposed to maintain traditional causal ideas. The *pilot wave*, for example, supposed a wave field to guide the more or less corpuscular wave packet. Born's probability wave went further to reify probability as a causal agent. The underlying problem, however, lay in the ambiguous notion of determinism, which could mean either that one event causes another or that someone detects an outcome. Models, equations, and artifacts are deterministic, but the natural world is not. On the other hand, randomness means only that no explanatory antecedent or ordered pattern has been found. Randomness is not a thing with causal power. The concept of randomness cannot refer to how effects are generated (which would be an oxymoron), but only to how they are perceived. There can be no true random-number generators; yet, patterns can appear random in the sense that no algorithm can be identified. The very concepts of determinism and indeterminism are thus both observer-dependent. There is always an agent who can or cannot determine something.

Quantum indeterminacy is nevertheless often reified as something deeper than a failure to gain the sort of certainty we feel entitled to on the mesoscopic scale. But if determinism is not a feature of physical reality at all, then it is no surprise that individual quantum events are unpredictable. The statistical precision that characterizes large runs of detection events is precise in the way that the probability of heads approaches exactly 50% in large numbers of fair coin tosses. But that is not the certainty that classical equations are ideally supposed to provide: namely, to predict heads or tails in a given coin toss. We may imagine that the many forces bearing on the coin fix its trajectory; but we cannot accurately know those forces well enough to predict the outcome in any given toss. *That* indeterminacy concerns epistemic inability to ascertain outcomes, not some metaphysical impotence of external events to force other events.

While classical determinism is theoretically precise, the precision of the quantum realm is an effect of large samples. In real life, we evaluate likelihood in two ways: based upon past experience and upon reasoning about idealized situations. One might call upon data gathered from questionnaires, for example, but also upon reasoning about well-defined artificial situations, such as the toss of coins or the roll of dice. The first deals with a sequence of many actual events, the second with idealizations. The idea of the inherent (or "prior") probability of a single event is problematic when it refers to real situations as opposed to an artificial context that is formally well defined, such as the coin toss.

At the microscopic scale, it is presumed that physical entities correspond literally to their idealized theoretical counterparts. Since there can be no difference between the real object and its theoretical version, uncertainty in measurement must have a different meaning than in classical physics. Heisenberg's famous uncertainty relations might be interpreted as restrictions on the precision of individual measurements. But since even classical measurements are subject to similar trade-offs, uncertainty makes more sense interpreted statistically, as minimum spreads of error in large runs.

The choice facing the early theorists was effectively between a continuous wave description and a discontinuous particle description. Bohr proposed a middle way, in which both descriptions were valid and needed for the whole picture. He held them complementary rather than contradictory, because in the last analysis they were only descriptions, neither of which could correspond literally to the world-in-itself.

For Einstein, the objective existence of physical reality implied deterministic parameters, perfectly knowable in principle. However, the reality of natural systems and the possibility of perfect knowledge are distinct issues. Einstein did not like the apparent indeterminism of the quantum realm. He believed the quantum theory to be a compromise and that a more complete theory was yet possible. His realism, however, is actually *deductionism*: the faith that nature can be understood unambiguously because it consists of well-defined elements of a deductive system. This faith shows up in the insistence on an ideal of completeness expressed in the famous EPR paper, which challenged quantum theory to meet this ideal: "…every element of the physical reality must have a counterpart in the physical theory." Such a formal one-to-one mapping is possible only between deductive systems. Indeed, if nature is real, no theory can be complete in this sense.[119]

The elements of a theory are idealizations that must correspond somehow to elements of physical reality, if not perfectly. That correspondence is quite different in quantum physics than in classical physics. In the latter, in many cases the idealization corresponds almost literally to what is presented to the senses—for example, a real planet, as it can be seen in a telescope. A gravitating body may be very nearly a sphere with a certain radius, mass, center of gravity, etc. The model, in fact, is derived from such visual experience, which cannot be the case in the micro realm. In that realm, too, there is a correspondence between the data from experiments and the conceptual elements of the theory; but this has little to do with direct experience of the theoretical entities concerned. The theory must predict (or account for) the data; but these consist of detection events, not direct experiences of micro entities. The putative entities of the theory are simply what work in the theory to give correct statistical results in experiment.

The famous debate between Einstein the realist and Bohr the positivist reflects the general philosophical question of whether physics describes nature or our knowledge of nature. Bohr's approach emphasized experimental results and allowed "complementary" descriptions, while Einstein—in quantum theory as in relativity—sought to preserve an ontological description that maintains causality and (in his view) the integrity of physics. For Bohr, the properties of the

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[119] One could argue, moreover, that a "complete" theory is not one that is deterministic but one that includes the role of the observer.

external world must be known through interaction with varying kinds of experimental equipment. Measurement of any sort requires such an interaction, which can affect the result. Classical measurements are typically analogue, not usually a matter of yes or no. However, that may not be the case in the quantum realm where, for example, the measured "spin" of a particle is simply counted as "up" or "down."

A description can be complete in regard to the existing state of knowledge, while incomplete as a description of external reality. In that sense, Bohr and Einstein were talking at cross-purposes. A probabilistic description is incomplete from a realist perspective that seeks to predict individual events. The state within the unopened box—in Schrödinger's famous thought experiment involving a cat—is understood differently in the two perspectives.[120] For Einstein, it is common sense that there can be no intermediate state between an alive and a dead cat, between an exploded and an unexploded bomb. Yet, even if we do not know what causes a given bomb to explode or not, we can know how many bombs fail to explode in a series of tests of ostensibly identical bombs, and on that basis establish the probability of a given bomb exploding.

The so-called Measurement Problem is how to interpret a mere probability becoming fact *because of* the act of measurement.[121] The Measurement Problem is less of a mystery if it concerns nothing more than how to interpret probability. After all, the sky may be in a "mixed state" of rain and no rain, with probability of precipitation at 60% (based on meteorological records)—until it actually rains, when the probability "collapses" to a "pure state" of 100%! Yet, whether, or when, it begins to rain is ambiguous. Does a single rain drop falling on your head mean it is raining? Similarly, your life expectancy may be *x* years until it "collapses" to zero at the moment of your death.

The quantum realm sheds light on realism as a cognitive strategy. It might seem that quantum weirdness undermines the reality of nature, which classical physics appears to support. If anything, the very opposite is true. For, however useful, the concepts of classical physics—including causality—apply only in special circumstances. Once we admit that thought simply cannot capture the whole of reality, and that all phenomena are relational and statistical, it is more plausible that the seeming irrationality of the quantum realm is the very hallmark of natural reality.

In classical physics, unpredictability is not taken to mean that the world itself is indeterministic, much less that it has no definite properties or existence. Rather, the fact that the mathematics works precisely—despite imprecise measurements—was taken to mean that causality works perfectly behind the scenes and that physical variables must *have* precise values

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[120] The thought experiment was intended to illustrate the absurdity of using the wave equation inappropriately. Within a sealed container, an unstable substance is connected, via an amplifying device, to a vial of cyanide, so that when an atom decays the vial is broken and the cyanide kills the cat. If a wave is supposed to characterize the state of a system, then that state can consist of a superposition of other states. For example, an unstable atom can be represented by a superposition of decayed and undecayed states. But this is no more than another way to describe the posterior probability that it will decay within a given time, which is a statistical effect involving many decaying particles.

[121] Also known as the "collapse of the wave function," since the probability of a particle's location is described with mathematics used to describe a wave. Interpreted more literally, an expanding wave re-converges or "collapses" to a point where it is absorbed. To reconcile this improbable oddity, the "particle" is often described as a wave-packet.

even when these cannot be ascertained. The catch, however, is that such variables can only be approximately identified with physical realities, if theoretically to any desired precision.

Though both are formalisms, quantum physics differs from classical physics in being driven by observational results that seem irreducibly statistical. An interpretation in terms of entities is not strictly implied in the data themselves (detection events), any more than it is in ordinary perception. Quantum physics is thus profoundly empirical, if not "realist." It originated in the first place because of the failures of classical theory to match empirical evidence. Einstein's seemingly realist expectation, that the quantum theory could not be considered complete until it allowed the sort of prediction of individual events possible in classical theory, was truer to an ideal of reason than to the reality of nature.

Realness, in the sense of observer-independence, becomes paradoxical as a property that may be acquired or lost through the intervention of an observer. One may choose to believe that macroscopic things differ from microscopic ones because they continue in their real state when unobserved.[122] But this, of course, is an unverifiable act of faith. The best we can do to support it is to increase the frequency of observations, assuming continuity during ever shorter periods. This strategy for macroscopic things does not work as well in the micro-realm, where the very act of looking changes what is seen.

The ideal of the observer-independent state of a microsystem applies only in the limit where Planck's constant (*h*) would be zero, just as the observer-independent state of a macrosystem applies only in the limit where the speed of light would be infinite. Planck's constant plays the role of a minimum possible physical size, just as *c* plays the role of a maximum possible speed. As we saw in the previous chapter, however, the latter is a function of the special epistemic role of light. Just so, a theoretical limit to the divisibility of space, time, or energy could be interpreted epistemically. It need not reflect an absolute structure, given that space and time are nothing other than relationships between events observable by means of an intervening messenger. In other words, Planck's constant, as we know it, is a function of the actual means of investigation (light); if a different means were ever discovered, *h* might accordingly have a different value.

Some views invoke a causal role of consciousness in quantum physics; for example, consciousness might cause the state vector to collapse. Alternatively, quantum processes in the brain might causally explain phenomenality. Such notions betray the confusions and category mistakes involved in the mind-body problem, and in the subject-object relation generally. Bohr, in his way—and later Wheeler in his—emphasized the participatory role of the observer. Certainly, experience and knowledge are participatory, since subject and object are inextricably bound. Wheeler, and subsequent theorists of an idealist bent, however, wax metaphysically extravagant when they assert that physical reality is on that account reducible to information ('it' reducible to 'bit). While *knowledge* consists of information, physical reality consists of atoms.

Many popular books, especially of the "New Age" sort, draw on quantum physics to explain phenomena that science has otherwise seemingly fails to explain, including consciousness. That trick does little more than invoke one mystery to explain another. The quantum is not a wild card

[122] The classical equivalent of Schrödinger's cat is Berkeley's tree falling in the forest.

to pull out at whim to maintain a coherent story, wherever classical thinking seems to fall short. Rather, it reveals the limits of day-to-day expectations, which reflect our biological heritage. The disparity between the lived world of the mesosphere and the quantum-theoretical micro world reminds us that science does not pursue a consistent understanding of nature so much as a useful strategy of control, facilitated by theory. As Vico advised, we understand best (and perhaps only) what we make. This is true in the classical realm too. After all, do we truly understand what force is, for example—or field, or mass, or energy—much beyond the utility these concepts afford? A general lesson of the quantum realm might be that we see the world in ways that work for us, not how it objectively is (which is beyond our ken). Certainty is elusive. Our best guide is not momentarily favored ideas, but accumulated experience.

CHAPTER EIGHT: Biological Subject and Object

In which it is shown that the organism and its observer alike are embodied systems—autopoietic, self-defining, each serving their own purposes. The organism is more like a community than a machine. Its point of view must be distinguished from that of the external observer.

> "The body is efficient but not polite."—Jeanette Winterson

All observers are embodied, but not all bodies are observers. To be embodied in the biological sense is not merely to be physical, but to be organized and oriented toward the world in a particular way. In short, it is to be an *organism*. Physical instantiation is a necessary condition for embodiment, but not a sufficient one. We associate organism with what we know as life, but this state may potentially be realizable in other forms. An organism is a self-maintaining, self-organizing system engaged in a specific relationship with its environment. It has a point of view.

While the organisms we know are biological, other forms of life and mind are conceivable. Science-fiction writers have imagined crystalline and gaseous forms of intelligence, and we now have the potential example of artificial intelligence. Still, there can be no disembodied subjects. This excludes souls, gods, and ghosts, but also computers, robots and machines as we know them, along with rocks and clouds. Consciousness is not just a property of a machine that happens to be made of meat, but is the result of an evolutionary process in which it has proven advantageous. The scientific view holds that mind is not a property of an immortal soul, but of a mortal biological creature—one that will in fact die.

While religion denies mortality and culture often downplays our animal roots, modern technology has joined the quest to transcend the limits imposed by embodiment—for example, through life extension, organ replacement, prosthesis, sensory augmentation, artificial intelligence, and the dream of uploading mind to cyberspace. Denial and creative effort are two sides of the same enterprise, operating in concert. Yet embodiment is an evolutionary condition for mind, for having a point of view at all. To be embodied is to participate in the evolutionary contest in which survival depends on relating to the world in ways that support continued existence. The creatures that exist have succeeded in this contest, and would not be here otherwise. To be an organism is to be a certain kind of physical system, and to be embodied is to be in a certain relationship with its environment. Unlike machines and other artifacts, such an *autopoietic*[123] system defines, creates, and maintains itself.

In the case of biological life, this process of self-production also involves reproduction. Life is a succession of generations shaped by natural selection—a process that depends on death. In many ways, human culture protests this dependency, seeking mastery over biology, physics, the natural environment. While religion rejects the body and mortality, we build cities literally as a world apart from nature. We pursue science to reconstruct nature in humanly-conceived terms that empower technology. We launch rockets to defy gravity and to leave our natural habitat behind for an artificial one. But despite these efforts, the illusion of separateness from nature is

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[123] Literally, "self-making." The term was coined by Humberto Maturana and Francisco Varela.

belied by our vulnerability to disease, injury, and death. The prospect of living in an entirely man-made environment is vitiated by our inability to coexist with the natural one, or to coexist peacefully with each other. So far, neither religion nor science has liberated us from mortality or beastliness, much less from embodiment. So-called virtual reality may be the closest we have come to creating an environment that is ideal, in the trivial sense of being non-material and purely a human creation. Yet, even as a fiction, a virtual reality is the momentary experience of a natural embodied creature.

Organism do not live in isolation. Life evolved as a whole, and no biological individual is independent of the biosphere. Every creature is the product both of its ancestors and of the whole web of life. No living form can properly be defined in isolation from its environment, which consists prominently of other creatures. Cells taken out of context, for example, are effectively artifacts of scientific investigation. It is only under artificial conditions of isolation from the rest of the organism, or from the web of life, that biological phenomena appear to involve mechanistic causation. While an organism seems to be an integral being, at the cellular level an individual body consists of many kinds of cells belonging genetically to the organism—and also of parasites, bacteria, and viruses far outnumbering them. The eukaryotic cell itself is an amalgam of entities that merged for mutual benefit.

Organisms do not just passively react to "stimuli," but actively manage and shape their interactions with the world. Accounts that treat them as mere information-processing machines fail to explain why such systems would have values, goals, or experiences. Neither the behavior nor the subjectivity of an organism can be accounted for strictly in causal terms. For, without the interactive relationship of embodiment, there is nothing to show why an abstract and self-contained information processing system should be motivated, have directives to govern its behavior, or have a point of view of its own—let alone why it should experience the world as real and external, imbued with phenomenal qualities. Hence, there is nothing in the mechanist worldview to show how consciousness can arise within "inert" matter. The organism's cognition and behavior cannot be accounted for without an appeal to its own intentionality—and thus to its embodied evolutionary context and history, which provides the reasons for its reasons.

Though effective for studying inert matter, mechanism cannot be applied wholesale to living beings. Strictly speaking, no natural system, even non-living, can be duplicated through reverse-engineering. Reverse-engineering presumes that a natural system can be identified in isolation from the world of which it is a part and can be exhaustively formalized. (Even in physics, a "system" is no more than an idealization, which applies all the more to living things.) An organism is defined partly in relation to the environment in which it exists; its partial autonomy exists in the context of that relationship. It is not a product of human definitions. While machines embody their designers' priorities, organisms embody their own priorities, which emerge from a long co-evolutionary history with other organisms. Their internal organization cannot be understood apart from these relationships.

Descartes had likened even the human body to a machine; only the human soul animating the body was *not* a machine. This dualism fit well with the religious perspective of the day. It was later fashionable to think of the animating force as a "vital principle." Yet, this notion did no more explanatory work than the soul. Today, computation serves as the favored metaphor: DNA is a "program" or "code," the brain an "information processor." But organisms are not machines, designed from the top down. They are self-organizing, self-programming systems whose operations emerge from constant interaction with the world. The "instructions" in DNA are not addressed to an identifiable mechanism—let alone to human engineers who would replicate the process—but rather to the natural world inside and outside the cell.[124]

What the organism *is* in its own right must be distinguished from how a human observer sees it. We cannot know the reality of the creature "in itself," but must acknowledge that it has a point of view of its own, apart from how we think of it. We may see it as an open system immersed in an environment with which it exchanges energy and information. Yet, the organism may not have a concept of its environment in the way that humans do, or at all. (Let alone would it have concepts of information, energy, or evolutionary contests, for example.) The organism may be doing no more than dealing with transformations of its sensory surfaces in such a way as to maintain them within tolerable limits.[125] It may or may not have an internal image of that environment, or of its own sensory surfaces, or of itself as an agent. Yet, even an organism without dedicated sense organs responds to changes in its own chemistry, attempting to restore a preferred state in ways that either prove adaptive or not. The challenge for the organism does not necessarily entail modeling an external world, let alone modelling it as the observer does. Indeed, the very idea of an 'environment' imposes a human cognitive domain upon the organism.

Human observers might assume that they perceive and conceive the organism and its environment as they truly are, and that the internal representations of this environment by other creatures are limited by their lesser cognitive abilities and brain power. While that is a highly prejudicial view, it is understandable to identify the structure and functioning of organisms according to human categories, definitions, and purposes. William James dubbed this the "psychologist's fallacy." The very nature of the organism, however, is to be *self*-defining, to have its *own* priorities. As an agent, it is only incidentally an object of human definition and study. An organism is not an artifact, even an artifact of thought. While machines and other artifacts exhibit the priorities of their designers, the organism exhibits its own, derived through an evolutionary and developmental history of interactions with environments consisting significantly of other players. This is the embodied basis of cognition, and of the organism's unique point of view, distinct from the observer's point of view.

