Realism vs. Instrumentalism and the Limits of Scientific Description

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Scientific theories provide extraordinarily successful descriptions and predictions of the physical world, yet their epistemic success does not by itself determine the ontological status of the entities, structures, and concepts found in those theories. This paper examines the distinction between epistemology and ontology through the broader philosophical tension between scientific realism and instrumentalism. It argues that a successful scientific representation should neither be regarded as merely a convenient computational instrument nor automatically identified with reality itself. Rather, scientific knowledge occupies an intermediate domain in which conceptual and mathematical structures provide access to an objective reality while simultaneously imposing conditions on how that reality can be represented and understood. The distinction between form and content provides a framework for examining this relationship. Mathematical form may possess extraordinary predictive and explanatory power without settling the question of what, ontologically, constitutes the physical content represented by that form. The analysis presented in this paper differentiates epistemic limitations from ontological indeterminacy, mathematical determinism from metaphysical determinism, and conceptual descriptions from the realities they seek to represent. Moreover, we can state that scientific theories can provide genuine knowledge of objective structures in reality while remaining epistemically limited representations rather than transparent descriptions of reality in itself. Recognizing this distinction does not weaken science; rather, it establishes a more careful boundary between what a theory demonstrates, what it represents, and what may legitimately be inferred about the ultimate nature of reality.

1 Full disclosure: the ideas expressed in this paper are entirely of the author's, while the wording was partly formatted by AI (CHATGPT-4).

1. Concept vs. particular thing

A **concept** is a general mental or intellectual representation that allows us to recognize, classify, describe, and reason about things, properties, relations, or possibilities.

For example, *tree*, *red*, *justice*, *electron*, *cause*, and *freedom* are concepts. A concept is not necessarily a physical object; it is something we use **to think about and organize what we encounter**.

From a philosophical point of view, however, the idea of a concept becomes much more interesting.

Suppose you see three different trees:

- an oak
- a pine
- a maple

They are physically different objects, yet you can apply the same concept **TREE** to all three.

This raises a fundamental philosophical question: What exactly makes different things instances of the same concept? This is the ancient **problem of universals**. Plato[1] famously argued that universals have a reality independent of particular things: the individual trees participate in something like the universal *Tree*. Aristotle[2] took a different approach, locating universals in things rather than in a separate realm.

This issue remains alive today.

2. Concepts are not the same as words

This distinction is extremely important. The word **"tree"** is a linguistic symbol. The concept **TREE** is what the symbol is used to express. And the actual **tree** in your backyard is neither the word nor the concept. So we can distinguish: **word → concept → object.** But the relationship isn't always that simple. A concept can refer to things that don't exist physically at all:

- unicorn
- infinity
- God
- square circle
- justice
- possibility

Consequently, having a concept does not guarantee that something corresponding to it exists in reality.

That distinction becomes crucial in metaphysics.

3. Concept vs. perception

A concept is also different from a perceptual image.

You can have the concept **DOG** without having a particular dog in front of you. In fact, you can think about dogs when there are no dogs anywhere near you. The concept therefore allows the mind to **abstract beyond immediate sensory experience**. This is one reason concepts are so important to science. You never directly perceive:

- an electron
- a wave function
- spacetime curvature
- entropy
- a Hilbert space

You perceive measurements and experimental outcomes. Concepts allow us to organize those observations into theoretical structures.

4. Concepts allow generalization

Perhaps the most important function of concepts is **generalization**. Suppose you encounter:

Dog A → barks
Dog B → barks
Dog C → barks

Eventually you form concepts such as **DOG**, **BARKING**, and perhaps **ANIMAL**. Conceptual thought allows you to move from: *this particular thing* to *things of this kind*. And then to: *things of this kind behave in this way.* That transition is fundamental to **inductive reasoning and science**.

5. Concepts can be more or less precise

Not all concepts have sharply defined boundaries. Consider **BACHELOR**. It is relatively precise.

