Science and Necessity:

Epistemic Revision Under Modal Pressure

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Introduction

In this paper, I explore Saul Kripke's views on naming, identity, and natural kinds and some criticisms of the causal view of reference he endorses to (1) defend a causal picture of reference and meaning that I think is essential to scientific epistemology, and particularly to the acceptance, revision, and rejection of knowledge claims and (2) argue that epistemic revision in science occurs under the dual forces of empirical discovery and a kind of progressive cognitive and logical constraining analyzable through possible worlds that I call *modal pressure*. To bolster this view, I frame Thomas Kuhn's conception of a paradigm shift as a paradigmatic example of how epistemic change embodies Kripkean semantics and can be viewed as a reference-fixing event in which facts, presuppositions, beliefs, terms, and conditions for knowing are intentionally reshaped in response to empirical discovery and modal pressure. My motivation is to throw light on relations between semantic questions in metaphysics, epistemology, and the philosophy of language and structural ones in the philosophy of science that bear on the nature of meaning and scientific semantics. To conclude, I propose a concept I call *cognitive flexibility* to account for the rational ability to revise, replace, and alter knowledge during the course of scientific inquiry and offer some impressions about its broader epistemological significance.

Science and Necessity

Necessary truth is a fundamental aspect of scientific knowledge. Scientific knowledge is grounded in causal assertions of identity statements containing natural kind terms, for instance "water is H_2O" or "heat is molecular motion". These kinds of assertions are fundamental to the structure and progress of science as they are meant to express necessary, rigid truths about reality. However, *epistemic revision*—the revising or updating of knowledge—is commonplace in scientific practice, so how necessary are such statements if they are, by nature, flexible? Particularly during scientific paradigm shifts, it becomes apparent that some truths about natural kinds believed to be necessary might in fact be contingent. Their rigidity is put under pressure in the process of epistemic revision that paves the way to new paradigmatic worldviews. Historical examples of such revisions include the replacement of humorism in medicine after centuries, the usurping of phlogiston theory by oxygen chemistry, and the discovery of the neuroimmune system in the 21st century. Once taken as truths, statements from times before these epistemic revisions are now mere fossils. How do these changes occur exactly? What are the semantics of knowledge revision, and how do they relate to the logical criteria for identity and necessary truth? Is epistemic revision a destructive, constructive, or other kind of process? The idea of necessary truth may need wider framing to make room for the possibility of epistemic events that challenge the *degree* of necessity identity statements may have.

Kripke's Concern

Kripke (1980) rejects paradigm analytic arguments from Frege (1892) and Russel (1905) about how proper names are anchored to the world. By showing how reference fixing by description

fails in counterfactual contexts, he argues that the meaning of a name isn't a set of descriptions of an individual by showing that *semantic detachment*, or the failure of a term to refer in some near possible worlds, destabilizes descriptive theories of reference. This leads him to classify proper names as rigid designators that necessarily pick out their referents in all possible worlds. These mechanics ground his conception of identity as a necessarily true relation across possible worlds. Kripke also extends his causal view of names to natural kind terms like "water" or "heat", stipulating that they must also rigidly designate their referents in all possible worlds.

Against Frege and Russell, Kripke asserts that names are not synonymous with definite descriptions, for the latter may pick out things in the world with specific properties but fail to pick out a singular referent. Kripke is opposed to descriptive theories of reference on grounds that descriptions or sets thereof are inescapably too ambiguous to sufficiently determine meaning and pick out an individual in the world. *Descriptivism* entails that the individual referent of a name is fixed by a definite description of the form "the x such that φx" where φ specifies a description that picks out the referent uniquely and therefore constitutes the meaning of the name. For Russell specifically, the reference and meaning of descriptive statements are established by direct acquaintance with sense data or by knowledge. Kripke, however, thinks that this view and others like it that use description to dually fix reference and determine meaning are fundamentally flawed because they imply a "looseness or weakness" in language that introduces ambiguity. In his dissent, Kripke specifically classifies Wittgenstein's (1953) *family resemblance* and Searle's (1958) *cluster concept* and other descriptivist approaches to meaning as theories that do not stray far from the Frege-Russellian view, having "abandoned its letter, while retaining its spirit." (30) because they employ sets of descriptions rather than singular ones to account for meaning and so still fail to necessarily pick out individual referents. Kripke waxes:

> "It really is a nice theory. The only problem I think it has is probably common to all philosophical theories. It's wrong. You may suspect me of proposing another theory in its place; but I hope not, because I'm sure it's wrong too if it is a theory." (64)

To begin dissolving the ambiguity of descriptivism, Kripke invokes Mill's view that names have causally-determined denotation—that is, objects, concepts, or sets of truth conditions to which they refer—but *not* connotation—abstract meaning that determines reference. He attempts to modify Mill's view to include connotation, however, he observes this generates contradictions in modal contexts. If a name (*x*) is taken to be *semantically synonymous*—that is, synonymous in reference (*Bedeutung*) and meaning (*Sinn)*—one can imagine possible world with conditions that *detach* a description (φ) from its referent and therefore break the name's semantics. Kripke provides a puzzle as evidence for the phenomenon: in a possible world W* with counterfactual conditions in which the city Dartmouth retains its name but does not physically lie at the mouth of the River Dart—say because the soil at the mouth of the Dart was too nutrient-poor to sustain farmland and too wet to support architectural development, but the city founders wanted to pay homage to their nearest river —the name "Dartmouth" (*x*) fixed by the description "city at the mouth of the River Dart" (φ) detaches from the actual city called Dartmouth. It does so under what I'll call *modal pressure,* that is, a degree of logical constraint imposed by possible worlds thinking defined by how distant a possible world is when it results in semantic detachment. The notion of distance I have in mind is logical and proportional to how different from the actual world a possible world might be. At W*, speakers correctly asserting that "Dartmouth isn't at the mouth of the Dart" (*x* is ~φ) are in contradiction if the description "city at the mouth of the Dart" (φ) is taken to be the meaning of the name "Dartmouth" (*x*), illustrating broken semantics under modal pressure. Kripke thinks that all names demonstrate semantic detachment under modal pressure if their meaning is determined by

description and therefore that reference must be fixed in some other way that survives modal pressure and necessarily picks out individuals in all possible worlds.

Reference Beyond Description

Kripke constructs a descriptionless picture of reference that entails causal reference-fixing by an ostensive act of naming or *initial baptism* and subsequent passage of the name from speaker to speaker in a language community by communicative interaction. He accounts for how names acquire meaning by appealing to community usage and speakers taking part in the causal chain stemming from the naming event of an individual and adds an intentional component to the use of names:

> When the name is "passed from link to link," the receiver of the name must, I think, intend when he learns it to use it with the same reference as the man from whom he heard it. If I hear the name "Napoleon" and decide it would be a nice name for my pet aardvark, I do not satisfy this condition. (96)

Gareth Evans (1973) criticizes Kripke for ignoring context, passing over conversational constraint, and resting on a causal "magic trick" that passes the capacity to denote with intention from speaker to speaker. Evans argues that *conversational history* constrains the meaning of utterances by actively determining the context and establishes a shared body of information among speakers that determines meaning, not an initial baptism or causal story. He illustrates that if I say "Louis was brave" in a conversation about King Louis XIII of France, it is known *from the context* that the utterance "Louis" refers to the French king and not some other person like the American trumpeter Louis Armstrong. For Evans, meaning is squarely its use in the language. (Wittgenstein 1953)

Further, Evans thinks Kripke's assumption that the intentional capacity for a speaker to denote a particular thing in the world is grounded in becoming a link in a causal communicative chain overlooks cases in which speakers use names correctly but do not know their actual reference. Speakers, he rightly observes, may pick up a name from a conversation or some fragment of information and merely appear to use it correctly. This echoes Chomsky's (1965) distinction between speaker *competence*—their knowledge of a language—and *performance*—their actual use of that language in concrete situations. (4)

There are many possible cases in which an incompetent speaker can perform linguistically by using a word, phrase, or name without *knowing* its real meaning. For Evans, performance is insufficient for attributing knowledge and intention to a speaker, although the speaker may appear competent by, as he puts it, the "mouthpiece syndrome" that leads us to "attribute sense and reference to a man's remarks only because we hear someone else speaking through him; as we might a messenger, carrying a message about matters of which he was entirely ignorant." (192) Evans further contends that Kripke's move to rigid designation and causal reference fixing does not solve the ambiguity of reference by description. For Evans, the relevant ambiguity is that a description or cluster refers to whatever items happen to satisfy them at a given time and so do not necessarily pick out any particular things or have a fully determined meaning:

> The problem is clear enough: what conditions have to be satisfied for the speaker to have said that *p* when he utters a sentence which may appropriately be used to say that *q,* and *r,* and *s* in addition? Two obvious alternative answers are (a) the extent to which it is reasonable for his audience to conclude that he was saying *p* [and] (b) his intending to say that *p*. (194)

Evans reframes the problem by distinguishing between conditions for expressing propositions that are (a) related to the interpretation and speaker intentions and (b) constrained by conversational history and knowledge or belief states. Looking at Kripke's view in this light, it becomes apparent that although speakers may utter a name whose referent is causally determined, they may be ignorant of its denotation, connotation, or both and also lack the intentionality he ascribes to them. Therefore, Evans advances that meaning is not determined by causal reference either:

> …it may begin to appear that what gets said is going to be determined by what name is used, what items bear the name, and general principles for contextual disambiguation. The causal origin of the speaker's familiarity with the name, save certain specialized "mouthpiece cases", does not seem to have a critical role to play. (195)

It is intuitive to think that there is more to meaning than initial baptisms and causal stories. Context plays a crucial determining role in what utterances are used and how they are understood. However, meaning requires some causal element to doubly bind it to language and to the world. Without some causal relation to the world, meaning would be unanchored and ungrounded in it, depend on already meaning-laden context to be determined, and so may detach entirely from the world that language represents and is used to discuss. This is reasoning in a circle. To escape it, the meaning of utterances must have a way to be determined that points to individuals or sets thereof. How else could this sentence refer to Charles Darwin, Issac Newton, atoms, or tigers? How do names and terms refer to individuals if they aren't somehow grounded in the world? The idea of meaning without causality introduces, in my view, perplexing complications, especially to scientific discourse, which relies on the identification of concrete individuals like hydrogen atoms, gold particles, brains, and patients that are all grounded externally to any context, conversations,

knowledge, beliefs, or attitudes about them. We need a way not only to refer without ambiguity, but also to *select* individuals with language. These abilities are, in my view, necessary for any theory of reference to get off the ground and have a chance at naturalistically accounting for meaning. Since names are narrow in the sense that they refer to persons, broadening the discussion to natural kinds is useful, as well as more relevant to the concerns about scientific knowledge expressed at the ouset. Luckily for us, Kripke moved in this direction as well.

Possibility, Identity, and Natural Kinds

Robert Stalnaker (1997) argues that Kripke's key philosophical contribution lies in the distinctions he makes between three kinds of metaphysical and semantic questions: (1) *descriptive* semantic questions about language use and semantic mechanisms, (2) *foundational* semantic questions about the facts that determine semantic mechanisms, and (3) questions about *capacities and potentialities* that ask about what might have been true of the referents of names. Stalnaker believes Kripke answers the descriptive semantic questions with Mill's view that the *semantic value*—Stalnaker's neutral term for that which makes expressions intelligible—of a name simply *is* its referent, the foundational semantic questions with causal connections between speakers and the world, and the questions about capacities and potentialities by employing the possible worlds framework as a logical apparatus for talking about a language independently from what it refers to.

Kripke's causal-intentional view of reference and meaning is motivated by concerns about identity statements containing names, which he argues express necessary truths in all possible worlds. This view is grounded in a two-pronged constraint that (1) identity statements *cannot* be analyzed by substituting definite descriptions for proper names and (2) that the meaning of a name *is* the thing it picks out in the world. Why? This stance solves cases like the Dartmouth puzzle by

fixing the referent of a name to the same individual in all possible worlds so that a name functions properly under modal pressure. It also makes it possible to talk about language abstractly with possible worlds. The value of Kripke's frame is that it lets us examine the role of language in logical space and at a sufficient level of abstraction from concrete terms and statements. Abstraction from concrete particulars helps us get a grip on identity relations and on the metaphysics of necessity. What is it for something to be necessarily identical to something else? What grounds the identity relations that structure assertions about what exists? What are we saying when we say that something *is* something else? These questions are not only essential for metaphysics and semantics, but crucial in scientific activity, which is squarely in the business of clarifying what things are.