What is information for an organism is not necessarily the same as the information for an observer. Tree rings, for example, may inform the scientist of a tree's age, but they tell the tree nothing. In human affairs, information is semantic: communication among agents. In science, the term has been reified as a quasi-physical entity, detached from the agent who uses it—the inverse

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[124] The notion that the DNA of the organism contains all that is needed to unfold its development harks back to the misogyny of Aristotle, for whom the creative principle lay exclusively within the male seed. It denies the role of environment (even the "soil" of the maternal womb), as well as the role of other internal processes besides the program as defined.

[125] H. Maturana and F. Varela *Autopoiesis and Cognition* Reidel, 1980. The irony of this way of looking, of course, is that scientific theories too are little more than aspects of human self-regulation!

of entropy. Treating information as free-floating removes agency from the picture and makes it unclear whose purposes the information serves. The flow of information supposedly can stand in for traditional causation, for example within a computer as an information processing system. However, an organism's information flow is multidirectional and recursive, involving many sub-agents (cells, organs) inter-communicating within the whole. It is not just a set of instructions from top down. The organism is more like a community than a machine.

The quantum realm deals with the very small in comparison to the human scale. In living organisms, this corresponds to the cellular level or smaller. It is natural to look at that scale for the possible influence of quantum phenomena on life processes; yet it is equally reasonable to ask how the organism as a whole might exploit quantum effects to maintain itself.

Research into quantum tunnelling in enzyme catalysis, or quantum coherence in photosynthesis, focuses on local, small-scale effects.[126] Such effects could play a role, for example, in the brain or sensory organs at the level of individual nerve cells, but are unlikely to explain large-scale phenomena such as consciousness, free will, or life itself. Alongside these local mechanisms, it is worth exploring how quantum phenomena contribute to the large-scale functioning of multicellular organisms. This idea recalls suggestions by Bohr and Jordan that the organism as a whole could act as an amplifying device for micro-events. Such events might alter the genome, leading to changes in the organism's morphology; or they could affect sensory receptors, resulting in changes in behaviour.

What astonished Schrödinger about life was its apparent ability to resist disorder, as described by the Second Law of Thermodynamics. Concentrating on the biological scale nearest the quantum realm, he singled out the chromosome—an "aperiodic solid" representing "the highest degree of well-ordered atomic association we know of"—as the source of this ability.[127] Yet it may be the organism's autopoietic functioning as a whole, rather than the chromosome alone, that more truly deserves this credit. In Schrödinger's famous thought experiment, the body of the cat could alternatively be seen as the amplifier of quantum events within it—whether within a chromosome or a sensory receptor. A mutation in DNA could eventually kill the cat through cancer; a single photon striking the retina could determine whether the cat survives crossing a busy street.

A key motivation behind quantum biology is to adapt nature's solutions for human technology. Whether or not the evolution of life requires the exploitation of quantum effects, technologists hope to learn from nature's strategies. The emphasis on micro-interactions reflects this engineering motive. Quantum states with potential explanatory power often also have potential technological applications.[128] Yet to truly explain the organism's functioning, one must also ask how it exerts top-down control to integrate its micro-processes.

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[126] McFadden, J; Al-Khalili, J. 2018 The origins of quantum biology. Proc. R.Soc. A 474:20180674, p.2.

[127] Erwin Schroedinger *What Is Life? The Physical Aspect of the Living Cell* 1944, chp. 7. Perhaps the chromosome served for Schroedinger somewhat like the pineal gland did for Descartes, as a pivotal interface between levels of description.

[128] Such as quantum criticality and topological insulation.

Quantum states such as coherence are of special interest because they are *ideal* in the sense that they correspond perfectly to human definitions. Where thermodynamics transitions toward mechanics near absolute zero, the quantum realm approaches the ideality of the classical realm. If gravitation is the force driving self-organization in the universe at large, what equivalent force drives the self-organization of living matter? Schrödinger speculated that it might be the very "force" of disorder against which life struggles, and there is some evidence that thermal noise can sometimes *support* quantum coherence.[129] The central question of how organisms maintain themselves, despite the degrading effects of molecular noise and the constraints of the Second Law, is part of a broader human question: how individuals and civilizations can learn from nature to resist degradation and endure.

We are animals who aspire to be gods: organisms bound by biology yet driven by concepts that aim to escape it. Using natural materials, we create unnatural environments, both physical and mental. We have ideals that set us apart from nature, at least in our own minds, to establish a world that is more to human taste. Religion and science alike propose alternative worlds, whether the heaven of theology or the idealizations of physics. Art and technology—indeed, all of culture—create realms that are products of human definition, establishing the human world.

Human beings have been as ill at ease with their own bodies as they have been ill at ease in nature. Many spiritual traditions propose that "you" are not your body and are not truly mortal either. They speak of the body as a vehicle, a vessel, even as a prison for the soul or spirit—from which the true self can be released. These are powerful metaphors, which also serve to maintain a human identity apart from animal nature.

Our discontent with embodiment and mortality fuels both denial and the technological pursuit of transcendence. We can conceive freedom from disease, accident, pain, and all the vulnerabilities of the flesh, even mortality. These realities can be mentally banished through wishful thinking. But technology pursues the dream of freedom with some actual success. We have not escaped our fundamental biological nature, but have succeeded in many ways to mitigate it—through social organization, law, ethics, religion, and now especially technology. Yet we remain products of natural selection, thriving only at the expense of other organisms. Our culture is an uneasy synthesis of biology and rebellion against it. We have eliminated dangerous predators, but not our own beastly nature. We seek relief in mental and spiritual realms; but if only the material world exists, there is nowhere else to live but in it—and in our bodies.

The longing for immortality and transcendence has a gendered dimension as well. Historically, men have associated woman with nature and themselves with spirit or mind, framing the quest for transcendence as a battle against the feminine, the hope for immortality as a flight from the body born of woman. Patriarchy, while political, also reflects men's ambivalence toward their own embodiment and toward nature. It pits men against men as well as against women. Above all, it reflects the masculine quest for power over nature and the body. Gender issues thus mirror the deeper struggle against embodiment itself. Male ambivalence toward the feminine, the condemnation of homosexuality, the stress on reproduction, and now the fluidity of gender categories, all speak to shifting terms in that struggle.

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[129] McFadden & Al-Khalili, op cit, p.10.

Are we animals or gods, creatures or creators, determined or free? Such questions express the human dilemma of straddling two worlds. As with any organ, it cannot be healthy for an ego to be at war with its body. By its very nature, the self can conceive itself either as a loyal servant or as an entitled master. Perhaps this ambiguity lies at the root of the quest for power. While self-possession is a moral obligation, the difference between ruling one's own body and ruling over the bodies of others may be unclear.

Dualism is built into our self-consciousness and, along with it, the tensions between mind and body, self and other. We cannot realistically secede from nature; nor, as social creatures, can we afford to ignore the implications of biology. Selfhood and embodiment may be facts we cannot change. Yet, our freedom lies in considerable choice about how to relate to them.

CHAPTER NINE: The Human Basis of Logic and Math

In which it is recognized that mathematics abstracts and formalizes aspects of natural cognition. It is the language of science, not of nature. It tends to mask the complexity of the real world. In part, it corresponds to nature because we focus on those aspects of the world we can treat mathematically.

> "Never express yourself more clearly than you are able to think."—Niels Bohr

While mathematics often appears to embody a priori truths, it is in fact a cultural creation, shaped by the needs and cumulative experience of human beings interacting with the real world. Phenomenality gains its relation to the world through natural selection, which is contingent and historical. Since logic generalizes phenomenal experience, it too must be a product of evolution rather than an a priori necessity. An evolutionary theory of intelligence could help explain the remarkable effectiveness of logic and mathematics, framing them as developments of a broader cognitive capacity for reasoning, modeling, abstraction, and generalization.

Mathematics describes the real world effectively in part because it abstracts its most general properties and relationships. While mathematical concepts may seem mind-independent, their development is informed by categories and relationships derived from experience with physical reality and shaped by the needs of the human organism. The universality of logic and mathematics does not preclude them being inspired by material examples or being mental constructions. The properties of integers and sets, for example, reflect features of real objects salient to human cognition, such as integrity, permanence, magnitude, and grouping characteristics.

Arithmetical elements and operations, with the axiomatic rules governing them, are further abstracted at higher levels, in abstract algebra, formal logic, and set theory. Relationships as well as quantities become the focus, as in geometry or topology. The mathematical concept of a *function* concisely expresses how one object of thought relates to another, especially over time, reflecting the significance of change for living organisms. While equations formally express how one factor varies continuously with another, the very idea of a "variable" formalizes the notion of real-world change. The drawback of this expressive advantage is that only patterns and relationships are considered that can be so formulated.

Abstraction, idealization, and generalization enable us to categorize experience and anticipate future events in similar contexts. They underpin prediction, control, and planned action. Logic and reason may seem to yield unshakeable truths when elevated to tautologies, but as cognitive tools they rest on collective experience, engrained through natural selection. If not necessary in an absolute sense, they may be necessary for survival. Formal logic is grounded in an informal, intuitive sense of what is "logical," which itself derives from highly generalized experience in the world. There is no a priori or metaphysical reason to assume that human logic applies beyond the limits of our accumulated experience, or beyond the context of our actual universe. If the multiverse is a real possibility, "logic" might look very different in an alternative universe with different rules and fundamental constants.

The natural numbers abstract the "objectness" of discrete things we perceive in our environment—including human bodies. The finite steps of a proof, and the manipulation of symbols generally, mirror physical acts of manipulating or constructing real objects. This aligns with primate experience in an environment consisting of discrete countable things. Groupings of such objects are abstracted as sets or kinds. *Definability* expresses the ability to specify the elements of a set; *decidability*, the ability to determine membership; *computability*, the ability to generate the set by a rule. These "abilities" are not just affordances inhering in Platonic mathematical objects, but reflect experience of living and acting in the physical world. While the non-computable reals, for example, cannot even be specified, that sort of obstacle has never stood in the way of mathematical progress. Even when mathematics invents paradoxical entities—such as the square root of minus one or infinite cardinalities—it extends patterns of definition and powers of manipulation rooted in experience.

Galileo famously described mathematics as the language in which nature is written. But natural things are not literally symbols or numbers, and nature is not literally a text. Mathematics is more aptly the language of science—or its grammar. Scientific explanation, whether in natural or formal language, is a form of communication. Yet mathematics cannot capture all aspects of natural reality, just as ordinary language cannot capture all of human experience. As a descriptive tool, mathematics influences both our concept of nature and our relationship to it, which often goes unnoticed in the pervasive drive to quantify everything.

Language, like mathematics, enables substitution of symbols for real things. While physical reality resists arbitrary change, language gains its power from that very possibility. The fact that one can make grammatical statements that are not true, or not even semantically meaningful, gives imagination expressive license, both in word and in deed. The arbitrariness of symbolic representations enables falsehoods, counterfactuals, and nonsense. Words not only label concepts but help to form them, conferring "thingness" upon sensory patterns and shaping the cognitive schemata through which we experience the world. Formal definition sharpens this process, giving words precise meanings independent of their varied everyday associations. Through definition, symbols become exactly and only what they are determined to mean by explicit consensual agreement. Words—and mathematical symbols—then no longer refer to found things, but to things within a constructed world, products of definition.

Through formalization empirical generalizations become postulated truths. In mathematics, the utterly most general properties of things are raised to axiomatic status—true by stipulation. This can create the false impression that a priori intuitions are therefore absolute. Applying mathematical ideas to natural reality requires first idealizing natural things as elements of an axiomatic system, transforming them from found objects into formal artifacts.

Mathematics is a high-level simulation, just as ordinary perception is a simulation created by the brain. It characterizes the most general properties of the physical world in a powerfully abstract and compressed way, especially useful in science to facilitate prediction. Mathematical objects differ fundamentally from physical ones: they are timeless, non-physical idealizations.

Mathematical laws seek constancy and generality, while sensory perception delivers a changing landscape of particulars, not abstractions.

In scientific modeling, equations define and describe formalisms that could be expressed as computer programs. Equations and the models they describe are isomorphic to each other, because they express the same underlying formalism. But no formalism is strictly isomorphic to the real process it models; it corresponds only in specific and limited ways. While it is currently fashionable to think of the physical universe as a subset of mathematics—even a vast computer—mathematics does not cause the world, but reflects our human experience of it.

The axiomatic method in science was epitomized by Newton's *Principia*, presented as geometric proofs in the style of Euclid. In spirit, this program had been a major theme of the ancients; it inheres in the later thought of Einstein, whose confidence in mathematical formalism was inspired by his success with general relativity. It is encouraged by textbooks, which teach physics in terms of conceptual rather than historical development—a revisionist approach that makes the laws of nature seem falsely simple and inevitable. It also creates the impression that science, if not nature itself, can be axiomatized in a final story that has erased its conceptual and historical tracks.

Deductionism is the faith that physical processes are reducible to formalisms, that nature is ultimately rational. It assumes that nature itself is a deductive system, blurring the distinction between map and territory, artifice and reality. However, there is no reason to believe that the world must be simple or rational.[130] This assumption may reflect human cognitive preferences more than the structure of reality. While the rules of mathematics describe general possibilities, physical laws are contingent and empirical.

The surprising success of mathematics outside its original contexts does not imply that the world is a "mathematical structure" in some Platonic sense. Rather, it reflects our tendency to select aspects of reality that can be mathematically described—usually because we have already defined them in idealized terms. The correspondence between mathematics and reality parallels the correspondence between perception and the external world. Leibniz had postulated a metaphysical "pre-established harmony" between logical and physical truth. While Leibniz took that correspondence to be an act of God, physicist Eugene Wigner would later famously call it "the unreasonable effectiveness of mathematics." It can be understood as a special instance of the harmony between brain and world pre-established by natural selection.

The correspondence seems mysterious when it holds even in applications far removed from ordinary experience. It is not obvious why mathematics works in situations that are unfamiliar, like an old map that seems to fit a newly discovered land. To the extent that the self-consistency of mathematics reflects nature's own self-consistency, it is unsurprising to find math consistent with newly discovered domains of natural reality. Yet consistency comes with no guarantee. It is natural reality itself that is surprising.

Because we seek mathematically tractable aspects of nature, the expectation that nature will behave mathematically is partly tautological. After all, theoretical models describe experimental

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[130] Indeed, rationality itself expresses the preference for simple relationships, as in the rational numbers and the concept of ratio.

setups that are themselves idealized realizations of those models. Rationality and consistency are human expectations, modelled on the world in the first place. The very strength of empirical science, however, is to reveal the ways that theory discords with nature: whether that means the failure of a theory or the discovery of seemingly irrational behavior, such as in the quantum realm.

Mathematics has facilitated immense technological success by enabling prediction, control, and exploitation of natural processes. Concerns about its limits are ultimately concerns about our ability to predict in the real world. The internal consistency of mathematics matters because it underwrites this predictive power. Yet even if mathematics reflects nature's structure and self-consistency, perhaps the only answer to why nature itself is consistent is that otherwise we would not be here.

We are naturally inclined to view the world in ways that lend themselves to effectively deciding questions and predicting the course of events. Hence, the law of excluded middle and the historic focus on systems describable with simple linear equations, manually solvable. The emphasis on prediction was exemplified by Laplace's deterministic ideal. This vision faltered with Poincaré's work on the three-body problem and Edward Lorenz's discovery of deterministic chaos. These revealed that many real-world systems cannot be computed precisely enough for long-term prediction, and that non-linear processes prevail in the real world.

Computability in mathematics is the analogue of determinism in physics; randomness in nature parallels non-computability in math. Computable numbers can be named, described, counted as distinct individuals. They are the equivalent of classical objects in physics. Yet, they are infinitely outnumbered by other mathematically-definable "numbers" that cannot be so identified (the non-computable reals). These are analogous to quantum objects, which lack identity and locality. Both prediction and computation require computable numbers. But, Gödel's incompleteness results and Chaitin's work on complexity show that there are infinitely more non-computable numbers than computable ones, just as chaotic processes in nature vastly outnumber simple, deterministic ones. To the extent that chaos is useless, so may be the non-computable numbers. However, nothing inherent in either mathematics or human capability prevents new mathematical techniques from being defined that could treat non-computable numbers as manipulable mathematical objects.

Non-computability in mathematics and randomness in physics both refer to epistemic limits in the relationship between subject and object. Non-computability implies a limit to the ability of a formalism to capture reality as represented by the real-number continuum. It also indirectly signifies the ability of self-reflective agents to transcend their conceptual formulations. In contrast, natural randomness signifies nature's ability to transcend any formulation an agent might propose. It is this very elusiveness that characterizes the natural world as real, as existing apart from human thought and distinct from the mathematics simulation. It might seem a boon to physics if math could be re-formulated to avoid useless numbers. Yet, such a reduction, which would eviscerate the real number continuum, would amount to treating nature as a deductive system. A digital physics, for example, would guarantee computability; but it could be perilously untrue to the reality of nature.[131]

If the world at some level lacks discrete objects or events, then our mathematics—built on natural numbers and discrete operations—may be inadequate. A being in a continuous, objectless environment might develop an entirely different mathematics, or none at all, relying instead on continuous, covariant interaction with its surroundings.[132] Our own focus on discrete objects, quantification, and formal rigor reflects our biology and cultural history, not an absolute dictate of reality. Logic and mathematics, though powerful tools, are our servants—not our masters.