But consider:

- tall
- beautiful
- intelligent
- mountain
- species
- consciousness
- life

These can have fuzzy boundaries.

This leads to an important distinction between **classical concepts** and **prototype concepts**. The classical view says that a concept can be defined by necessary and sufficient conditions. For example: Triangle = a three-sided polygon. But many ordinary concepts don't behave this way. What exactly is the necessary and sufficient definition of **GAME**, for example? This is one reason philosophers and cognitive scientists became interested in **family resemblance**, associated particularly with Wittgenstein[3].

On the other hand, a **prototype concept** is a concept organized around a **typical or representative example** rather than a strict definition.

Example: BIRD

Consider the concept **BIRD**. A robin is a very good example of a bird. A sparrow is also highly representative.

But consider:

- penguin
- ostrich
- emu
- kiwi

They are unquestionably birds, but they don't resemble our typical mental image of a bird nearly as much. And yet there is no simple set of properties such as: "Has wings + flies + is small + sings" that defines *bird*, because penguins don't fly, ostriches don't fly, and some birds have unusual characteristics.

So our concept **BIRD** can have a kind of psychological center: **prototype → robin/sparrow** and decreasing similarity as we move toward less typical members.

6. Concepts can be constitutive of a theory

This distinction is particularly relevant to both physics and philosophy. Consider the concept of **TIME**. Physics does not simply discover "time" lying in nature in the same way that we discover a rock or a particle; rather, it develops a conceptual framework in which temporal relations can be defined, represented, and measured. As we have explored previously [4], what we directly encounter in the physical world is **change and motion** (aside note: change is the result of energy exchanges, and according to our latest theory in Quantum Field Theory, energy exchanges are the result of particle exchanges, that is, particles in motion. So ultimately, the basis of change is motion[5]). In the absence of any change whatsoever, the concept of time would have no operational significance: there would be no physical process by which the passage or duration of time could be distinguished or measured.

A clock illustrates this point. A clock is a physical system undergoing some regular, repeatable process—whether the oscillation of a pendulum, the vibration of a quartz crystal, or the transition between energy states of an atom. In this sense, **we use one physical process to quantify other physical processes**. We do not observe "time itself" moving; rather, we observe changes and establish temporal relationships between them. A clock therefore does not measure time as though time were an independent substance. It provides a standardized physical process against which durations and sequences of other processes can be compared.

Our ancestors employed this principle long before they understood its physical basis. They observed recurring changes in their environment—the apparent motion of the Sun, the phases of the Moon, and the changing seasons—and constructed increasingly sophisticated systems of temporal measurement. The calendar, for example, provided a conceptual and practical framework for organizing these recurring astronomical changes, long before the Earth's rotation on its axis and its orbit around the Sun were understood.

The history of physics subsequently illustrates how profoundly our **concept of time** can change. Newtonian mechanics incorporated **absolute time**, conceived as universal and independent of physical processes. Special relativity replaced this with a framework in which temporal measurements depend upon the observer's state of motion, while introducing the invariant concept of **proper time** along a worldline. General relativity went further, incorporating temporal and spatial relations into a four-dimensional, dynamical geometric structure—**spacetime**.

The important philosophical point is that the successive development of these theories does not simply represent increasingly precise measurements of an independently obvious entity called "time." Rather, it illustrates how our **conceptual representation of temporal reality evolves as our understanding of physical phenomena develops**. The question therefore remains open whether time, as represented in our theories, is a fundamental constituent of reality or whether it is an emergent or relational feature arising from something more fundamental.

So an important philosophical question that arises is: Are scientific concepts discovered, invented, or constructed? The answer is probably some combination of all three**. We invent the conceptual framework, but we don't have unlimited freedom in doing so. Reality constrains which conceptual frameworks successfully describe experience.**

7. Concepts can be ontological or epistemological

Suppose we have the concept **electron**. There are at least two questions:

Epistemological: What observations justify our concept of an electron?

Ontological: Does something corresponding to the concept electron actually exist independently of our conceptual scheme?