Kripke analyzes the logical status of identity statements containing names as necessarily true in all possible worlds on grounds of rigid designation, then extends this analysis to natural kind terms like "water", "tigers", and "gold" that identify groups of individuals in the world. He argues that identity containing such terms (A=B) is necessary if and only if its terms are rigid designators and is otherwise contingent. Kripke believes such contingency is the source of much error in the analysis of identity statements that may rather be relations between synonymous terms and not actually identical things. Scientific activity proposes and establishes identity relations—discovery either solidifies necessity by promoting identities to knowledge or revising them by revealing a previously unknown or poorly understood contingency. Propositions containing natural kind terms that express necessary scientific truths such as "water is H_2O", "light is a stream of photons", or "heat is molecular motion" assert identities. If modal pressure from a possible world can break an identity statement (Is there a world where heat is not molecular motion?), then that statement doesn't express a necessary truth but rather a contingent one and science was mistaken about the nature of the individuals in the relation.

For Kripke, the relation between a natural kind term and its referent must be such that imagining things being any other way requires conditions so far away from reality and logically distant from the actual world that these worlds degrade as legitimate possibilities at all. Resistance to modal pressure then, in my view, is a crucial characteristic of scientific assertion and a proxy for the degree of rigidity of an identity statement. If an identity holds in more and more distant possible worlds, it has high resistance to modal pressure and a high degree of rigidity constituent of necessary truth. If it breaks in some reasonably near worlds, it has low resistance to modal pressure and lower rigidity. Perhaps what scientists are fundamentally doing is engaging in a long game of reference fixing and identity grounding—that is, clarifying the actual relations among things in the world and statements of identity containing natural kind terms and testing their rigidity against modal pressure as they carve up logical and actual space.

Kripke's modal arguments entail that identity statements are in fact identity relations and necessary truths if and only if it is impossible to imagine things being otherwise, i.e. that there are no near possible worlds at which the relation is false, or, put differently they have high rigidity and resistance to modal pressure. The meaning of natural kind terms also depends on the facts, as Kripke notes in discussing the meaning of the term "gold":

> I believe that, in general, terms for natural kinds (e.g. animal, vegetable, and chemical kinds) get their reference fixed in this way; the substance is defined as the kind instantiated by (almost all of) a given sample. The 'almost all' qualification allows that some fool's gold may be present in the sample. If the original sample has a small number of deviant items, they will be rejected as not really gold. If, on the other hand, the supposition that there is one uniform substance or kind in the initial sample proves more radically in error, reactions can vary:

> sometimes we may declare that there are two kinds of gold, sometimes we may drop the term 'gold'. (135)

The point of the example is, I think, to illustrate that natural kind terms like "gold" are causally fixed to reference samples of material *believed* to be members of that kind until inquiry or observation challenges otherwise. Generalizing the point, Kripke argues that in the case where a sample set of items *I* are believed to belong to a kind *K* but in fact belong to a previously known kind *L,* that *observational error* led to the false belief that the members of *I* possessed some characteristic *C* that excluded them from *L*, and that we would, under these conditions, say kind *K* does not exist despite its reference being fixed to the original sample. This basic scheme, in my view, is a model for epistemic revision and scientific inquiry. For instance, a biologist might believe that some newly discovered plants (*I*) are a new species (*K*) because they metabolize energy exclusively in the dark (*C*) but may later discover that it photosynthesizes regularly during the day but is capable of long-term energy storage and therefore is part of the existing natural kind "photosynthetic organisms" (*L*). The crucial point, I think, is that phenomenology, empirical discovery, and observation can be misleading and misattribute contingent properties to the nature of things. The assertion "heat is the sensation of feeling warm" isn't an identity statement nor a necessary truth. However, discovery that all cases of heat are cases of molecular motion in conjunction with the modal impossibility of imagining heat not being coextensive with molecular motion grounds the *a posteriori* necessary truth of the statement "heat is molecular motion". In these *I-K-L* cases, we come to believe some identity statement that relates a natural kind term to what it picks out in the world based on observation, and that belief is promoted to knowledge or revised based on discovery and serially subject to modal pressure on the way to rigidity. These dynamics of identification, investigation, discovery, reference fixing, and epistemic revision are, in my view, fundamentals of scientific inquiry that provide an

account of the mechanics of epistemic and semantic change. As the causal stories associated with the natural kind terms are uncovered and subject to modal pressure, knowledge is generated and refined.