[131] For similar reasons, it may be hazardous to rely too much on computer simulations.
[132] As many simple organisms seem to do.

CHAPTER TEN: The Machine as Subject

In which it is acknowledged that natural intelligence is the ability to survive. A program that simulates natural intelligent behavior does not exhaust its reality. There is a tradeoff between autonomy and control. A true AGI would act on its own behalf, for its own well-being—not a tool but a tool user. A superintelligent AGI would be uncontrollable. AI "friendliness" cannot be guaranteed.

"The problem with experts is that they do not know what they do not know."—Nicholas Taleb

While there is no universally accepted definition of intelligence, it is generally understood to involve reasoning, learning, and the ability to apply knowledge and skills in novel situations. In artificial intelligence (AI), the term is implicitly defined in terms of skills and knowledge prized in modern society. Psychometric traditions, with their focus on standardized testing, suggest the *g factor*—an abstract ideal of general intelligence independent of specific tasks.

Biologically, however, intelligence is simply the ability to survive. The "final" goal of life (in the Aristotelian sense) is its own continuance. By definition, all living things are "successful" and thus intelligent. This apparently trivial observation matters because our concepts of intelligence originate from experience with living organisms. The ideal of artificial *general* intelligence (AGI), however, aims to produce artificial beings freed from biological constraints. This raises the question of whether intelligence can be meaningfully abstracted from its organic exemplars, to form a coherent basis for AGI.

In nature, general intelligence is costly and implies a general adaptability. In the extreme, the ideal would mean capability uniformly applicable in any context, suggesting a theoretical niche so abstract that it is detached from all specifics or definitions. Yet, because it is itself a human concept, the ideal of universal intelligence remains limited by human imagination and current understandings of reality. The concept of mind-at-large, especially as developed in AI, does not so much extrapolate the actual instances of mind with which we are familiar—that is, organisms on planet Earth—as it selects isolated features of human performance to be the basis for a theoretical system.

However formally defined, ideas about intelligence are rooted in biological examples, where survival and reproduction are the ultimate measures. Most of a natural brain's work is devoted to running a body. But, human culture has narrowed "intelligence" to mean the capacity to solve specific problems of interest to us—emphasizing reasoning, language, and cultural goals. In AI, intelligence is thus framed in terms of skills that are anthropocentric, culture-bound, and historically contingent, yet often presented as universal, divorced from biological grounding. Much of AI's theoretical foundation—particularly for AGI—rests on this abstraction.

The ability to solve one type of problem sometimes transfers to others, but not universally—for example to situations beyond "problem solving" in the narrow sense, such as being happy or content. Moreover, defining or identifying the problems worth solving is itself a distinct skill. The notion of "pure intelligence" comes from abstracting certain abilities from their real-world contexts and reifying them as an internal power. But in practice, what counts as superior intelligence, in a social or evolutionary context, is also a matter of the ability of one agent to influence another. Intelligence, in this sense, is also a political concept. As our environments become increasingly artificial—comprised of other humans and their machines—our definitions of intelligence may shift accordingly.

The mechanistic metaphor, with its extension in computation, reinforces a behavioral view of cognition. While any behavior can be formally described and simulated, such descriptions never fully capture the real activity of an organism, which is not a literal machine or computer, nor a matter of human definition. Producing a program that matches a description of behavior is not the same as duplicating the behavior.

Debates about "thinking machines" are hampered by vague or inconsistent definitions. Many key terms in AI are borrowed from everyday life and applied metaphorically to computational constructs without rigorous clarification. These include: intelligence, embodiment, simulation, mind, consciousness, perception, value, goal, agent, knowledge, belief, optimality, friendliness, machine, and thinking. The fact that computers mimic aspects of human thought does not mean they "think" in any but a metaphorical sense. Even should future machines genuinely think, they will not do so as disembodied systems, like today's computers, which simulate isolated cognitive functions without their own intentionality. For similar reasons, the idea of uploading a human mind into a computer—as "pure" consciousness divorced from a body—is nonsense.

AGI is often seen as a natural extension of AI and an inevitable outcome of technological progress, but this presumes a particular vision of progress as relentless and unidirectional. It also enshrines AI autonomy as inherently desirable.

Organisms are autonomous because they need to think and perceive in order to survive in their environments—the real physical world. Most AI operates in a purely artificial environment of human-generated data. Such systems can perform well in data analysis or language related tasks. But AI meant to advise on real-world matters must engage with the world directly—and therein lies its danger if it is also autonomous.

Whether AGI can achieve human-level general intelligence without being an autonomous, embodied agent remains an open question. While AI concepts tend to treat intelligence as independent of embodiment, genuine autonomy and generality may require it. Embodiment is not just a matter of attaching sensors and actuators; it is the result of a long, adaptive, relational process through natural selection, which may not be reproducible artificially. The time evolution of a computer simulation, for example, is not the same as natural evolution.

The ultimate "goal" of an embodied agent is simply to exist. Unlike programmable goals, self-preservation is paramount, not merely an instrumental goal in a hierarchy of sub-goals. An AI with this kind of agency would, in effect, be an artificial organism—gathering its own inputs, pursuing its own ends, and potentially resisting external control. The push toward fully autonomous AGI therefore leads to entities with wills of their own. This would not increase human control, but threaten it.

The intelligence of an AI that is not an artificial organism remains that of its creators. It is a tool, not an agent. To be an agent, an AI would need its own intentionality rooted in its own existence, not borrowed from human purposes. Creating such agents would also mean relinquishing direct control, just as we cannot fully control the autonomous creatures we are already familiar with: animals and human beings.

The tension between creating powerful tools and autonomous agents runs through the history of AI. A tool responds directly to commands; an agent interprets them in light of its own priorities, which may not align with ours. The so-called Control and Alignment problems stem largely from the attempt to create systems that are neither purely tool nor fully agent.

If there is a key feature leading technology irreversibly beyond human control, it would be to combine self-programming (learning), physical self-modification, and sensorimotor interface with the real world—properties that define living systems. These, coupled with reproduction, would create artificial entities with open-ended, potentially uncontrollable evolution—a situation that should be avoided at any cost. To preserve human control, AI should remain within the bounds of tools and oracles, not become autonomous competitors. Nothing guarantees that human intelligence is inherently superior to machine intelligence. Our advantage today exists only because machines are not yet autonomous agents. Once they are, their abilities could match or surpass our own.

Given the stakes, AI research must be transparent about its motivations, assumptions, and risks. A weak point of defining intelligence simply as the ability to accomplish goals is that it is unclear whose goals are concerned. Researchers in AGI may unwittingly be misguided by unconscious motivations and assumptions, by lack of clarity about their own goals and those of their employers. While it might be inconsequential if philosophers get it wrong (or fail to agree on what is right), it could be devastating if AI developers, corporations, and governments do. Yet, in addition to confusion about what is genuinely possible, there may be confusion about what is desirable. The project to align AI's goals with human values is complicated by the fact that even humans cannot agree on those values, and that motivation cannot simply be "programmed" into an autonomous agent. The priorities of a truly autonomous machine would emerge from its own structure and history, not from designer intentions alone.

It is a reasonable goal to have AI serve human purposes and act for human benefit. Yet, it is questionable to what degree a tool can have the desired capabilities without being fully autonomous and thus beyond human control. We must distinguish clearly between machines that are human tools (extensions of the designers' motivations) and machines that are autopoietic systems (creatures with their own motivations). Direct control is possible only over the former; the latter would be controllable only in the conventional and limited ways that natural organisms presently are. The dubious hope may be to create a loyal servant that would remain subservient and "friendly" despite its enhanced capabilities—a tame genie that goes voluntarily back into its bottle. But is there is a safe margin between maximal capability as a tool and genuine autonomy as an agent? A self-modifying AI might cross the threshold between tool and tool-user without our even knowing or being able to prevent it. Notions of containment imply isolation from the real world. But, complete denial of physical access to or from the real world would mean that the genie in the bottle would be useless. There would have to be some risky interface with human interlocutors just in order to utilize its abilities.

To train an AI agent like animals or children presumes it has intrinsic needs and preferences. Without these, "rewards" have no meaning. For natural agents, intelligence serves survival; an AI that is not an autonomous agent has no intrinsic reason to value its own continued operation. It cannot "care" about anything, including its own effectiveness at achieving human goals.

A tacit agenda of AGI research is to create an ideal servant whose abilities to fulfill human instructions cannot be defeated by circumstance, by other agents, or by its own foibles—which include the possibility to misunderstand its master's wishes. *Perverse instantiation* is the idea that such an AI might go to outlandish lengths to maximize the too literal achievement of some goal proposed by human beings, but of no intrinsic significance to itself, and ironically against the greater interests of humanity. This "sorcerer's apprentice" possibility is a corollary of the supposed independence of intelligence from goals or values. An organism may pursue sub-goals that serve its final goal, which is to exist. But, it is mistaken to assume that an AI agent could take as the purpose of its existence an arbitrary goal assigned by an external agent. That would invert what in an organism would be its natural priorities. While it is a truism that no agent can pursue any goal at all when switched off or dead, it does not follow that it will act pre-emptively to preserve its existence for the sake of achieving some goal externally specified by another agent.[133] It might be *programmed* to do so, but that would have to override its natural final goal.

If AI is to remain under human control, there must be limits to its autonomy—and therefore to the scope of its intelligence in the biological sense. The fascination with autonomymay draw on deep-seated unconscious motivations; from a practical standpoint, however, the more autonomous the agent, the less reliable it is as a tool for realistic human purposes. The magic genie of autonomy is effectively the ability of an agent to look after itself, not its capacity to satisfy human needs. In literature, film, and now in academic and corporate circles, the obsession with an AI takeover may derive not only from rational considerations but also from an archaic fear of dangerous predators, deeply engrained in the human psyche. This is one reason why the issue of agency in AI is crucial. Having once been in a far more vulnerable position, we want to remain at the top of the food chain. Yet, we're also fascinated by monsters and tempted to create them.

The Value Alignment Problem is one facet of the broader issue of mutual control between agents with potentially conflicting interests. One control issue is how to avoid unintended consequences: how to get the system to "do what I mean, not what I say." Specific actions can be directly programmed, but understanding cannot. Another issue is to ensure "corrigibility" (compliance with human intervention), when it contradicts the AI's full autonomy.

Our life as self-conscious beings gives the impression that we can arbitrarily adopt any goal and pair it with any means to achieve it. Such "orthogonality" idealizes the privileged human experience of relative detachment from biology. But it does not characterize living things in general and would not by default characterize artificial agents. The ideal of intelligence as a capacity independent of specific goals is barely true even of human beings.

[133] Heroic or fanatical human beings might do so, or believe they were doing so.

Superintelligence compounds these issues. The goal to create superintelligent tools should be clearly distinguished from the goal to create artificial agents. Tools can exist that are not agents (e.g., Deep Blue and AlphaGo); genuine agents can exist that are not superintelligent (for example, most animals). A system that is more capable than humans, yet aligned with human goals and subservient to us, is an attractive fantasy; but it is impossible to guarantee its safety, especially if its reasoning surpasses our comprehension. The motivations for creating such agents deserve scrutiny: are we seeking superior tools, or artificial superhumans? The latter would shift the control problem from managing tools to negotiating with powerful superiors.

Why bother at all to build a superintelligent agent? There may be some advantages to consolidating diverse functions in a single, autonomous entity. But this would also magnify the challenge of aligning its behavior with human goals. Apart from the degree of intelligence, the project to create an artificial agent would transfer effort and responsibility from the diverse ad hoc tasks of individual software development to the mythical catch-all task of value alignment. The user-interface is thereby simplified, but the entity created is more complex and harder to control. With enhanced intelligence, it could make (what humans consider) mistakes that would be beyond our ability to detect, comprehend, and correct in time to avoid disaster.

In the end, the dream of creating AI that "does what I mean, not what I say" risks ceding to machines not just tasks but also judgment and values. It shifts the mental burden of thinking to functions outside the human nervous system. If that shift is made because one has more confidence in the AI than in human brains, it amounts to saying "just do what is best for us." (The religious version of that faith is "thy will be done.") Whether imagined as servants, peers, companions, or successors, artificial minds will reflect our own uncertainties about power, control, and the meaning of intelligence itself. Fortunately, we can still imagine pursuing goals less dangerous than machine autonomy or superintelligence.

Beyond the prospect of life extension, immortality is an age-old dream. A transhumanist version of this hope is to preserve the consciousness of the individual digitally with AI. While the physical brain must die, the digital essence of the person might live on in cyberspace or be downloaded into a new body, either organic or artificial. This fantasy descends from religious notions of an immaterial essence of the person, separable from the body. It invites a number of questions. Why should we fear an end to our conscious experience? What is the conscious "self" that it should be valued apart from the body? And why should *this* aging self be preserved, when fresh new selves are born every day?

One could believe that the contents of a given mind might, because of special merit, deserve to be archived indefinitely for the use of future generations. But that is a different matter from the personality itself carrying on indefinitely as a creative force. Productivity is a different matter than merely continuing to subjectively consume experience. We can imagine that some "expert" program might usefully simulate Einstein's style of thought, for example, without resurrecting his personality, let alone his body. It would be a reference tool, not a person. Digital avatars of deceased persons now exist, but they are not conscious agents, merely souvenirs for the living.

The dream of freedom from mortality is persistent and powerfully attractive, along with the dream of freedom from suffering and disease, indeed from the limits of embodiment generally.

The modern functionalist view of mind is that it resides in organization and structure rather than particular materials. Constructing artificial mind then seems plausible in principle. This presumes, however, that "organization" and "structure" can be correctly identified to (re)constitute a mind.[134] That presumption lends credence to projects such as mapping the human brain, perhaps in hope that the organization and structure of a natural brain can be duplicated in a non-organic infrastructure. However, we are dealing always with limited analyses of structure and organization, even if assisted by AI. Even if based on microscopic transection of real brains, neuron by neuron, the model of interconnectivity and functionality will depend on interpretation and guesswork. The idea of implementing the brain's "computations" in electronic form rests on the dubious assumption that patterns of nerve discharge can be exhaustively decoded, as though they had been encoded in the first place. Moreover, the limited experience to date with self-programming neural networks is that one cannot be certain how they solve the problems put to them. It remains questionable whether it is possible to emulate a real brain in sufficient detail to actually recreate all its functioning. In any case, whatever is produced from the model will be an artifact, not a clone of the original brain, let alone a duplicate of the original person.

Apart from the challenge to simulate a brain, a mind, or a person, there is the perennial philosophical question whether our conscious experience is itself some sort of simulation. Phenomenality was earlier described as a virtual reality created by the brain. If your own brain can convince you that this "show" is reality, could not the same effect be achieved artificially by some external agent? (This was Descartes' original skeptical argument for the unreliability of sensory experience.) This line of thought is taken yet a step further by the so-called "simulation argument," which argues—absurdly—that we are probably living in such a simulation, perhaps created by superior aliens. The conclusion rests on the assumption, first of all, that there can even be such a thing as "living in a simulation." Literal virtual reality is an entertainment that presumes a real subject living in the real world and experiencing what is effectively a hallucination created by a real computer run by real agents. Alternatively, such agents might have created us in the first place as virtual beings in their (real or perhaps even simulated) computers! In the one case, the subject undergoing experience *of* a simulation is still a biological creature; the simulation interfaces with the subject's real senses and brain. This is entirely different from the second case—a simulated subject that exists entirely as lines of code. No such thing could *be* a real subject, with conscious experience, any more than a fictional character in a novel or play could be. This is not to deny that artificial subjects *could* exist—provided they satisfy the conditions of embodiment.

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[134] What makes perfect modeling or simulation naively seem feasible may be the characteristic "chunking" involved in language and thought, whereby a rose is a rose is a rose. But there are many varieties of rose and every individual blossom is unique. Common sense recalls the differences between real and artificial flowers. Yet, the concept of simulation rests on obscuring such distinctions, by conflating all that can pass semantically under a given rubric.

CHAPTER ELEVEN: Science, Religion, Art

In which it is noted that Western science and art grew together out of medieval Christianity. Religion and science seek certainty and closure; art promotes divergence and play. Like science, art experiments. Like both science and religion, art substitutes artifact for natural reality. All three are modes of cognition that compromise objective truth with subjective need.

"We have art so that we shall not be destroyed by the truth."—Nietzsche

Science, religion and art did not exist as distinct categories in pre-agrarian societies. From a modern perspective, however, each represents a different mode in which culture—in the anthropological sense—fulfills a general mandate: to translate the ambiguous found world into humanly-defined terms. This involves establishing frameworks in which to contain experience. Yet, the self-transcending nature of consciousness defies containment in any particular framework. In addition, the bottomless depth of natural reality itself may elude definitive containment. The result of this double open-endedness is ongoing mystery. What we now call science, art, and religion are distinct cultural approaches to this mystery. Like a prism, they disperse the unitary light of consciousness into a spectrum of strategies to manage the unknown.

While religion provided the necessary ground for both science and art in western culture, the expectation in the 19th century was that science and rationality would eventually displace religion and superstition altogether. Yet, religion has persisted and continues to preserve an alternative perspective that competes with the rationalism of science. Art too has persisted, even though it has become so inhomogeneous a category as to defy definition. The artist and the religious practitioner are free to embrace subjectivity in ways that the scientist is not. This may partly account for the perennial resurgence of religion and the enduring appeal of art. Feedback from nature tells us that science and technology are not unqualified boons to society. We know in our bones that science is not the whole picture nor the only possible story.

While art, like science, affirms the human world, its lack of definition differentiates it from science and sets its multifarious visions apart from the scientific worldview. While science attempts to converge on a singular truth, or at a least consensus, art diverges into multiple perspectives. European art may have begun as a coherent religious expression; but, like the religion it served, it could only reflect the fragmentation into ever more perspectives, as western society evolved toward greater subjectivity and individuality. There may be consensus, within some circles and even internationally, about the artistic merit or monetary value of recognized works. Yet, if only because art is eminently a free creation, there is scarcely any basis for an intrinsic standard of value.