These are different questions. And this is where philosophical confusion often arises: The fact that we possess a concept does not establish the ontological reality of what the concept represents.

For example, we have perfectly coherent concepts of: unicorns, fictional characters, possible worlds, infinity. Conceptual coherence isn't the same thing as existence.

8. Concepts influence what we perceive

There is also a fascinating reverse direction. We don't merely use concepts **after** perceiving reality. Our concepts can influence what we notice and how we interpret what we perceive. A physicist looking at an experimental result sees something quite different from what a person unfamiliar with physics sees. The raw sensory input may be similar, but the conceptual framework is different. It doesn't necessarily mean that reality is invented by us.

Rather: **Our access to reality is mediated by conceptual structures.** That's an important distinction.

9. Concepts can be mistaken

A concept can be:

- vague
- internally inconsistent
- overly broad
- overly narrow
- based on a false assumption
- empirically inadequate

This is why **conceptual analysis** is such an important philosophical activity. Philosophers frequently ask: What exactly do we mean by X? Before asking: Is X true? For example, before debating whether **free will** exists, we should clarify what *free will* means. Is it: freedom from causation? Or the ability to act according to one's reasons without coercion?

Those definitions produce very different philosophical problems.

10. A particularly important distinction: concept vs. reality

I'd put this at the center of the philosophical understanding of concepts:

A concept is a tool for representing or organizing reality; it is not automatically a constituent of reality itself.

This is especially important in discussions about physics. For example:

Concept: spacetime

Mathematical representation: metric tensor $g_{\mu\nu}$.

Empirical phenomena: clocks, rods, gravitational effects, light propagation, etc.

The philosophical question is whether *spacetime itself* is ontologically fundamental, or whether it is a particularly powerful conceptual/mathematical representation of something deeper. That is an **ontological question**, not merely a mathematical one.

11. Concepts, propositions, and theories

It's useful to see a hierarchy: **Experience → concepts → propositions → theories.**

For example: We observe objects falling. We form concepts: object, mass, acceleration, gravity. We formulate a proposition: Objects near Earth's surface accelerate downward. We construct a theory: Newtonian mechanics. The same applies to quantum mechanics: observations → concepts such as state, observable, amplitude → mathematical propositions → quantum theory.

This distinction can help prevent a common philosophical mistake: **confusing the mathematical structure we use to represent something with the thing being represented.**

12. The deepest philosophical question

Before we delve into this question, noteworthy to revisit the two giants from the classical Greek world, Plato and Aristotle, and a very brief summary of their perspective philosophy.

Plato

Plato held that the world accessible to the senses is imperfect and changing, while genuine knowledge concerns eternal, unchanging **Forms** or Ideas, such as Beauty, Justice, and the Good. He therefore drew a strong distinction between **appearance and reality**, and between opinion (*doxa*) and knowledge (*epistēmē*). Philosophy is the attempt to move from appearances toward understanding the deeper rational structure of reality. His dialogues also emphasize that philosophical inquiry often exposes problems rather than providing simple final answers.

Aristotle

Aristotle rejected Plato's separation of Forms into a separate realm and instead held that form and matter are united in actual things (**hylomorphism**). He placed much greater emphasis on observation and began philosophical inquiry from the phenomena and puzzles presented by the world as experienced. His philosophy developed systematic accounts of substance, causation, change, logic, biology, ethics, and human flourishing.

In broad terms, Plato looked **beyond the changing world for its underlying Forms**, whereas Aristotle looked **within the changing world for its organizing principles**.

Ultimately, the philosophy of concepts leads to a very profound question: **Does our conceptual framework reveal the structure of reality, or does it impose structure upon an otherwise unconceptualized reality?**

There are several broad positions.

Realism: Our concepts can correspond to structures that genuinely exist independently of us.

Conceptualism: Universals and categories are primarily products of conceptual activity.

Nominalism: There are no universals in reality; there are only individual things, and we group them using names/concepts.