Paradigms and Propositions

Paradigm shifts are, in my view, shining examples of *I-K-L* cases at work driving epistemic change and promoting new observations to knowledge. Kuhn (1962) defines paradigms as "universally recognized scientific achievements that for a time provide model problems and solutions to a community of practitioners" (viii) and that evidence-based explanations are scientific orthodoxy until enough anomalous observations cause a shift of theoretical and methodological revision or replacement. During the shift, scientists revise and replace terms and logical relationships, including identity relations, with finer grained or new terms and logic because of some new disruptive discovery. After a paradigm shift, scientists see the world differently than they did under the previous paradigm. (§X) They revise and replace elements of their worldview, beliefs, and knowledge. This revision and replacement process instantiates new semantic dynamics and fundamentally alters the truth conditions of identity statements and other propositions, context, conditions for knowledge states, the strength of beliefs, the domain of discourse, and even constrains the logical limits of projection and hypothesis:

> …if new theories are called forth to resolve anomalies in the relation of an existing theory to nature, then the successful new theory must somewhere permit predictions that are different from those derived from its predecessor. That difference could not occur if the two were logically compatible. In the process of being assimilated, the second must displace the

> first…It is hard to see how new theories could arise without these destructive changes in beliefs about nature. Though logical inclusiveness remains a permissible view of the relation between successive scientific theories, it is a historical implausibility. (97)

If new techniques and theories developed to account for the anomalies can skillfully cope (Dreyfus 1972) with the anomalous data, this results in the simultaneous rejection of the old paradigm and substitution of the new—not rationally adjusting in this way, Kuhn says, would be to reject science itself. (1962, p. 79) Semantically, a new paradigm's rational and cognitive adjustments semantically detach natural kind terms from their referents, restructure domain-specific logic, and sharpen identity statements in an upwelling of new knowledge and beliefs that grounds new paradigmatic reasoning. For example, the molecular revolution in genetics and biology is grounded in the paradigmatic empirical discovery that DNA is the genetic material (Watson and Crick 1953) and assimilation of that and related assertions like the central dogma of molecular biology—that DNA codes for RNA and RNA codes for protein—into biological thought and semantics through theoretical, epistemic, methodological, and doxastic revisions were necessitated by accepting the identity to be true in all possible worlds. To apply modal pressure, we might imagine a world W** in which DNA is not the genetic material. In fact, scientists were at one point imagining this world in a striking instance of Kripke's *I-K-L* case.

A microorganism that substitutes arsenic for phosphorus in the backbone of its DNA (*I*) was discovered in central California in 2010, however the consensus was that this alternative biochemistry (*C*) did not disqualify the organism as a DNA-based living (*L*) thing and classify it as some new kind of organism (*K*). (Wolfe-Simon 2010) Even in light of a new discovery that *looked* like a new building block of life had been discovered, scientists accounted for an anomaly by determining that the arsenic substitution wasn't enough to destabilize Watson and Crick's

paradigmatic natural kind identity and usher in a new paradigm. Continuing to apply modal pressure, what would W** be like? Likely foreign and alien, for it would have differed in all the ways that determined the fact that deoxyribonucleic acid is the biological basis of living things. W* might include non-carbon-based biochemistry, novel molecular biophysics but, given the rigidity of chemistry and physics this world could only be logically entertained in the same way as square circle. This combination of empirical discovery tested with modal pressure is, in my view, a fundamental mechanism for propelling or halting epistemic change, promoting discoveries to knowledge, revising current identities, and so a crucial aspect of scientific activity. It provides a semantic picture that complements the sociohistorical one of scientific revolutions. If knowledge can be altered in this way, which I believe it regularly is and has been throughout the history of science, medicine, and other disciplines, what might this imply in a broader epistemological sense?