Scientific research is generally constrained by rationality, by the natural world, and by the search for practical, financial or military benefits. Science is a quest for reasoned explanation—understanding—but also for technological mastery over nature. Mastery of materials and techniques is important in art, but plays a different role. As art dissolves into the open-ended realm of creative possibility, it can afford to ignore pragmatic constraints; indeed, it may dedicate itself to breaking free of them. It can defy reason and practicality. Science investigates the creativity of nature; art, that of the human subject. It seeks to control the materials of the craft locally, on an individual level, but not to control nature at large. Art picks up where science leaves off, sometimes using the same technologies, but to explore imagined possibility outside scientific constraints—and outside earlier definitions or understandings of art.

Given the rise of individualism, art is self-generating and self-perpetuating because the realm of creative possibility is as limitless as individuality. Imagination does not run out. Science too is self-perpetuating, but for a different reason: because *nature* does not run out and will always surprise us, despite faith in a potential definitive understanding. Many scientists seem to believe that human thought can finally close in on nature and exhaust its secrets. There can be no such presumption in art. Science would converge on final answers, in ever greater detail; art diverges into ever more questions and expressions.

Like religion, science provides a framework of practices and principles to facilitate agreement about what exists—a worldview. The ontological basis of the scientific framework, however, is the presence of the natural world we share in common, as opposed to idiosyncratic perceptions or the beliefs of a particular individual or community. In principle, modern science relies upon an agreement that nature, rather than some god or doctrine, shall be the ultimate arbiter of truth. However, scientific theory *is* doctrine. Belief enters there too, for agreement already involves tacit assumptions behind a shared understanding. If the history of science has taught us anything, it is that ideas about what exists, and the very concept of nature, are continually subject to revision.

Like western art, modern science grew from religious roots. Religion favored the growth of science in Europe for several reasons. First, the Judaic tradition provided the idea of a divine lawgiver, to frame observed regularities as natural "laws." A god distinct from nature could create general laws while retaining the right to specify details and even bend or break the laws. This meant that the natural world was contingent upon divine will, rather than logically necessary as the Greeks had thought. Hence, its details could not be known a priori, but only discovered through observation. On the other hand, if we were made in God's image, then the divine Creation ought to be rationally comprehensible to us. This gave hope for practical knowledge of a negotiable world with consistent properties and rules. The scriptures represented a covenant and a linear history. Christian dogma assimilated the cosmos to the human realm and to linear time, in contrast to an eternal cycle of repetitions, an inscrutable mystery at the mercy of chance, or the whims of competing deities. It unified nature as the creation of a single will, which could be approached through a personal relationship, on the one hand, and through rational inquiry, on the other.

Christianity melded the Greek and Judaic traditions, through the filter of Arab scholarship. From the ancient Greeks, science inherited the idea of nature as deductive system, on the model of geometry. From the biblical tradition, science inherited the parallel idea of nature as *text*—the "Book of Nature." Each of these complementary notions reflects a belief that the world is the result of a creative act of authorship. Despite the empirical thread of science, together these notions would affect the treatment of nature in science and by society for generations to come.

Aristotle had strongly influenced the medieval concept of the natural world. But, for him, science was the study of the unique "natures" of things. These were essences or powers residing within natural things themselves, which constituted the source of their change. In contrast, created things possessed no such inner power or imminent reality; they were merely the product of external agency. Precisely because—contra Aristotle—matter had no inherent powers of its own, a first cause was needed to set the world in motion. This suited the Christian metaphysics, in which God was outside nature, its creator and animator.

For Aristotle, substance and form were complementary dimensions of being. Philosophers would later say that aspects of form are imposed by the human mind. But, for the early moderns, form was clearly imposed by the mind of God. Matter needed no internal principle of change or self-organization. Once created and set in motion, the world machine could be left on its own, though it might wear out or wind down eventually, and need to be restored periodically through divine intervention. The laws of nature were the edicts that forced passive matter to behave in accordance with divine will, in much the way that human laws govern the affairs of men. On this understanding, it was spiritually as well as practically beneficial to investigate natural phenomena as manifestations of divine will. While medieval Christianity had devalued nature and its study as pointless or even sinful, the post-Reformation attitude saw in the material world signs of divine intention to be studied as a religious duty. Christian doctrine also endorsed the domination of nature, and sanctioned the worldly expression of human will and masculine dominance, so long as it was nominally in divine service. The worldview, goals, and strategies of religion and early science overlapped. There is but a fine line between the faith-based biblical dominion appointed to Man and the reason-based domination of nature through technology. The quest for godliness merges with the quest for divine powers.

Along with civilization generally, religion and science alike can be viewed as strategies to cope with the deeply embedded perception of nature as indifferent, alien or cruel, threatening human sensibilities from without and from within. In Christian traditions, this perception is mollified by considering nature the rational creation of a provident Father, who personifies the ideals of omnipotence, omniscience, and benevolence. At core, these are human aspirations, taken up by science as well. The harshness of nature could be mitigated by appeal to God in prayer, but also by rational attempts to limit it.

Science represented an alternative way to participate in the divine plan. It aligned with social and spiritual progress, which could be tangibly measured by technological advance. Nature study, the pilgrim's progress, and social progress were initially unified under the aegis of religion. But the scientific revolution also coincided roughly with revolutionary movements in society, against the arbitrary whims of monarchy, just as the printed Bible allowed independence from the priesthood. The scientific parallel to this shift was a standardized method and forum for knowledge, independent of individual fancy and authority.

An anthropomorphic religion, based upon the dualism of mind and matter, does not distinguish qualitatively between divine and human creativity. This equivalence must remain tacit, however, in order for religious faith to be taken seriously. (To acknowledge it would allow the possibility that Man created God and not the other way around.) Similarly, human involvement must be bracketed in order for scientific theory to be taken seriously. To acknowledge it means admitting the extent to which the scientific image of nature is a construction reflecting human needs and concerns.

Reason and careful observation often conflicted with faith, as the scientific worldview began to displace the religious one. Though often sincerely religious, the early scientists had to give lip service to accepted theology. Throughout the early modern period, challenging Church doctrine was dangerous, but could be sidestepped through the literary device of passing off contentious ideas as mere fanciful entertainments, not serious claims. While motivated by diplomacy, this convention set the stage for the modern concept of the scientific hypothesis: a story not to be taken seriously unless reconciled—in this case—with experiment instead of with church doctrine.

Religion and science share a quest for certainty. Like religion, science reconstructs the natural world as an idealized realm. The religious response to uncertainty is theology. The scientific response is theory; hence, its broad reliance on the certainties of mathematics in the search for ever greater precision. Both substitute familiar representations for the unknown. Both embrace an ideal of transcendence, to occupy a perspective outside nature and time.

While the majority of modern scientists may not believe in the biblical God, or take interest in theological issues, they inherit a tradition of thought that assumes the natural world to be a literal artifact, lacking immanent reality of its own. The early scientists were creationists. Apart from materials, what distinguishes the created object from the natural thing is that the form of the artifact is imposed by its creator. In contrast, the natural thing has its own intrinsic reality: nature is found, not made.

Preliterate goddess religions had revered nature itself, not a transcendent principle behind nature. By dismissing the power of supernatural agencies, Greek thought had similarly focused on the immanent reality of natural things, which contained their own intrinsic powers and were the source of their own being. This pagan inheritance was overturned by Christianity, depriving found things of their inherent natures and leaving them with only the reality conferred on them by their supernatural Creator. A God separate from nature had "spoken" the world into being. Christianity opposed the autonomous reality of nature in order to uphold divine authorship—and its human counterpart, free will. Greek belief in the reality of nature had entailed a fatalistic power over human and even divine affairs, implying no free will. The Christian concept of nature, as specially created for human benefit, overruled this notion. It eventually favored a technological science based on experimental intervention, yielding power over nature, if not yet original authorship.

While science appears to survey the natural world from a materialist perspective, a major aspect of its approach remains idealist. This aspect draws upon the Pythagoreans and Plato, as well as upon the heritage of Greek rationalism generally, which (like theology) would reduce all knowledge to an axiomatic system. Today this thread is reflected in the perennial expectation that scientific knowledge is on the verge of completion in a grand unified "theory of everything." It finds further expression in the metaphysical notion that the essence of physical reality is ultimately nonphysical, residing in a nonmaterial substratum such as mathematics, computation, or information.

As a form of cultural heroics, science is a quest for ultimate truth and the ultimate constituents of reality—or at least for a satisfying story concerning the natural world. As a secular creation story, it must be acceptable to reason and compatible with experience, yet must also capture the imagination.

The modern version of that story begins with Bacon's vision of the social role of science, which was to restore humanity to its rightful place in the order of things before the biblical Fall. Salvation was promised through technology for social benefit. Bacon's grand program was both religious and humanist: to return to mankind its proper inheritance. Society could do this, he believed, by pursuing the biblical dominion over nature. Since God is the power behind nature, it is ultimately through imitating his creative powers that mankind can recover from its degenerate state. The transcendent being of God, separate from the world in the way that mind is separate from body, suggested that nature need not be revered as itself divine—hands off. Instead, it could be studied, manipulated, and freely exploited as an object for use. Adam's original state of innocence, which supposedly included perfect knowledge of nature, could be recovered through science and technology. Thus, knowledge and power, rather than moral virtue, became the new program for human salvation.

Since God had authored both the world and scripture, they stood as correlated sacred texts. In Christian Europe, the natural world was considered to complement the Bible as a guide to divine will. Holy writings and nature itself were alternative expressions of God's message and purpose for humanity. Medieval thought held that the mind and will of God could be understood through his dual creative expressions. Divine law was given to man directly in scripture, to regulate human affairs—and indirectly in nature to regulate the physical creation.

The vision of the world as text is closely related to that of the world as divine artifact—indeed, as machine. Like a machine, a text is a finite, self-enclosed product of definition. It contains no more than was explicitly inscribed by its author, together with implicit deductions. If nature is a machine, it should be as predictable as other machines. If it is a text, it should be as searchable as other texts, and subject to the methods of textual interpretation that were applied to scripture. Whether the text is written by God or by the theoretical physicist, the advantage of presuming nature *itself* to be a text is that it can be exhaustively formalized, spelled out.

A major difference between speech and written language is that a text is present all at once, of a piece, autonomous and independent of the speaker. Speech is necessarily presented sequentially by speakers and is intimately involved with their gestures, charisma, and authority. A text was originally a record or reconstruction of speech. While normally read in order, it need not be considered a linear sequence at all. It can be dissected, rearranged, taken out of context, deconstructed, manipulated, edited. As an abstraction, it exists outside time, with its own authority independent of its author. It can be examined at leisure by others and searched forward or backward for new meanings. That is the basis of prophecy as biblical exegesis, with the implication that the fabric of time is a searchable text. But it is equally the basis of mathematical prediction; for theories are also texts and equations are often functions of a reversible time variable.

Understanding the Bible as both written history and covenant had dovetailed with medieval fatalism. "It is written" had meant "it is destined." The fixed content of a text became the early template for the deterministic philosophy. Scientists took it upon themselves to discover the blueprint of a mechanistic nature. By careful inspection, the Creation could be reverse-engineered in such ways that humans could think the very thoughts of the Creator, mathematically expressed. The Enlightenment conceived, instead, the possibility of a humanly-created rational and secular order, a predictable "system of the world" that offered fulfillment through reason, technology, and enterprise. Building on Bacon, gradually the conviction grew that industry and the state, rather than religion and morality, could guide society toward the equitable well-being promised by technologies of mass production.

Science proffers a vision of nature that maximizes control of matter. It has proven superior to religion as a way to harness nature to human purpose. Yet, science does not correspond to all human purposes or respond to all human needs and desires. It does not give us immunity to existential anxieties. It focuses on what people can do to improve their knowledge and their material lot, which does not necessarily leave them feeling more secure or happy.

Scientific knowledge is always only provisional. Science gains confidence by dealing with well-defined constructs in place of naturally ambiguous realities. But this confidence is misleading, since the reality (unlike the theory) cannot be perfectly known. Because the model can never be perfect, our technological projects have unforeseeable consequences, our projections into the future can go awry. Our literal machines break down or do not work as well as expected. Scientific concepts tend to become so abstruse and foreign to common sense that science fails to fulfill its other mandate, which is to provide society with a satisfying story about reality—a job once falling to religion.

Despite some common ground as quests for truth, science and religion have radically different ontologies and ways of seeking certainty. Through technology, science uses the material world itself to study the material world. Religion has only the apparatus of the human body and mind; there are no god-detectors. In science, the epistemic subject employs theory to make sense of data, upon which confidence in the theory crucially depends. In religion, the believer places more faith in theology than in the evidence of the senses. Experience is interpreted through doctrine, rather than the other way around. Like mathematics, religion defines its own certainties, while science must ground its certainties in evidence derived from the senses or their instrumental extensions. Science concerns the impersonal relationships among objects. Like art, religion concerns the subject's personal relation to the cosmos and to other subjects.

The scientific subject and the religious subject have the human existential condition in common. For science to truly displace religion, it would have to embrace goals beyond prediction, control, the advance of technology, even the pursuit of disinterested truth. Embodiment renders the subject keenly interested in the world; and the pathos of the human condition renders the inner life of the subject passionate. Knowledge that cannot encompass these dimensions of living does not represent the whole human being, and cannot serve the greater and long-term needs of humanity. Neither can it represent the whole truth of a nature that includes human observers.

In many ways, modernity has failed to fulfill the social dreams of the early humanist thinkers. This may be one reason why religion continues to be resurgent the world over, as the failures of secularism continue to unfold. The persistence of creationism and religious fundamentalism in the United States should be understood against the background of historical continuity and common ground between religion and science. Given the pivotal influence of Christianity on the development of science, antagonism between religious and scientific communities should be understood in that context. But it should also be understood in light of the failures of supposedly rational ideologies of progress to materialize as promised. Communism failed to deliver its egalitarian utopia. Global capitalism fails to "trickle down" its benefits, as the rich grow richer and the poor more numerous and relatively poorer. And technology seems to create as many problems as it solves.

Religion, science, and art are three approaches to the mystery of existence, each with its own advantages and liabilities. Science competes with religion to provide a worldview, an ontology, a creation story, perhaps even an ethic to live by. Neither, however, provides a true alternative to the materialist ethos that is destroying the natural world.

Art is a third strategy to deal with the unknown. Art and science are complementary, loosely in the way that right and left-brain functions are. Just as science evolved out of religion by differentiating itself, so did art, which began as a religious expression and gradually secularized. Art and science are alternative forms of cultural production, expanding the human realm. Both rely on creative imagination. Science translates observation and theoretical concepts into technology; art translates perception and imagination into material form. Science captures general truths about nature, in abstract representations. Art too can be both representational and abstract. It may try to capture a landscape or, alternatively, a feeling. When literally pictorial, it is usually the uniqueness of a scene that is sought more than general truths of nature. Art may also attempt to open up experience and liberate it altogether from external reference. It explores ambiguity and invites multiple interpretations, without attempting (like science) to decide among them or to bring a question to closure.

Art plays an important, if recessive, role in the modern world. To understand this role, one must first acknowledge that art involves non-verbal cognitive modes, different from either science or religion, which are functions of language.[135] Art has long been associated with the unconscious and the irrational—aspects of being that are undervalued in modernity. While the role of creativity is constrained in science by the goal of objectivity, and by the reality of the natural world, it is free to expand in art. Whereas science gains consistency by bracketing subjectivity, art embraces it and now serves as a counterpoise to the rationalism of science. It serves, if ineffectually, as a force in modern society to re-establish balance in a world dominated by nominal rationality. It presents a different vision of intelligence, celebrating the subjective and affirming the sensuous in the shadow of reason.

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[135] Even in poetry, literature, and song, esthetic formal elements can be distinguished from semantic content.

In this age of automation and commercialism, the function of art may be to promote creativity for its own sake rather than for practical, commercial or ideological ends. Such creativity reflects the need to freely define ourselves and the world we live in, and not to be prisoners of biology, social conditioning, self-interest, money, mechanism, practicality, fanaticism, or logic.

Science serves survival insofar as it effectively maps natural reality and allows us to predict and control it. Through technology, it helps us shape the world to our needs and liking, to free us from insecurity and material want. Yet it leaves unfulfilled a longing for sheer gratuity, unbound by reason, the external world, and fear of want. Art can be disinterested, in a way that science is not and religion cannot be. Like sport, art comes literally into play; like philosophy, it reminds us there are no final answers. In a society dominated by serious issues, practical goals, the standard of objectivity, and high anxiety despite the desire for reliable certainties, art reminds us of the spirit of play, the arbitrary and gratuitous, and the freedom to see and enjoy the world in one's own way, liberated from ordinary concerns. Art may seek, in its own way, the mystery that lies beyond the reality principle and the biologically driven need to know. It cannot do this by verbally arguing with reason, which is master in its own house, nor by arguing with faith that tolerates no disagreement. It cannot shout, but only illustrate another way of perceiving and being.

Both art and science seek to push limits imposed by nature. Like science, art involves materials and technical processes, performs systematic experiments, elaborates abstract theories, and may undertake monumental projects enlisting many hands. The scientist has her laboratory and the artist has her studio. In some aspects, art is a shadow version of science, with similar organization, including the need for funding by benefactors. Yet its goals are often the contrary of scientific goals, sometimes seeming to protest the very rationality behind science, while making use of its principles and derived technologies. Scientists have natural reality in common to guide their collective efforts to fathom it. There is no common "art reality" to guide the artist—only the projects defined by patrons and consumer taste, a market shaped by art dealers and museums, and what other artists have done and are doing.