Kantian view[6]: The mind contributes fundamental conceptual structures through which experience becomes intelligible, while we cannot simply assume that those structures describe reality "as it is in itself."

A useful formulation might be:

Epistemology asks how we construct and justify our concepts of reality; ontology asks whether the structures represented by those concepts actually exist.

That distinction is one of the best safeguards against accidentally turning a **conceptual or mathematical necessity into an ontological necessity**.

A useful way to distinguish them is to ask **what kind of necessity is doing the work**.

13. Conceptual necessity

Something is **conceptually necessary** when denying it conflicts with the meaning or definition of the concepts involved.

Example:

A bachelor is an unmarried man. If someone says: "John is a bachelor and John is married." We have a conceptual contradiction **provided "bachelor" retains its ordinary definition**.

Another example: A triangle has three sides. You don't need to measure actual triangles to establish this. It follows from what we mean by *triangle*.

But notice the philosophical caution: **Conceptual necessity tells us about the relationships among our concepts; it does not by itself tell us what exists in the external world.**

14. Mathematical necessity

Something is **mathematically necessary** when it follows necessarily from a mathematical system's axioms, definitions, and rules of inference.

For example: 2+2=4. Or, in Euclidean geometry: The angles of a Euclidean triangle sum to 180^0. The second example is particularly instructive. It is mathematically necessary **within Euclidean geometry**. But it is not necessarily true of physical triangles drawn on a curved surface. On a sphere, for example, a triangle can have angles whose sum is greater than 180^0.

So: **Mathematical necessity can be conditional on the underlying axioms.**

This becomes very important in physics.

15. Ontological necessity

Something is **ontologically necessary** if it must exist or be the case **because of the nature of reality itself**, rather than merely because of our definitions or mathematical conventions.

For example, suppose someone argues: "If physical objects exist, they necessarily occupy some physical state." That would be an ontological claim. A stronger example would be a metaphysical claim such as: "A contingent universe necessarily requires a necessary ground of existence." Whether that is actually true is highly controversial. But **if** it were true, the necessity would be ontological/metaphysical.

The crucial question is: **Is the necessity imposed by our conceptual framework, or is it imposed by reality itself?**

A very useful comparison:

Type	Example	Source of necessity
Conceptual	A bachelor is unmarried	Meaning of the concept
Mathematical	2+2=4	Axioms, definitions, logical rules
Ontological	"Massive bodies necessarily have gravitational effects"	Claimed structure of physical reality

The third category is much harder to establish.

<u>Physics gives us an especially interesting case</u>

Consider: $E=mc^2$. Is this equation **conceptually necessary**? No. You could define concepts differently. Is it **mathematically necessary**? Not in isolation. The equation isn't a theorem of pure mathematics. It is a consequence of the mathematical structure of **special relativity**. Is it **ontologically necessary**? If special relativity correctly describes the physical world, then the mass-energy relationship reflects something about the physical structure of reality. But even then, we should distinguish: **necessary given the physical theory** from **necessary in reality independently of any theory.**

That distinction is often overlooked.

Suppose general relativity uses a four-dimensional manifold M equipped with a metric $g_{\mu\nu}$. One might say: "Reality is necessarily four-dimensional spacetime." But that conclusion does **not** automatically follow. At most, we initially have: **GR represents physical phenomena using a four-dimensional manifold.** That's a mathematical fact about the theory. Then comes the philosophical question: Does the mathematical structure correspond to something ontologically fundamental? That's the difference between **mathematical structure** and **ontology**. Someone could instead argue that spacetime is an effective or relational structure emerging from something more fundamental.

16. Logical necessity

One more important distinction: logical necessity.

A proposition is logically necessary if its negation produces a contradiction under the relevant logical rules. For example: $P \vee \neg P$ (the classical law of excluded middle of P or not-P). So we can roughly distinguish: **Logical necessity** → follows from logic. **Conceptual necessity** → follows from meanings/definitions. **Mathematical necessity** → follows from mathematical axioms and inference. **Physical necessity** → follows from the laws/structure of a physical theory. **Ontological necessity** → follows from what reality must be like independently of our particular descriptions.