Toward Epistemic Pragmatism

Knowledge is fundamentally a relation between an agent and some proposition, information, or evidence embedded in a context. It also exists in a feedback loop with the states of knowers and believers, and with the conditions and contents of the world. Contextual or environmental change may affect the conditions of knowledge and belief states, as well as the facts on which beliefs and knowledge rest. Modal pressure and empirical discovery may influence our understanding of propositions and an important point, I think, is that these relationships and dependencies are *not static*—they change by nature. I do not mean this in a relativistic sense but rather in a pragmatic and natural one pinned to knowledge and belief as we experience and use them in ordinary rationality, choice, observation, scientific activity, and other contexts. In ordinary life and in science, our knowledge is not completely opaque and concrete, nor are our beliefs, desires, and other dispositions

that play a crucial role in how we think about the world and engage in rational activity, scientific or otherwise. In these activities, we employ knowledge to *act* appropriately—to determine what to say in a conversation and what to ultimately do in any given context. To *calibrate* those actions to the world and to information, data, events, states, conditions, and possibilities, knowledge must be *adaptable* and therefore inherently less concrete and opaque as one might like to imagine it. In reasoning and action, we exhibit *cognitive flexibility* when we adapt what we know, believe, and think to contexts, discoveries, new information we encounter in making contact with reality in various ways, including scientific inquiry and experimentation. I think this flexibility accounts in a general way for our inherent ability to revise, replace, alter, and renew our knowledge and beliefs under new paradigms in science, and other sets of new conditions in ordinary experience. It also grounds the ideas that knowing involves more than merely being aware of bits of information and is rather a more networked phenomenon embedded into the larger cognitive topography.

A thought experiment reminiscent of epistemic puzzles related to Gettier (1963) problems raised by Kripke (2011) provides a context in which to sharpen some of these impressionistic thoughts about the relation between knowledge and broader rationality. Consider that it may appear to an agent *S* that there is a red barn in the foggy countryside (*p*), yet *S* may not know or believe this to be the case, formally: $\Diamond(K_s(p) \vee B_s(p)$—it may be too foggy to clearly see, or *S* may guess that she sees a red barn and so not claim to know in any strong sense. Although *S* doubts that she is in a state of knowing that *p*, we can *ascribe* to her a belief or knowledge that *p* if *we* know *p* is true, say by having lived in the countryside for years and having repeatedly seen the barn in question under a range of different conditions. As such, what *S* thinks she knows or believes—and so her attitudes directed at *p*—is at least partially constrained by the contextual relations among *S*, some information, perceptual content, and the actual state of world corresponding to the truth or falsity of *p*. There are also possible worlds in which *p* is true with different conditions and others where it

is false. These different possibilities and potentialities modulate and determine whether *S* knows or rightly believes that *p*. As framed, the truth or falsity of a proposition is a major, yet not the sole determinant of knowing—one may therefore come to know or believe through normative, dispositional, or other qualitative and cognitive phenomena.

Merely having information may also not necessarily entail knowing anything due to a wide range of possibilities that could influence the entailment. For instance, *S* may have a neurological condition that makes green barns appear like red barns in foggy conditions, or *S* could be red-green colorblind. In these worlds, *S* may think she knows there are red barns in the countryside by some basic, normally reliable mechanism, yet nevertheless be wrong. If we imagine that *S* is aware of her neurological condition, the appearance of a red barn in the fog would leads *S* to believe that there is a green barn in the fog, despite having an experience that presents the world in a way that it is, in fact, contrary to reality. In this case, *S* knows that *p* via a "faulty" perception, but how faulty is it if *S* can attain knowledge through it? Is there a cognitive parallel to "mouthpiece syndrome" that applies more widely to epistemic performance and competence? This case is not intended to solve any of the issues it raises, but to suggest that the character of knowledge is determined simultaneously by causal realities about the world, conditions of thinkers, and the context in which thinkers interact with these elements.

Perhaps knowledge is fundamentally shaped by coping with the possibility of things being otherwise such that what we don't or might come to know strongly determines what we do in fact know. This leaves a fundamental role for modality to fill not only in the epistemology of ordinary knowledge but that of scientific knowledge as well, as illustrated by the resonance of Kripke's excursions into modality and meaning with Kuhn's paradigm shifts and epistemic change. Having the information—the *data*—alone is perhaps not all that matters for knowing as an infinite set of descriptions isn't sufficient to determine necessity across possible worlds. Knowledge is grounded in

activities that *calibrate* one's attitudes toward propositions about the world such that they link up with the common body of terms, concepts, conventions, attitudes, and knowledge we share. From this vantage point, knowledge looks highly determined by interaction with the world and rational activity and must have a degree of flexibility if it is able to accurately represent the world and the relations among the things in it.

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