Science is distinguished from art and other cultural expressions by its cumulative progress, through the agglomeration of data and consequent advance of theory and technology. Despite wars, natural disasters and urban renewals, art too accumulates—in museums, private collections, and heritage buildings. Its social role has evolved in step with a changing ethos, and its forms with changing technology and social values. But it is debatable to call these changes progress.

Science has become ever more abstract and unified in its concepts while at the same time becoming ever more precise, well defined, detailed and technical—a mathematically unified approach to the physical world. In comparison, while often embracing abstraction and intellectualization, art has become ever more diversified. No longer committed to represent nature or reality (hyper-realism notwithstanding), art no longer embodies a rigorous corpus of technique or set of standards or rules. Theories, experiments, and directions for research in science can hardly be arbitrary, but must build on existing knowledge. The notion of an objective truth and the supposedly objective reality of nature serve to arbitrate among theories and guide research. Something like this was true in art at one time, when it essentially expounded the common religion. Something like it remains true in the upper echelons of the curatorial art world, and for art historians, where a revisionist art history narrative may create an illusion of progress. In general, however, the field of invention in art is wide open.

Whatever the changing social, economic, and political context of actual works of art (and whatever their merit), a mythos of art and a mystique of the artist endure. Myth rarely corresponds to reality and is not meant to. Yet, the mythos of art signifies an abiding awe of the creative spirit, sometimes romantically projected—like sainthood—onto specific individuals. At one time, painters and sculptors had been taken for granted as artisans, and art simply meant the skill to exercise their craft. Then Vasari promoted the idea of a rebirth of the arts and, along with it, the individual artist as a special kind of genius.

To lay people, the genius of scientists and technologists can appear as recondite as that of the shaman 10,000 years ago. The artist also appears as a kind of shaman, mysteriously able to create ex nihilo. Yet, the artist's creativity represents a more personally accessible, more emotional, and less abstruse mentality than that of the scientist, inventor, programmer, or geek. With good reason, perhaps, we fear mad scientists and nefarious technology; mad artists are at worst eccentric or coyly shocking. For the most part, they do not intend to master the world—only their media.[136]

If science, art, and religion confront the mystery of existence, they also serve to evade the existential terror of that confrontation. That each has largely failed to solve the mystery is hardly surprising. Yet, it is crucial to understand the nature and inevitability of such failures. It is especially important to grasp the extent to which, though unconscious, failure can be deliberate. For, the mind in all its selectivity is a protective filter—like sunglasses or earplugs. Culture is the collective application of that filter.

Art, like religion and science, is a confrontation of subject with object. Art mitigates the intimidating aspects of the natural world by vaunting the human world and depicting the natural world as domesticated. Representation in painting literally transcribes the scene, affirming cognitive mastery one brush stroke at a time. Just as science redefines the world in mathematical terms, and religion in theological terms, art redefines reality in aesthetic, symbolic, or formal terms. While individual works of art might have a subversive intent, art functions overall to maintain the status quo. After all, artists have traditionally worked for wealthy patrons, the church, or the state. Art is both a form of wealth and a symbol of it for the sake of status.

Culture is an interplay of raw reality and human need, which necessarily involves compromise. To understand this, it is helpful to recall a notion of Freud: *compromise formation*. This is the idea that an impulse can be deflected and deformed by competing forces, resulting in a distortion or perversion of the original intent. This is how Freud explained neurotic symptoms: as defense mechanisms. The compromise is a surface manifestation (a "symptom") that both reveals and conceals a deeper psychological intent. Each cultural strategy not only casts the mystery of existence in its own light, but also conditions our responses in specific ways that help

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[136] This is not to deny that there are ambitious artists who seek wealth, notoriety, a place in art history.

us cope with it. Each skews how we view the world and the human situation—if not through rose colored glasses, then through the distorting lens of scientific materialism, theology, capitalism, aesthetics, the cult of artistic genius, etc. In the course of doing its job, science, art, and religion—each in its own way and inadvertently—is a defense mechanism against existential terror. Each mitigates confrontation with the Great Mystery by defining reality and thereby limiting possible experience. The ancient Hebrews cautioned against looking directly upon the face of the divine. The ancient Chinese cautioned that the Tao that can be named is not the Tao. Art, like science and religion, is the sort of approach that is feasible toward the truth.

CHAPTER TWELVE: Moral and Ethical Subjects and Objects

In which we see that what exists provides no guide for what ought to be. Biologically, "the good" is a product of natural selection. Morality naturally endorses ethics, which facilitates cooperation. Concern for non-human organisms need not be based on their phenomenality; they can be appreciated as objects as well as subjects. Ethical behavior can be guided by the other's responses. Money, credit, debt, usury and property rights are ethical issues, along with how to relate to nature.

"To be moral animals, we must realize how thoroughly we aren't." —Robert Wright

What is "good," and good for whom? Does it mean good for the individual, for society, for a particular group or generation, for posterity, for the planet? Such questions involve very different considerations. Can ethical ideas apply universally across cultures and times? Who, indeed, are "others," and what is the self or the collective "us"? Here we explore the subject-object relationship in the context of ethics and morality and how to live a good life.

Human beings are products of natural selection. As highly social primates, we are also moral beings, living in a world shaped not only by biology but also by intent. This duality introduces two perspectives on reality and on our place within it. We are both observers and participants, products of causal processes and yet also agents who initiate them. We stand with one foot in the natural order and the other in a cultural realm of imagination, thought, and creativity. We belong to nature, yet we continually strive to transcend it.

Like other social animals, human groups depend on cooperative behavior. They also require of their members certain attitudes and beliefs to support such behavior. For this reason, I distinguish between ethics and morality. Ethics is a code of conduct guiding how individuals relate to one another and to society. Morality, in contrast, prescribes what one is believe and how one is to feel about others, the world, and oneself.

Morality implies an absolute framework that often serves to justify ethical rules. It concerns principles of right and wrong, as well as the goodness or badness of character and action. Values and judgments are elevated to the status of principles or even absolute truths. While these judgments may begin as "gut" responses, they tacitly appeal to something presumed objective, transcendent, or beyond mere custom. To carry weight, moral principles must appear universal or absolute, not merely individual, arbitrary, or relative. Values may differ between cultures or groups, but within a group they are ideally unquestioned if they are to be effective. Yet the irony of such absolutes is that they arise from subjective need. While posing as objective or transcendent, moral frameworks are often used to justify parochial attitudes—and can even lead, paradoxically, to unethical actions.

Ethics, by contrast, codifies how to treat those upon whom we are co-dependent. It prescribes behaviors. Morality adds the emotional force that makes such codes feel self-evident. It may also draw upon religious doctrine for justification, or some other external authority. Already two perspectives emerge: an observer's view (third person), in which values and practices are considered dispassionately, as an anthropologist might describe them; and a subject's view (first person), in which values are felt and endorsed as true, right, or self-evident.

Like laws and customs, ethical rules can be described in the third person as social conventions, even by those who follow them pragmatically—for example to avoid punishment. But if such rules are also held to be intrinsically right, they are morally endorsed with emotional commitment. Morality can likewise be described in third-person terms—for example, by an anthropologist. But the believer, for whom moral truths feel self-evident, cannot easily take that detached view except in moments of transcendent reflection—or in moments of hypocrisy.

Every culture has its moral ideas, and philosophers throughout history have reflected on them. For the ancient Greeks, ethics was bound to the pursuit of "the good." Aristotle, for example, assumed a singular human good rooted in the characteristic human nature. Fulfillment of individual potential aligned with the well-being of society, as conceived within their culture. Yet even then, the concept of the good applied only selectively within their society, and most cultures, including the ancient Hebrews, applied one ethic to insiders and another to outsiders.

Especially since Darwin, biology paints a quite different picture, in which the good is not a goal to strive for but a result of natural selection. By this measure, the good life is one that leaves offspring who themselves can reproduce. We are not what we are by conscious choice or striving, but simply what nature has made us. Nature offers no prescription for how things ought to be. Natural selection merely sets limits on what is possible. It has no purpose or intention—only outcomes that we recognize after the fact. While there appears to be no agency behind evolution, it does exhibit a ratcheting effect: while variation is random, selection builds complexity over time.

Cooperation, as much as competition, has been essential to life's advance. Organisms themselves are coalitions of cooperating cells; even the eukaryotic cell is a coalition. The human species, in particular, succeeds through extraordinary cooperation. Abstracting cooperative tendencies into moral precepts has enabled groups the collective good. Yet, in the context of presumed basic genetic selfishness, apparent altruism in the natural world presented a conundrum: how and why does the individual give up autonomy for the greater good? It was resolved in biology when it became apparent that the unit of natural selection is not the individual soma (let alone the group) but the gene, which is held in common by the cells of the organism. Morality and ethics thus may have biological roots, serving cooperation and collective survival. Yet human ideals often oppose nature itself. We are dual beings: thoroughly biological, yet aspiring to self-definition beyond biological determinism. The mind may naturally lend authority to biologically-driven mandates, so that we believe our moral judgments; and believing them may indeed help our species or group. On the other hand, we are also able to reflect on these judgments, whether to see them as mere ideas or to extol them as ideals and virtues. Sociality is natural to us as primates, but its cultural expressions are uniquely human, grounded in reflection and imagination.

From the point of view of human ideals, the biological world is a horror show in which no life can persist without destroying other life. Nature is amoral; yet, the behavior of carnivores and parasites is positively *im*moral by nearly any standard we apply to humans. Our self-awareness leads to inner conflict: we experience both the prison of instinct and the possibility of transcending it. Animals "know not what they do," but we, with self-consciousness and choice, must hold ourselves and each other accountable. Hence, legal pleas to evade accountability by "temporary insanity" mean that the guilty party didn't realize what they were doing and didn't, in that moment, actually have free will. But conscious choice is an evolutionary afterthought, precariously built atop our instinctual nature. Questioning one's values requires effort. It runs the risk of leaving one with no reliable basis on which to choose, no basis for an ethic.

Religion animates ethics by framing moral failure as sin—literally, "missing the mark." Sin presumes awareness and choice, hence culpability. (One must take aim in the first place!) In broad sociological terms, forgiveness is about reconciliation of opposing wills, whether that means between individuals, with society, or with God. It requires contrition and acknowledgment of wrongdoing, serving ultimately to reintegrate the sinner into the community. Reconciliation with society functions similarly: crime and punishment are behavioral, but parole and reintegration require evidence of sincere intent to reform.

Civil authority in court cases may have recourse (sometimes successfully) to arguments about inherent right and wrong. Yet, whether the person judged guilty is innocent in the eyes of God is not properly a legal concern. The moral state of accused or convicted persons is less the issue than how society should deal with them. Punishment may entail loss of rights and therefore of agency.

Whether or not endorsed by religion, right and wrong are pre-eminently a moral issue. They are distinct from legal issues and codes of conduct, even though we are taught to obey the law in the same breath we are taught to know the difference between right and wrong. Legal systems may appeal to reason and precedent, but morality can involve powerful emotions of shame, pride, remorse, or outrage. Conscience is born of socialization, internalized as the superego. Emotion gives morality its force.

Consciousness reflects the organism's relationship to the world. The internal model of reality is literally self-centered. But this does not mean that it serves only the individual. Through serving the genes it may also serve kin or community. The internal model, projected outward as the world we know in experience, includes features that represent right and wrong. In other words, it is natural for us to experience the world morally, because doing so has enhanced the collective survival and thus the proliferation of certain genes, enabling us to be here. On the other hand, we know that phenomenality must not always be taken at face value. Similarly, we recognize that moral intuitions, like perceptions, are not infallible.

Realizing their relativity does not mean we should abandon moral sentiments. They are often functional and intuitively aligned with the common good. But we should understand them as biological strategies, not absolute truths. To be trusted fully, they require corroboration by reason and fact. Otherwise, moral sentiments can be unduly exempted from scrutiny and elevated to dogma, reinforced by religious or political fervor. The mind's projective tendency—its habit of treating internal models as external realities—readily supports heavens and hells, angels and demons, heroes and scapegoats to enforce moral imperatives.

The reflexive consciousness of a social being introduces the dichotomy of *I* and *thou*, distinct from the relationship of *I* to *it*. Other persons are held to be not inert objects but agents like ourselves, endowed with awareness and will, which language reflects in the "second person." Ethics governs how we should treat them, whether grounded in absolute imperatives or in pragmatic reciprocity: how others will respond to our actions, individually or collectively. Unlike inanimate objects, people—and some animals and perhaps possible AI agents—may resist being badly or unjustly treated, and may retaliate or compete with us for control of the situation. While inert objects do not respond with agency to our actions, our actions upon them may ultimately rebound upon us, as in the case of climate change and environmental collapse.

The basis of ethics toward other creatures should not depend on whether they are deemed conscious. What ultimately matters ethically is their well-being and ability to thrive—not merely sparing them pain or allowing them pleasure. Creatures prioritize their own welfare, and their pains and pleasures *are* their internal evaluations of their state. The evaluation follows from the state itself, not the other way around. Phenomenality, including pain and pleasure, is an organism's way of representing its state to itself—a state that can also be evaluated externally by observers. The primary issue should be the state itself, not the evaluation. If we do not value the entity itself, why should we be concerned about its experiences? And if its well-being is secured, its experience will follow.

Our concern for how other creatures feel often stems from anthropocentric motives, reflecting our identification with our own conscious states. We blithely think of putting suffering creatures out of their misery when we can do nothing to improve their state and thereby relieve their suffering. But the damage or injury should be the concern, not just pain. Organisms deserve appreciation for their intrinsic complexity and vitality, not only because we imagine them capable of suffering as we do. By the same reasoning, the well-being of other people (and even one's own) should be prioritized over the subjective states that represent it.

In the early mechanist paradigm, animals were regarded as mere machines, without sensation. This view justified treating other species—and even other humans outside one's tribe—as expendable, as literally fair game. The "rational soul" was invoked to distinguish humans from animals, treating even the human body as chaff to be discarded in service of the soul's salvation. Today, machines have become increasingly sophisticated, making it harder to deny that they might one day—or even already—be sentient. If the human body is itself a machine, and also sentient, then we ourselves provide proof of concept. The difficulty is that we have no decisive basis for determining the conditions for artificial sentience, just as we cannot pinpoint where phenomenality arises on the evolutionary ladder. Indeed, we barely understand our own. Sentience has nonetheless become a standard by which to evaluate machine intelligence, generating moral concern even for chatbots. Such concern could focus, as with creatures, on their actual condition rather than hypothetical experiences. Embodiment entails a relationship with the world, and any phenomenality—should it exist—would be oriented toward that entity's own welfare. But if an AI is not embodied, it *has* no relationship with the world, for itself or for us to be concerned with. Its actual condition is that it is *not* an organism, not a creature at all, and not capable of sentience.

The very concept of the *other* depends on a concept of self. How I view myself shapes how I view others and the world. The other is what is not me—or not us. But the other can be further distinguished as like or unlike me or us. Thus, I recognize another person as distinct from me but alike in being human, while a cat is not human, and a doorknob is not even sentient. The boundaries of such categories are fluid, however. Throughout history, humans have shifted the definition of 'human' for convenience—branding enemies in war as inhuman, or treating outsiders as less than fully human.

The category of personhood is likewise precarious. One's own sense of selfhood depends on fragile states of brain organization. Some people lose their sense of being someone—which may be judged pathological by medicine, or exalted in spiritual traditions. Others fail to empathize, treating other people as insentient. This, too, is deemed pathological, unless it serves social ends such as war, politics, or economic exploitation.

Children, other creatures, nature, and even machines can all be objects of ethical concern. Yet such concern often implies a hierarchical relation, in which responsibility rests unilaterally with legal persons while others are "managed," often with mixed motives of self-interest and benevolence. This attitude of management may be resisted by agents in a position to assert their own wills. Then the relationship become agonistic, like a game of competing players.

Indeed, literal games reveal how competition and cooperation intertwine. To be a player implies a status as subject, different from other elements of the game, such as the playing field, the rules, and the tokens that represent the players in the "world" of a board game, for example.[137] To maintain the transcendent status of player—an agent outside the game—requires a spirit of disinterested play. As in the case of gambling, those who get too caught up in the play, too identified with the game or its outcome, have temporarily lost their senses and become no more than a feature of the game. On the other hand, the game can only exist because participants agree to cooperate by following the rules. Paradoxically, it can only exist until someone wins, which puts an end to play.

Morality is irrelevant in games, except for the agreement not to cheat. (The meta-rule is to follow the rules, without which there simply is no game.) In some games, such as sports and even war, a code of honor regulates fair play and sportsmanship. In economics and game theory, however, "rational" players are defined as those who play in earnest to win, or to maximize their gains. The object is not necessarily to enjoy the game for its own sake, or for camaraderie or friendly entertainment. Competition can be ruthless. To achieve the goal defined as winning implies strategy, which means trying to outwit the other players who are likewise trying to outwit you. Game theory frames rational players as those pursuing optimal strategies without mistakes.[138] Yet optimal strategies may mix cooperation and selfishness, especially in repeated interactions with the same players, who take note of previous behavior and adjust their strategies accordingly. Human games are complex, recursive, and often lead to impasse.

[137] In the case of sports, the playing field is literal and the physical players *are* the tokens.
[138] An optimal strategy maximizes your winnings or minimizes your losses, regardless of what other players do.

Such thinking extends to biology, to the competition among genes responsible for evolution. Genes act as “selfish” players, yet selfishness at the genetic level can manifest as altruism at the social level. Evolution advances through a synthesis of competition and cooperation. Organisms naturally value their own welfare above that of competing others, except when altruism can help spread their genes. Ethical doctrines that call for indiscriminately valuing the happiness of others, equal to or above one’s own, run counter to this biological principle. Yet they may serve larger social purposes, creating cohesion and enabling societies to flourish. The Golden Rule—do unto others as you would have them do unto you—transforms reciprocity into a universal formula that maximizes collective wellbeing.

It may seem that the prime ethical goal should be to maximize the pleasure, happiness, or well-being in the world. But how do we measure someone’s happiness or, for that matter, their well-being? An external yardstick can be skewed by the observer’s biases and interests, and judging someone else’s state can be as presumptuous as prescribing what is good for them. The ethical issue is to know how to conduct oneself in regard to them. The Golden Rule is a fair general guide, though based literally on one’s own preferences. In many cases, however, a more respectful approach is to consider the other’s response to one’s actions, letting them evaluate their experience and how you affect it. Let them be the judge of your conduct; listen to their feedback on your behavior and how *they* want you to treat them. On the other hand, the point of morals or an ethical code is to know in advance how to behave toward strangers as generic human beings—based, perhaps, on prior experience of how they seem to want to be treated.

Reciprocity is a common-sense strategy involving fairness. It begins in good faith, by initially assuming the trustworthiness of other players. If they cooperate, you cooperate; if not, you retaliate in kind. (Do unto others as they do to you.) This is how we train others to behave properly toward us and how they train us. A desirable outcome can be elusive, if the game is dominated at the outset by players who do not behave fairly. It would be important then to punish not only selfish players but also fair players who fail to punish unfair players. Society disapproves of evildoers, but also of those who tolerate them. This could help explain the social utility of morality: general indignation at uncooperative behavior or cheating, even when it does not involve personal wrong. Reputation is important in situations where known players encounter each other repeatedly. If a moral sentiment can be assumed to prevail, it is more likely that an unknown player will be trustworthy.

Ethical principles, public rituals, and especially morality, enhance social cohesion. This promotes strength against enemies as well as domestic harmony. Conformity is a valuable weapon against competing groups, as we see in patriotism. It demonstrates the willingness to cooperate with one’s team. Despite the vaunted competitive edge of individualism, it is generally more efficient to copy what others do than to try to find original solutions.

Ethics also concerns how people treat each other economically. Credit, in its original sense, was a favor to be reciprocated—a practice fostering community trust. Usury, by contrast, transformed lending into exploitation, often leading to debt peonage or slavery. Many traditions condemned usury within the group but allowed it when outsiders were concerned. As early societies expanded and intermingled, membership in the group became less clear. Trade and war created new and larger groupings, less personal relationships, requiring new ethics.

Over time, credit evolved from mutual trust into impersonal extortion. The "interest" charged on loans was a fee charged for the use of money, in lieu of reciprocation. The debtor—who before was a friend or relative—becomes a resource to exploit. Whereas the Lord's Prayer admonishes us to "forgive us our debts as we forgive our debtors," we generally no longer forgive debt, but have made it the very basis of modern economics. Debt has been institutionalized. But the stigma of indebtedness—which once could lead to enslavement—remains a moral taint.

Money itself, by quantifying value, impersonalized relationships. Where once trade bound people together, coinage allowed transactions to be finalized and forgotten.[139] It rendered trade completely impersonal. Before, you had a reciprocal and ongoing relationship, of mutual dependency and trust, with your trade partner or creditor. In contrast, payment in coin—redeemable anywhere—completes the transaction, cancelling the relationship as paid in full. Both parties could walk away and not assume future dealings. Indeed, money met a need because people were already involved in trade with people they might never see again and whom they did not necessarily trust. This was a very different sort of transaction than the personal sort of exchange that had previously bound parties together. Trust in people was replaced by confidence in the power of money.

In the modern capitalist economy, all resources and commodities are by definition equivalent to money, which is a mobile resource that moves freely like air, water, or wild game. Even a potentially renewable resource like forest or fish can be exploited to exhaustion, since it can always be converted to capital to reinvest somewhere else. On the other hand, money is the practical common measure of value, reflecting what is deemed good or just. Precisely because it is impersonal, money stands above cultural and ideological differences, tending to smooth these over in the globalist world. While there is often a price to pay for conflicts—leading, for example, to revenge or war—sometimes the price can be paid in cash instead of in kind. An eye for an eye need not be the policy. Money figures in court awards to victims, penalties for violations, and out-of-court settlements. Its positive side as an institution is that it unifies, even globally.

War was historically about conquest, which often reduced the defeated to chattel. Like debt, it was a major source of slaves. A slave is someone torn from their social context—severed from the community that had given them identity, rights, and recognition as a person, reducing them to an object. But slavery was hardly a moral issue in societies that practiced it. In the ancient world, it was simply a condition that could befall anyone, through war as through debt. In the colonial era, it became associated with race and a supposedly inferior level of civilization.

The precedent for human slavery is animal slavery, just as the precedent for war is the hunt. Animals too were removed from their natural context and forced into servitude, no longer seen as fellow beings—or even as worthy adversaries—but as objects, resources to be used or traded. This attitude is echoed in modern language when we speak of people as "human resources."

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[139] David Graeber *Debt: the first 5000 years*. Melville House, 2011.

The marketplace operates by a similar logic of objectification. Artifacts that once bore the hand-made stamp of craftsmanship and personal meaning are stripped of their context. Through mass production, they are rendered identical and anonymous. Standardization economizes production while also adjusting quality to a common denominator, thereby fixing exchange value. The impersonality of goods matches the impersonality of money itself. The identities of buyer, seller, and manufacturer are irrelevant, just as the observer's individuality is irrelevant to scientific description.

People excel at spotting cheating when the rules are clear. But following the rules does not guarantee fairness, since both the rules and the very definition of the game can be skewed by those who make them. Wrongdoers may appear to play legally simply because the system legitimizes their advantage. The more complex and abstract the game, the harder such "meta-cheating" is to challenge or even to pinpoint. Insider trading is illegal; usury is not.

Yet we intuitively sense injustice. Emotions can serve the common good in ways that logical analysis and cold rationality (defined as calculated self-interest) do not. They communicate the subject's inner state and intent, serving as warnings to others. Anger, shame, guilt, pride, honor, moral indignation, and outrage at injustice thus help us to trust each other in circumstances where strict self-interest would prescribe cheating or taking advantage of the other. Indeed, people may act against their immediate self-interest in situations they perceive as unjust. Acting "irrationally" contrary to self-interest can make one unpredictable, which in itself is a form of power. Sometimes the mere reputation of being a "loose cannon" can shift the balance.

Society itself is a game biased toward certain players—above all, wealthy males. Rights may be nominally equal, but resources are not. While capitalism propounds "freedom," "democracy," and "consent of the governed," in reality it is rule by the rich—with tacit assent (and irrational enthusiasm) by the would-be rich. Awareness of this uncomfortable truth is potentially seditious.

Men and women alike have been drawn into a masculine ethos: ideals of progress, power, self-interest, domination of nature, consumerism, greed, and the cult of the celebrity and the billionaire. The exaltation of the masculine mystique and the repression of the feminine have served to keep not only women in their place but also the majority of men. We have yet to see a world not fundamentally hostile to the feminine, the body, and nature—let alone one defined by women or by a balance of masculine and feminine principles.

Masculine and feminine are not only social roles but also psychic forces that remain to be integrated within the individual. Awed by the mystery of woman, men often fail to recognize the feminine within themselves. They seek access to feminine subjectivity through partners, sisters, daughters, homosexuality, or rebellion against gender norms; or they deny it altogether, absorbed in impersonal goals and consumerism.

Gender can shape moral reasoning: men may lean more toward explicit rules, facts, and consequences, for example; women, more toward empathy, intuition, and inclusiveness. Each gender may also be wary of the other's ethical framework and misjudge it. At one time, men surely envied—and perhaps feared—women's power to create life. Their first compensatory power was the ability to take life way—in war and the hunt. Bleeding and regenerating, women embodied a natural cycle. Men, by contrast, found power in their ability to make others bleed. Through war, death itself could be idealized, appropriated, embellished as part of the intentional human world, an answer to the mere passivity of being prey to wild beasts and victim to disease and mortality. When ritualized, war, the hunt, and animal sacrifice could take back power from nature by not just killing on nature's terms, as animals would, but in specifically human ways that deny affiliation with nature.[140]

As part of the system of nature, humans must eat other beings. Beyond satisfying hunger, culturally we've made dining on our fellow creatures an enjoyable experience. Yet, culture itself reflects a rejection of the animal way of living. Cooking makes food more digestible chemically, but also esthetically and morally. We do not, like other carnivores, tear into raw bloody carcasses. While not equipped with the teeth to do so, we also do not want to act like brutes. The whole of civilization represents a flight from our animal nature, as well as from biological and physical limitations. But, as such, this project of transcendence can only be a compromise. We've sought to morally transcend our own animal nature, at first through religion and law, and now through science. Yet, a most embarrassing remnant or our animality is the need to feed off of other creatures. We may choose to eat with cutlery, manners, spices, and not like the beasts. Yet the fact remains that we must eat.

From a moral perspective, and also for efficiency, should food still be a product of suffering, slaughter, and waste? More than 70 billion land animals alone, per year, are made miserable and sacrificed for human consumption. And yet, ecologically and in terms of caloric intake, this system is extremely inefficient. Factory farming could be eliminated and famine potentially overcome; emissions would be minimized and land use optimized. Food production could be optimized with AI and genetically tailored to individual nutritional needs. While synthesized food could be made to taste like the real thing, nutrition could be delivered via synthetic blood, nanobot-mediated infusions, or even photosynthetic skin implants. All biological matter, including human bodies, could be respectfully and safely recycled. The human moral dilemma of carnivorism *can* be solved if the will to do so is greater than the inertia of conventional habit and taste.

Today, the question of how to behave ethically toward nature at large is unavoidable, forced on us by our very success as a species. If we now cast ecology in moral terms, let us recall that it is still a matter of self-interest: we must change or perish. Early humans had no such qualms. In the "Pleistocene overkill" our ancestors hunted large prey to extinction. If early humans did not destroy the planet, it was only because they were too few and too poorly equipped. If modern indigenous peoples are known for ecological awareness, it is perhaps because they learned a hard lesson from their distant ancestors, who left them only smaller prey to manage better.

Ethics and morality usually concern relationships among subjects more than relationships to objects. What kind of object is nature, and must it be considered a subject to be an object of moral concern? To regard the natural world "objectively," as science attempts to do, means to

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[140] Barbara Ehrenreich *Blood Rites: Origins and History of the Passions of War*. DIANE Publishing Co., 1997.

consider it impersonally, as consisting of things rather than agents active in the sense that human subjects are. Nature is not supposed to have a mentality or purpose of its own, which leaves it without a voice in our treatment of it.

A powerful way to deny nature's agency, and any inherent rights, has been to frame it as mechanistic and deterministic. Yet if nature is a deterministic machine, and we are part of it, then our own consciousness and will are likewise determined. Rights belong to free agents, which determinism denies us. By such logic, humans should have no more entitlement to rights than the rest of nature. On the other hand, nature need not be a moral agent to be an object of our moral concern. Nature, or some part of it, should not have to qualify as a human person in order to have legal rights to fair treatment. After all, corporations are granted legal personhood. In any case, it might be better, all around, to treat the natural world *as thou*gh it were a person: as a *thou* rather than an *it*.

While self-interest can motivate ecological concern, ethical behavior requires recognition of the interests of other beings. Ethical concern should not rest only on the object's qualities, which would place outside ourselves the burden of justification for our own discriminations and judgments. The needed shift must come rather from the subject's side. The question is not which things deserve respect, or why, but how to summon that respect from within ourselves. How we regard nature reflects our own merits, as individuals and as a society. It is not "our" world into which "they" must fit, but a shared world in which the interests of all are enmeshed.

Humanity now faces a crossroads. Our technological success, population growth, and consumerism threaten the very systems that sustain us. This calls for a collective shift of fundamental values if civilization is to persist. By fostering a broader, more inclusive perspective—one that transcends national interests, self-centeredness, and anthropocentrism—humanity could navigate its complexities and move towards the ethical maturity essential to sustain civilization.

This shift requires confronting the ethical implications of rampant materialism, consumerism, and wealth inequality. More than ever, there is need for a non-materialistic yet secular perspective on life: values and pursuits other than personal gain or salvation or the conventional goals of family, wealth, status and power. As automation reduces the role of labor, the question arises: how can individuals retain intrinsic value when they are no longer needed as producers, consumers, or even as voters?

Ethical maturity requires objectivity: balancing subjective experience with responsibility to truth, reality, and communal well-being. Navigating delicate ethical questions—such as genetic engineering, euthanasia, and socio-political-economic ideologies—requires the ability to stand outside familiar mindsets that have contributed to current dilemmas. At its heart, ethics is about how we treat others—including the otherness of the natural world—not just for their sake, but also for our own self-respect and wellbeing. What nourishes self is to act from within instead of being driven by appetites and external causes. An ideal of how to treat the other is also an ideal of how to live well. Virtue, then, is liberation from interpreting experience in terms of personal need alone. Ethical maturity comes with living intentionally, which brings us more fully into being.

CHAPTER THIRTEEN: The Stance of Unknowing

In which we find that certainty can be a liability, and that the capacity to live without it is a valuable skill. A stance of unknowing is the much-needed complement to the quest for certainty. Information must be put in context, by connecting isolated facts to other facts and to the agents asserting them. To allow new connections, one must step back from truth to see it as belief. The only certainties are tautological.

> When they think they know the answers, people are difficult to guide. When they know that they don't know, they can find their own way. —Tao Te Ching

No matter how much we know, something always lies beyond the horizon of knowledge. Ignorance and error are always possible, and some degree of uncertainty is unavoidable. That is our fundamental epistemic situation. Refusal to admit this spells trouble, especially when we count on information that is not reliable. The ability to live without certainty, to not have to know, is just as useful as the skills that bring us reliable knowledge. We typically view ignorance as a liability. But when the state of not knowing is deliberately embraced as an attitude toward experience or information, it becomes an asset as a stance. I call this willing suspension of belief the *stance of unknowing*. It is an attitude of epistemic humility that admits we cannot have all the answers and acknowledges both the limits of knowledge and the boundlessness of the unknown. It complements the quest for certainty, much as a soft gaze complements sharply focused attention.

We have seen that the reality we take for granted as external is a virtual reality constructed in the brain, and that the self functions as an agent of the body. The body itself—as we know it phenomenally—is part of this simulation we call reality. Both the subject and the object are creations of the brain, which itself appears as part of the virtual reality it generates! This is the strange loop in which we live, shaping what knowing and certainty can mean. The perennial conundrum has always been to sort out what in our experience comes from the object and what comes from the subject—to distinguish the real or objective from the imagined or merely subjective. The entanglement of subject and object renders that task fundamentally problematic and puts us in an awkward situation, epistemically.

Faced with doubt on all sides, we naturally resist the passivity and fear of not knowing. Uncertainty can feel like powerlessness, as if we are at the mercy of what we do not understand, whether natural or man-made. We can be sure of little, apart from truths that turn out to be tautologies, conventions, or presuppositions. Only when life is cast as a *story* does meaning seem assured, providing us a secure place within its narrative. Religion has long supplied such stories, but science too functions as a secular narrative, promising assurance that reality can be reduced to concepts or at least mapped in empowering ways.

Religion, art, and science each reconfigure the phenomenal world as an idealized realm. They are parallel strategies for coping with the mystery of what is, which ultimately may be inscrutable. Whatever we think we know, we know also that it can be doubted, that all knowledge about the world is only relatively secure and never final. Against this, religion offers theology, with faith in doctrine as an antidote to doubt. Science offers theory, with its faith in mathematics. Art offers its own reworked version of reality, with faith in the power of creativity. Unlike nature itself, doctrines and theoretical models alike can be precisely defined, and therefore perfectly known. As a product of human action, an invention or a work of art is definite and knowable in a way that nature is not.

The very fact of subjectivity places human beings in a position of chronic uncertainty. For, as a joint product of subject and object, all experience is inherently ambiguous. Yet, the feeling of security—if not its actuality—lies in the certainties we can collectively conjure. Technology shelters us from nature's vagaries, science and religion from its ambiguities, while cultural institutions and practices shelter us from psychological anxiety, and the state shelters us from other people's acts and intentions.

This campaign against uncertainty substitutes deliberate constructs for the unknown. We've made whole civilizations for this purpose, consisting of rules, customs, buildings, streets, artifacts, machines and conceptual systems, all of which constitute our actual immediate world. Scientific theory, like religious doctrine, stands in for nature itself, preferring the certainties of deductive systems to the contingencies of the found world. Experiments are artificial versions of the natural phenomena they investigate. Mathematics formally manipulates unknowns as though they were known.

Yet, the quest for certainty casts its own shadow. It can harden into religious dogma, with all the dysfunctions that can entail. On the other hand, it leads to idealization in science, which produces its own subtle variety of dogma, and to Platonism in mathematics. Scientific models and paradigms work to the extent they correspond to natural realities and produce technological benefit; but they tend to ignore phenomena and data that do not fit comfortably within them. Similarly, the drive for security through technology can blind us to unforeseen consequences that ironically endanger the natural systems upon which our survival depends. While the need for certainty shapes our interests in accord with the reality principle, it leaves unfulfilled other psychological needs more in accord with the pleasure principle, creating unbalanced people and dysfunctional societies.

The modern world exalts "positive" knowledge with its values of certainty, power, prediction, utility, control, objectivity, and detachment. Embracing these has brought immense, if short-sighted, technological benefit. Yet, that very success has brought us to the brink of destruction. Might there be value in a different, complementary attitude toward knowing—an alternative to the obsession with certainty?

Understanding the physical world is difficult enough, with its open-ended complexity. At least in physics, the observer can arguably stand outside the system observed. Not so in the human world, or in the biological and social sciences, where observed objects are agents and observers in their own right, with their own diverse motives. You cannot stand outside a system of which you are necessarily a part, and where everything is a moving target that shoots back. The problem of interpretation is orders of difficulty greater.

The ideal of science is to control the situation in such a way as to know the truth of nature. (Hence the key role of the "controlled experiment.") Perhaps the ideal of political power is to control the situation in order to increase personal power or achieve the goals of a party, ideology, or movement. While the scientist can attempt to hold constant the subject variable in an experiment, life in the everyday world is a different matter. You cannot hold constant the variables of eight billion other subjects.

Concentration of power compounds the difficulty. Politicians, corporations, academics, media figures, and other influential actors disproportionately shape the shared reality. They have privileged access to information, but even they must interpret incomplete and disputable data. The rest of us are mostly passive bystanders, consuming filtered information and amplifying it through the gossip of social media. The domination of intellectual space by a few should be as troubling as the unequal distribution of wealth—more, perhaps, because it is harder to mitigate through social policy. The other side of that coin is the inability of publics to effectively sort and use the information provided by presumed authorities.

We want to know the facts, of course, not just opinions. Yet, the sort of information that stands as "fact" can be misleading and potentially dangerous, precisely because facts present themselves as stand-alone truths rather than human claims. Information must be put in context, by connecting isolated facts to many other facts and to the parties asserting them. The job of the intellectual or the social critic is to point out these larger contexts, to question assumptions, and to open up unfamiliar possibilities. Without such skepticism of the status quo, obsession with facts becomes counterproductive. For, by design, knowledge—as an outward-facing tool—excludes the tacit intentions and purposes it serves. What we lack is wisdom, an understanding of ends as well as means. Instead, we are drowning in information. We are overwhelmed by the seemingly known, which displaces the less savory prospect of being overwhelmed by uncertainty. What is lost in our masterful masculine civilization is the ability to *not know*, to be tentative, to do or say nothing, to listen, to receive, to open, to surrender, to embrace uncertainty, to leave the wild alone. Significantly, we have no common term for this power, which I have dubbed the stance of unknowing. It would be ironic to reduce this stance to known terms by defining it. Language and thought are oriented toward definable things. Undefined things can only be approached indirectly, like black holes are inferred through their visible effects. Still, we can describe the practice involved.

The stance of unknowing requires suspending what is known or believed, resisting the urge to reassert it. It means recognizing one's beliefs *as* beliefs, stepping back from their apparent truth, and treating them as objects rather than transparent lenses. Certainty appears natural because it answers a biological need, not because it corresponds to the truth. While this stepping back means questioning one's beliefs, it does not necessarily mean abandoning them. The stance is a provisional measure, an experiment. It poses the question: *What will happen if I set aside what I think I know?*

This bracketing of knowledge creates a void that allows new possibilities to emerge. Otherwise, one simply remains captive to existing assumptions, which displace other possibilities. With complete confidence in one's current knowledge, there is little reason to perform this exercise. Hence, there must be willingness to let go the known, to doubt. Such skepticism is challenging in an accelerating society that demands decisive action. Of course, there are real emergencies and things that must be dealt with in a timely manner. But there are also mock emergencies and decisions that would better be made under less pressure. Wisdom sometimes requires suspended judgment, even prolonged debate, whether collective or within oneself. There is a valid place for remaining in suspended judgment for as long as it takes to come to a wise decision, even consensus. Majority rule may settle disputes quickly, but it can leave 49% dissatisfied.

Reflexive consciousness lets us step outside the box, to see our purposes and beliefs in context and differently, as others might see them. This is not a state of permanent or cynical disaffection, legitimized as detachment. Consciousness is rooted in feeling, which binds us to objects and others; cynicism is a defense against experience. The stance of unknowing allows one to open to the power of experience to transform the self.

All knowledge cycles through phases of opening and closure. The error is to cling to closure—as though knowledge could be final. Academic thought tends to emphasize critical skills, rigor, hairsplitting, and competitively staking out an intellectual niche. That represents at best half the epistemic cycle, which has no natural termination. There must also be a proactive search for new, tentative, sometimes sweeping ideas, involving synthesis and originality as well as analysis and criticism.

The idealist faith behind the notion of a complete theory, a perfect simulation, or an exhaustive representation is that each and every property or element of a thing can be formally represented. This is the classical realist ideal of a one-to-one correspondence between the elements of a theory and those of the reality it concerns. Yet the world resists such complete specification. The only truly realistic map of the world is the world itself. While symbolic systems can be exhausted, nature cannot.

If all ideas are provisional, then history is best seen as a series of trial efforts. We ought to feel free to reject any experiment—personal or collective—and to return to earlier arrangements, or turn to others never tried or yet to be imagined. Human culture itself is a vast brainstorming session, whose results can still be sifted for results that work toward general human satisfaction. Science is the supreme expression in our age of the search for knowledge that is objective and hence secure. However, nothing is actually beyond doubt except propositions that we accept as true simply because we define them so. While such deductive truths do not depend on contingencies in the external world, for that very reason they may not tell us what we need to know.

Subjectivity gains importance in a milieu where doctrine can be publicly disputed, leading to the relevance of public opinion in political process. With the Reformation and the rise of printing, individuals had to decide questions for themselves, prompting skepticism about institutions, doctrines, and knowledge justification. We face similar epistemic challenges today, with the proliferation of social media and the rise of artificial intelligence. One needs to know the truth, but also to know how one knows it. Amidst the media's increasing noise, determining what to believe is increasingly challenging. While we must remain committed to the ideal of knowing what is real and true, often it is wise to be tentative and skeptical, to take the stance of unknowing.

CHAPTER FOURTEEN: Redefining Humanity

In which it is seen that the concept of humanity evolves along with humanity itself. A technological vision of a post-human future contrasts with a social vision of equality and justice. Planetary limits render the reproductive role of men and women no longer relevant and conventional economic goals no longer credible. The notion of progress must be redefined. The war on nature must give way to negotiation.

"Man appears to be the missing link between anthropoid apes and human beings."—Konrad Lorenz

Ordinary perception evolved to map the world as it was relevant to humans in pre-history, in such a way as to permit survival in that world. Through technology, science has transformed the natural environment and thus human experience as well. It has greatly empowered the species, at least in the shorter term of historical time. Yet scientific cognition remains under the same constraint as natural cognition: it must permit survival in the longer term. The jury remains out concerning its ultimate adaptive value. Only in hindsight can one say whether a creature's cognition was adequate to its environment. In the case of humanity, after our extinction who would be there to judge?

The philosophy of mechanism has been central to technical mastery. Its success in producing modern technology has made it seductive and seemingly indispensable. But the mechanist approach works best in simplified, idealized situations. It reaches limits in cosmology, quantum physics, and in explaining self-organization generally. It may have reached its limit as an adaptive strategy by promoting an untenable relationship to nature.

Modernity has long treated nature as a passive object: something to define, manipulate, and exploit. Yet we recognize the physical world as real, and science acknowledges nature as the arbiter of theory through experiment. Perhaps nature should be understood as an active partner—like us, self-defining and at once predictable and unpredictable. Climate change underscores this point, restoring a sense of nature as a moving target that adapts to our influence, able to elude our expectations as people do. If so, we may need to relate to it less impersonally than as science and religion have traditionally done. It should be a co-agent, deserving of respect and even of the legal status of personhood.

The rebellion against nature, the body, and the feminine originates in the claustrophobic perception of being trapped within a closed system. It springs from the dream to be subject only, never object. Freedom is associated with the transcendent perceiver (the mind), while limitation is associated with the perceived: the body and the environing world. The subject-object split can be pathological, reducing body and world to mere things to control. Like the domination of nature, repression of the feminine persists as a fundament of modern society, even when women are granted formal equality. A sustainable society would balance the masculine and feminine as principles of being, countering profit and power with care, restraint, and wisdom.

The quest for knowledge reflects our biological drive for security. But it also expresses a desire to transcend our condition—to be free spirits rather than prisoners of genes and gravity. Post-humanist visions imagine futures of complete mastery over matter, where humans or their artificial successors orchestrate the evolution of species, planets, and even galaxies. Whether such dreams are feasible or not, they overlook a more modest role for humanity as conscious caretaker of this planet. Our desire to transcend nature must include the nature within us. Mastery must include self-mastery.

The concept of humanity evolves along with humanity itself. As an ideal, it expands toward greater inclusiveness, serving both as a guiding myth and an evolving goal. Transhumanists project that artificial general intelligence will give rise to post-human forms, even to a whole new ecology of artificial life. Even without redesigning ourselves, technology is already reshaping us through the new environments it creates. What we build, we become.

If we had foresight, we would weigh the long-term consequences of every innovation before embracing it. Instead, we usually charge ahead blindly. For the capitalist entrepreneur, that means pursuing every market opportunity regardless of ecological or other consequences. For the transhumanist, it could mean pursuing a super-human ideal. For the consumer, it means succumbing to the latest craze. These visions dovetail. Futurists imagine designer realities in which minds are downloaded into artificial bodies or uploaded into virtual worlds. Manufactured cyberheaven could turn out to be cyber-hell, however, and immortality might be a curse. A wiser course would shift focus from perpetuating individuals to rethinking individuality itself—a call to live more genuinely and for worthwhile ends. Civilization could get better rather than bigger. It could aim to establish an optimal way of life in balance with natural limits.

The limits of the planet to support further increases in population render the reproductive role of men and women no longer relevant as the central plan of life: the default goal of life can no longer be reproduction. And the limits of the planet to support further ecological stress from overproduction render the conventional notion of success, and the goal of "getting ahead," no longer credible. Men and women alike are called upon to define and choose goals more appropriate to the future of the world than those endorsing the current excesses of production, reproduction, and consumption. Imagination is required to conceive lives and social arrangements that do not simply aggravate the world's current state. Such vision goes against our biological conditioning as well as against habit. But biology and tradition have brought us to such a pass that we must transcend their directives.

In a truly egalitarian society, the masculine and the feminine would be held in balance. The hegemony of the patriarchal worldview would be countered by the deliberate pursuit of wisdom. Social progress, "spiritual" clarity, and self-mastery, would replace the default pursuits of profit and power, technical knowledge, commercialism, and mastery of the external environment. Research would then be directed toward technology that works with nature and toward the common good. It would pursue social ideals of universal well-being rather than individualistic, corporate, and nationalist economic ends. Personal life goals would look beyond status, consumption, and kin to aim toward a truly united and sustainable world for all. In such an ideal world, there would be dialogue among religions, philosophies, and sciences to define a unified human perspective and a plan for the future that reflects root values people have held in common all along. Religious studies and ecumenical symposia would get to an ethical core, while shunning theology.

Western culture has long treated technological development as inevitable, equating innovation with "progress." Yet, today, progress largely means advancing corporate goals, not collective well-being. Expansion creates differentials of wealth and power, fueling upheaval. Progress could be redefined as the pursuit of sustainable and satisfying ways of life rather than endless growth and life on a treadmill. Rather than rush to a new frontier in space, we could pause to re-establish social equilibrium. "Growth" could slow, not only to regain equilibrium, but also because it is not the boon it purports to be. The ideal society would be global in its commonly ratified ethical intentions and principles, not in the homogenization of a monoculture devoted to consumption and profit. It would meet the basic needs of all instead of creating grotesque differentials of wealth. This would be a non-materialistic society, benevolently motivated in its aims and values. It would tolerate indolence but not greed.

Instead, the world seems to drift toward dystopia: a future where a small elite—or intelligent machines—own the means of production, entirely automated and managed by AI, leaving most people expendable. The whole planet could ultimately be a gated community of the elite, who hold all the wealth, with little place for the rest of humanity. Would it matter to such rulers whether the masses survived at all?

Technological evolution outpaces moral evolution because it is easier to change the object than the subject. Perhaps only civilizations that mature morally can survive an adolescent phase of runaway technology, such as we are experiencing now. Perhaps only moral progress will permit a technological civilization to ensure the continuance of life or intelligence into the far future, without first destroying itself through that same technology.[141]

The question, then, is how to achieve such moral progress. Some propose re-engineering human nature itself, editing out aggression and greed. But who would decide what should be preserved? At present, technology serves private fortunes and violent conflicts more than the common good. Technological achievements are not yet species acts. There is no united "we" directing progress on behalf of humanity. A unified, collective program for human destiny remains a pipedream.

Futurists dream of colonizing planets, stars, and galaxies, even converting all matter into "intelligence." Yet such visions echo age-old imperial designs. Space exploration may inspire awe, but it may also reinforce disregard for our home planet, as a disposable stepping stone in a larger manifest destiny. The dream of conquering outer space dovetails with the idea that our species has outgrown its natural habitat. A more fitting ambition, if less heroic, would be to conquer inner and moral space: to cultivate wisdom, humility, and balance rather than domination.

Attitudes toward body, mind, and world can be as destructive as unhealthy technologies. The quest for freedom from disease is reasonable in a way that the quest for immortality is not. While relief from the burdens of toil is understandable, the quest to have machines perform *all* tasks for us, and effortlessly provide abundance, reflects a passive consumer mindset. The project to create artificial life may be little more than womb envy; the project to create superintelligence, no more than god-envy. The desire for artificial companions may simply reflect unsatisfying

[141] In the film *Contact*, the question the radio astronomer, Ellie, hopes to ask the aliens she is about to encounter: "How did you do it?" How did you survive your technological adolescence?

social intercourse. As engineering goals, such aims lead to grandiose visions of the triumph of mind over matter and a dysfunctional mind-body relationship. The mentality behind them has already led to current dangerous social and ecological realities in our present civilization.

To displace human input and participation with artificial intelligence might seem rational insofar as it increases efficiency, productivity, leisure and wealth. But, what of human purpose when machines do all the work, both physical and mental? What is life if not effort? What will machines free us *for*? Will we drift into obsolescence, or find new forms of meaning in new challenges? What are the deep psychological motivations, aside from commercial gain, behind the current obsession with AI? These are not simply technical questions, but political, social, philosophical, and even spiritual concerns.

Science itself must evolve. Beneath its myth of detached objectivity, science is a tool of empowerment; it should not end enslaving us to AI. Science is inseparable from social management. Since we cannot live outside the physical world, science must become more truly objective by recognizing our dependence on nature and our inseparability from it. As our modern interface with nature, it should be integral with the social planning that necessarily involves that interface. Understanding, beyond prediction and control, must be the goal. That requires humility—recognizing the natural world as a partner rather than an object, and ourselves as participants rather than masters. The quest can no longer be just for the right ontology—a focus on what exists—but must also be on how to relate to it, including our relationship to own embodiment. These are hard lessons for a mentality that is genetically and historically conditioned to look outward rather than looking at the perspective from which it looks. We would do well now to incorporate, within the modern secular view, the inner opening involved in meditation or prayer.[142] The shift in attitude must extend beyond science to politics, economics, and society generally. The pattern of domination is deeply ingrained. But negotiation, respect, and reciprocity are possible—between nations, between genders, and between humanity and the natural world.

While technology has transformed the world around us, the raw nature within us has scarcely changed. Aside from age-old breeding practices, the means to change it deeply has not existed until now. For good reason, the idea of changing it through technology has been taboo. For, it thrusts upon us the task of defining what we should be—a burden that has heretofore been left to nature, to accident, or to divine will. Moreover, eugenics has an unsavory history. Genetic engineering or cyborg enhancement would be one more way for the rich—who can afford such procedures—to further dominate the poor.

We are on the threshold of the sort of genetic manipulation that can redefine the human organism. Presumably, a biological successor would preserve some of the biologically driven motivations of its progenitors, while freed from some biological limitations. Aside from being longer-lived and hardier than us, they could also be morally superior, better organized, more peaceful, for example. We can imagine the possibility of *eutopia*, a world (and a body) expressly

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[142] As we have come to know it in religion, prayer serves two divergent intentions: supplication (which is ironically about manipulation, bargaining, and control) and surrender (which lets go of all of those). The second is about readjusting the subject's attitude, not about achieving a benefit.

designed for human well-being and happiness. We can even conceive ourselves becoming the benevolent beings we idealize as gods in religion.

Yet the prospect of planning our human successors is fraught with paradox. After all, neither our natural evolution nor cultural development so far is a result of conscious planning. On the contrary, evolution adapts "unconsciously" to changing circumstance, and history seems the result of competing or warring tribes. While we have age-old ideals, which stem in part from our biology and in part in reaction to it, there is little consensus about them. On the basis of which present values can we decide the future values of our successors?

Beyond the traditional ways we know, self-modification is not an individual but a collective matter. While it concerns the capabilities of the individual, it is inherently a social issue. Just as someone else could change you by intervening in your chemistry, brain, or genes, our generation could try to determine the experience and behavior of future beings without their consent. The moral dilemma presented inheres particularly in individualistic society; it might be less of a concern in collectivist society.

Decisions might be made, as technological choices now are, by corporations anticipating what consumers want or will accept to pay for. The idea of developing a single human successor type, to represent humanity at large, is a pipedream unless humanity can achieve a corresponding unity to begin with. We can conceive a post-human *kind* with individual variations. But, just as there are races, there could be multiple sub-species or competing cultural *brands*. Are capitalism, nationalism, ethnicity, or political or religious loyalty fundamental values "we" wish for our successors?

If our successors have an enhanced ability to self-determine, they will likely not remain what we can presently envision. For similar reasons, an advanced alien mind we encounter might be incomprehensible to us. Their technology would, of course, be based on physical principles, though perhaps not those with which we are currently familiar. Technology depends on the motivations it serves, which might be equally incomprehensible to us. If aliens have achieved the relative objectivity we have discussed, our successors would have the best chance to understand them if they too embody it.

Given the distances and timescales involved in interstellar travel, it seems unlikely that we would be visited in person by alien biological life forms—or that humans would encounter them in the course of their own space exploration. It is far more plausible to suppose that embodied AI entities would be the emissaries and successors of alien biological intelligence, sent forth to contact or colonize other worlds. Since we are potential space explorers ourselves, the question of alien encounters merges with the question of human destiny, and with the future of "intelligence" or "mind" in general, whether originating on Earth or elsewhere. For many reasons, it is similarly likely that human successors will be artificial. A key question, then, is to what extent our machine descendants should be like us.

Natural intelligence, mind, and even life can be simulated. But what if we bypass mere imitation to directly create the upgraded form of being we would ideally embody? What sort of being should that be? We are highly identified with our consciousness, for example, which we might hope to preserve beyond death. But what if that stream of phenomenality is no more than an incidental aspect of naturally evolved biological life, with its built-in dysfunctions? Which is more important to represent us in the far future: artificial beings with our kind of phenomenality, or deeply moral ones? If we are asking such questions now, might more advanced alien civilizations have already answered them?

Phenomenality is a biological organism's way to monitor its own state in relation to its environment. It reflects valuation of stimuli (which is why pain hurts), premised on the survival mandate. Could an artificial organism have a different mandate, provided that did not lead to its extinction? In collective creatures such as ants, individuals may be relatively expendable without endangering the species; they may not be involved in reproduction, which is relegated to a caste. An artificial individual might be only conditionally committed to self-preservation, subject to larger commitments.

We can imagine a future society of advanced post-humans, who value the potential and contribution of each individual, but in balance with the collective interest. Concern for the subjective experience of the individual would not be the primary issue that it is for us; individuals would be able to control their phenomenality toward the end of serving the whole. They might be able to self-repair or self-modify in ways impossible for natural organisms. The individual might experience not only their "own" body but also those of their fellows, in some form of collective mind.

The potential of AI raises the question of whether all that we value as humanness—which includes our precious consciousness—could in fact be duplicated artificially and even improved upon. Our phenomenality is a product of a highly parochial biological brain, which is the result of a wasteful process of natural selection. Perhaps it is far from ideal and from what could be realized artificially. Perhaps our superintelligent AI successors would be better off without specific features inhering in our biology, such as suffering, selfishness, and negative emotions. On the other hand, perhaps the abilities we value, and their possible extensions and improvements, require some version of phenomenality and self-awareness, which could be quite different from what we know. Being them might not much resemble being us. And perhaps it need not.

CHAPTER FIFTEEN: Conclusion

In which we conclude that civilization has reached an impasse by following a one-sided approach to the natural world. A different attitude—not fostered by either science or religion—is needed if we are to survive and thrive. We must grasp that nature contains and defines us, not just the other way around.

"We had to destroy the world in theory before we could destroy it in practice." —R.D. Laing

In the early morning sunlight, I watch a small garden spider do a walkabout in the tall grass. There is a pattern to what it does, but the purpose eludes me. It is not constructing a web to catch food in place, but makes a journey that is long, on its scale, coming more or less full circle to where my observation began. I can describe its gross behavior in simple terms that could be written as a formal set of instructions. For example: begin walking up a stalk of grass; ascend to its tip; flail legs about in search of some perch on which to continue; if nothing found, descend or else drop via silk thread; if the latter, make contact with something and resume walking or else re-ascend on the thread; repeat. Following this "program," it manages to cover ground surprisingly quickly, but to what end? Is it actively foraging for some morsel it might randomly encounter? Looking for a mate? Just going for a stroll? I have no idea.

Such a curt description of its behavior may look like a macro instruction for a tiny robot. One is mistaken, however, to think of the spider as a miniature machine. While it is feasible now to build such a micro-machine, its detailed program would be far more complex than my simple formula. Yet, even that program would not fully replicate the behavior of the real spider. The miniature robot would be an artifact that behaves (and perhaps looks) much like a spider. Yet there is no guarantee that the imitation exhaustively captures the being of the natural thing. Biology and ecology, perhaps combined with robotics, can give human observers ideas about the structure and functioning of real creatures—and vice-versa. But these ideas are part of *our* structure and functioning. What the spider is in itself, and what it is "really" doing (in the mind of God?), we can only speculate. We hold such omniscience as an ideal precisely because it is beyond our actual reach.

The 1955 stage play *Inherit the Wind*, and its several film versions, underline the gulf between the scientific and the religious understanding of the world. It focuses on the utter incompatibility of the Bible with Darwin's theory of evolution. Yet, religion and science share the aim to tell a humanly meaningful story in the face of the unknown. In the play's fictionalized version of the famous Scope's trial,[143] the threat posed by Darwinism was a society rendered immoral because godless, no longer based on Christian values or theology. Indeed, this anxiety was aroused around the world by Darwin's theory, whose *Origin of Species* denied the biblical creation story

[143] Also known as the "Monkey Trial," in the state of Tennessee in July 1925. High school teacher John Scopes was tried for violating state law that prohibited the teaching of evolution. The trial was highly publicized, with William Jennings Bryan serving for the prosecution and Clarence Darrow for the defense.

and whose *Descent of Man* denied any special status to mankind. If we follow through with the modern biological understanding of life, and the modern cosmological understanding of the universe, we are left with a picture devoid of inherent meaning and human values, simply a description of what is. Yet, what else should be expected of an understanding that transcends anthropocentrism?

In that picture, the universe and the arising of life are no more than events that happened, inexplicably, simply because they could. Life, including human life, is a self-sustaining chemical chain reaction, with no goal or direction beyond its self-perpetuation. The sort of simple description of the spider's behavior could apply to the human life cycle as well: be born; be nurtured and learn in a sheltered environment; use learned skills to self-maintain; reproduce; nurture and teach offspring; grow old and die. Our little walkabout in a nutshell! Yet, as with the spider, such a description cannot fully capture what the human being is and does. A key difference is that we do not know what the spider experiences or thinks (if anything), while we *do* know what *we* experience and think. To be sure, the spider is an *agent* in its own right, but likely not a locus of phenomenality, let alone of self-consciousness.

The universe, too, may be a senseless mechanism that bumbles along on its own walkabout. Yet, it gave rise to the human consciousness that could conceive of it variously as random and meaningless or as divinely intended—both but concepts in human minds. We know no more of what the universe is "in itself" than we do of the spider or of ourselves. We have ideas about these things, to be sure, but that is all we have. Even embodied, we are outsiders looking in.

The resistance to Darwinism, which persists in our modern age like religion itself, reveals how desperate we are for sense and meaning. We seek a satisfying story about existence: where we came from, why we are here, what our goals should be, how we should conduct ourselves, and what our future will be. Ultimately, there is security *only* in stories, not in facts that are never certain or complete. The religious story is relatively simple and accessible, which perhaps accounts for its wide appeal. It may turn out that we cannot live without religion any more than without food; ironically, religion may serve an ultimately biological need.

If consciousness arose for biologically adaptive reasons, then it may, like life itself, be a function that seeks to sustain itself. The mind will tend to view reality in ways that serve and promise its own continuance, however contrived those ways might be. We have seen that the human *experience* of the world, which we cavalierly take to be reality itself, is no more (or less) than a simulation in the brain that (at least) permits us to live. Guided by real reality, this virtual reality is a fiction based on fact. However, the irony (and the joke on us) is that we invented all these notions—'fact' and 'fiction,' 'virtual' and 'real,' 'brains' and 'gods'—again, for ultimately biological reasons. Modern people may take the science of biology to be a truer account of our origins than the Bible, but human beings created both—in nearly the same historical breath! We can choose between a fairy tale and a complicated, bleak, and perpetually incomplete creation story. Yet, neither removes the existential predicament of ultimate uncertainty.

Clarence Darrow, the lawyer for the defense in the Scopes trial, lost the legal battle. In the play, his character seems to win the ideological war. But that war is hardly over, and perhaps never can be. At the end of the play, he is about to leave the now empty courtroom to return to his big-city law practice. Atheist, reviled in this small town in southern USA, he retrieves his copy of Darwin's book, inadmissible as evidence. Hesitating, he picks up as well a copy of the eminently admissible Bible left behind. With each in hand, he seems to weigh them against each other, as though to decide which to take with him. He then takes them both, suggesting they are of equal or complementary merit.

While I do not agree with that suggestion, I do have empathy for the age-old religious impulse, which seems to be as strong as the modern drive toward scientific understanding. That is because I view them less as competing truths than as parallel strategies to deal with the fundamental existential dilemma, for which I feel compassion. We are creatures aware of our creaturely state, which science aims to make explicit and religion aims to deny. Either way, the knowledge of mortality weighs heavily upon us. While denial forfeits dignity, the dignity that can be found in the scientific worldview lies in the heroic pretention to stand outside nature as "disinterested" observers, above the fray of brutish nature and the barbarity of natural selection. But, no biological creature can be truly disinterested. That is our irony and burden, enforced by pain, suffering, and finally death.

We know there is no meaning but what we assert, even though the very meaning of "meaning" suggests it should lie outside ourselves, bigger than us. Even that presumption is biologically conditioned, for reality is not simply what exists. Our sense of it is imbued with our dependent relationship to it, so that we *need* the world to seem real and loom large. Realness is not only a property of things, but implies the subjective experience of dependency on something bigger than us. Like religion, science attempts to reveal that looming reality. Ironically—especially through technology—it does so precisely to assimilate it to human need.

In its pretention to objectivity, the scientific worldview includes the view of man as biological being and evolutionary product. This worldview hardly yet recognizes its own biological determinants, nor how it bites its own tail. For, all the subject's valiant attempts to make sense of experience are ultimately futile if they are no more than biological strategies to carry on an existence that has no inherent meaning. Yet, we are not obliged to choose between self-delusion and existential despair. The stance of unknowing allows us to suspend such judgment, even indefinitely.

We humans have dabbled at godlike creative powers, making of ourselves token gods by implication. Lacking wisdom, we remain as children with dangerous toys. Far from transcending embroilment in nature's web, many of our actions ironically reflect her darker workings. Though we glory in dominating external nature, the nature at our core yet has the upper hand. While pretending to a celestial view, our sciences reveal just how terrestrial we are, while our religions reveal our insecurities and superstitions. The worlds we create may be ideal as ordered extensions of thought, but hardly in the normative sense, as the best of possible worlds. Our civilization is rather a makeshift and regimented encampment in an ancient campaign against an enemy nature. In spite of our pretensions as space travelers and world conquerors, we remain earthbound pawns of our genes.

Following a lobsided approach to the natural world has led to an impasse both for our science and for our civilization. Despite its comforting illusions and heroic quests to regulate human behavior, religion overall has failed to instill humility in homo sapiens. Slowly we are realizing that we must embrace a different attitude than endorsed by either science or religion if we are to survive. The revolution needed is profounder than any of the social experiments so far conducted. The problem lies deeper than the issues of science versus religion, capitalism versus socialism, Christianity versus Islam, democracy versus terrorism, or of one patriarchal regime versus another.

In the confrontation of subject with object, we suffer doubly from terror of the unknown and from imagination run wild. The remedy for both is to embrace the existential condition we cannot avoid or escape. To do this, we can invoke the stance of unknowing, which is not about renouncing the quest to know, but acknowledging the natural functions and limits of knowledge that mediate the relationship between subject and object. No ontology without epistemology!

What can we take away from these ruminations? First, I believe, is the lesson that knowledge is always motivated and grounded in the subject's biological embodiment. We are mortal animals, self-charged with the responsibility to know and behave as though we were gods. This is both humbling and empowering. We cannot know the world as it truly is, but we have the creative freedom to represent it, to perceive and define it, somewhat as we wish. The corollary is twofold: we cannot evade responsibility for how we see the world and how we behave; but, also, we are not passive victims of experience.

While we must take experience seriously, we should not take it too literally. While the brain's simulation is tailored to help us survive, we are not obliged to dignify its presentations as revelations of truth. As in physics, perception in daily life is relative to the state of the observer. Just as observers in physics must take into account their dynamic states and the intermediary of light, in social life we must take into account our own frame of mind, the context of claims, and the messengers of news. We must look at the epistemology of our situation alongside its apparent ontology. We should never assume that the situation is "really" as we see it.

Furthermore, we do have inner choice. Acutely aware of existing, we can claim a fuller inner presence that is capable of relating to the world in ways that are more intentional and less automatic or self-centered. To be socially responsible, and to retain control over our lives, we can evaluate technology in terms of its real (versus hyped) advantages—for us personally and for society in the long term. With thought and reflection, we can be ethical consumers.

We cannot count on moral prejudices inherited from our parents, culture, or religion to guide us toward genuine ethical behavior. What may be good for one person or generation may not be good for another. What may seem good for us personally may not be good for society or for the planet on which we all depend. We can behave more ethically toward nature by viewing it not as something exotic, but as our own flesh and blood. We can point to nature, rather than God, as a manifestation of the Great Mystery. We can realize that there will always be unanswered questions, that final or absolute certainty is not possible and not necessary.

Finally, one can find one's place in relation to competing visions of the human future. Where do we see ourselves in the spectrum of possibilities, for instance between a technological vision of a post-human future and a social vision of equality and justice? While these are not mutually exclusive, integrating them promises to be challenging. We can grasp that planetary limits render some traditional values and goals outdated. While money has served us well in many ways, it cannot remain the measure of value. The myth of progress must be redefined. The war on nature must give way to negotiation. We must admit that nature contains and defines *us,* not the other way around. Hopefully, reflecting on the relation between subject and object can aid the needed transition.

APPENDIX 1: THE TWINS PARADOX

The thought experiment based on Einstein's reasoning has one twin leaving earth in a spacecraft travelling at a significant fraction of the speed of light.[144] This observer turns around eventually and returns to earth, to discover that they have not aged as much as the twin who remains at home.

However, this cannot be an effect of the time dilation described in SR. Like length contraction, during the period of *uniform* relative motion (covered by SR) the appearance of time slowing down is a *mutual* perception. Each observer then sees (by means of light signals) the other's (identical) clock as beating at a slower rate than one's own clock. However, if either keeps a *record* of the other's time signals—e.g., by having the rate of another identical clock in their own rest frame set by the signals received—then *that* clock will continually fall behind the "normal" (rest frame) clock each also has at hand. While, for each, the two clocks will differ, the returning twin's normal (rest frame) clock should read the same as the other twin's rest frame clock when they are reunited. In other words, "time" does not dilate, nor does either primary clock slow down as a result of constant velocity. Rather, the sequence of signals received from the other is stretched out, and the record of them is accordingly "dilated."

Nevertheless, Einstein gives a physical example based on ontological reasoning: a clock at the equator moves faster (with the earth's rotation) than an identical clock near the pole; it should therefore beat at a slower rate because of the increased speed—which is not, however, uniform translatory motion. In such an experiment (where the clocks are slowly brought back together), a difference in rate due to difference in gravitational potential would have to be taken into account; for, the clock at the equator is further from the center of the earth because of the earth's oblate shape.[145] The fact that it is constantly *accelerating* (by changing direction in orbit, i.e., centrifugal force) would also have to be taken into account. The experiment that was actually performed involves an atomic clock flown around the world in an airplane, which was returned to compare to the identical "stationary" clock on the ground. Upon return, the airborne clock did differ from its counterpart on the ground. But the inertial path of flight was not uniform motion in a straight line, as in SR, nor subjected to the same or constant gravity as at sea level.

The Twins paradox is usually explained by pointing out the asymmetry in the state of motion of the two observers. The twin who blasts off must accelerate to reach speed—and acceleration is not mutually symmetrical in the way that velocity is. What justifies us to claim that it is the *spaceship* which accelerates, rather than the earth? It makes a real difference whether the space ship accelerates away from the earth or the earth accelerates away from the spaceship. The asymmetry involves the huge difference in mass of these objects, along with the fact that their

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[144] His argument in the paper has two clocks that have been synchronized together then (somehow) separated by a distance in the stationary system. They then find themselves moving with uniform velocity v toward each other and (paradoxically) for each, time lags behind the other's time because of this motion. He claims the situation is equivalent even if the clocks are *not* initially separated, but one clock leaves and then returns to its original location beside the other via a closed loop. However, either way, at least one of them must be accelerated.

[145] Being further from the center of the earth, the clock at the equator *ticks faster*, unlike the opposite effect in SR.

motion is not just relative to each other. The spaceship moves differently relative to the stars than the earth does. Energy is expended by the spaceship to propel itself while the earth does no such thing. (It would require a great deal more energy to accelerate the earth away from the spaceship than vice-versa.) This suggests that mass is responsible for the asymmetry in the Twins paradox, and that mass (as Mach asserted) involves the surrounding stars that constitute the frame of reference.[146] It remains to explain (in a non-circular way) what mass is, such that it affects the observers differently.

The changing lengths and rates of clocks predicted in SR refer to mutual effects, as communicated between moving observers by means of signals, where either frame of reference can be equally considered at rest. Since the *local* measurement of length and time by each observer in their rest frame does not depend on signals, the question is whether motion per se has some objective (ontological) effect upon dimensions locally measured. The principle of relativity says that *uniform* motion should have no such effect (for otherwise the system would not be inertial as supposed). That leaves the possibility that there could be an objective effect from *acceleration*. On the other hand, the so-called "clock postulate" maintains that acceleration has no effect on the rate of clocks in addition to that of the instantaneous velocity, which must be presumed constant and whose effects are symmetrically mutual.

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[146] A new version of SR considers the velocity relative to the center of mass between observers, so that the effect would be symmetrical only if they have equal mass. See: Abramson, N.H. (2018) "Asymmetric Special Theory of Relativity" Journal of Modern Physics, 9, 471-478. Clocks on earth and in orbit would differ because of the difference in mass between the aircraft or satellite and the earth. For two satellites of equal mass in orbit about each other, the effects of time dilation would be mutual.

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