And here's the philosophical trap I'd especially keep in mind: Moving from "X is mathematically necessary within our theory" to "X is ontologically necessary in reality" requires an additional philosophical argument.

That is precisely where questions about time, spacetime, quantum mechanics, determinism, causality, and even God become much more interesting.

So let’s examine 10 prominent concepts**,** chosen especially to illustrate the distinction between conceptual usefulness and ontological reality**.**

Concept	What it means / does	Applicability	Important limitation
a. Cause	Something that produces or contributes to an effect	Explaining events, science, ordinary reasoning	Causation may be difficult to define at the fundamental quantum level; correlation is not necessarily causation
b. Time	Orders events and allows us to describe duration and change	Physics, chronology, dynamics, everyday experience	Whether time is fundamental or emergent is unresolved; relativity undermines the idea of universal time
c. Space	Provides a framework for locating and relating objects	Geometry, mechanics, physics, navigation	In GR, space is not an independent fixed background; its geometry is dynamical
d. Object	Treats something as a distinct entity with properties	Ordinary experience, physics, metaphysics	At quantum scales, the notion of a persistent, independently existing "object" becomes problematic
e. Identity	Allows us to say that something is the "same thing" over time	Logic, mathematics, biology, personal identity	What makes something identical through change can become philosophically ambiguous
f. Probability	Represents uncertainty, possibility, or frequency	Statistics, quantum mechanics, decision theory	It is controversial whether probability represents ignorance, physical indeterminacy, propensity, or something else
g. Information	Represents distinctions, correlations, or reductions in uncertainty	Computing, physics, communication, biology	Information always requires clarification of *what* is carrying it and relative to what description

Concept	What it means / does	Applicability	Important limitation
h. Matter	Traditionally refers to physical substance composing the material world	Classical physics, metaphysics, ordinary language	Modern physics doesn't provide a simple, unified notion of "matter"; fields and quantum states complicate the concept
i. Energy	A conserved quantity associated with the capacity/ability of physical systems to undergo transformations	Virtually all of physics	Energy is not a substance or "stuff"; its meaning depends on the physical theory and symmetries involved
j. Self / Person	Treats an individual as a continuing subject or agent	Ethics, psychology, law, consciousness, everyday life	The apparent unity and persistence of the self raises difficult questions about consciousness, memory, and personal identity

17. The deeper point

Notice that applicability and ontological status are different questions**.**

Take energy**.** We can use the concept with extraordinary precision: $E=mc^2$, and calculate physical consequences to remarkable accuracy. But this doesn't mean that energy is a substance existing somewhere inside an object**.** Energy is a physical quantity—a property represented within a theoretical framework.

Likewise with information. Saying that a black hole has information associated with its quantum state doesn't mean that "information" is a little physical substance sitting inside the black hole.

17. Concepts have domains of applicability

A concept can be extraordinarily successful within one domain and inadequate outside it.

Consider object. At human scales: "This is a chair." Perfectly useful. At the atomic level: "This electron is a little object following a definite trajectory." Now the concept becomes much less straightforward.

Similarly, classical time works extremely well for everyday phenomena: $t = \text{common time parameter}$.

But special relativity tells us that different observers can disagree about elapsed time, while GR makes the geometry of spacetime dynamical. So we shouldn't necessarily conclude: "The concept of time is wrong." Rather: The concept of absolute time has a limited domain of applicability. That's a much more philosophically sophisticated conclusion.

Three different questions we should ask of every concept:

a. What does the concept mean? This is conceptual analysis**. For example: What exactly do we mean by "cause"?**

b. Where does the concept work? This is its domain of applicability**. For example: Causal reasoning works extraordinarily well in macroscopic physics.**

c. Does the concept correspond to something fundamentally real?

This is the ontological question. For example: Is causation a fundamental feature of reality, or is it an emergent relationship between events?

These three questions must not be conflated.

A particularly important principle**:** The usefulness of a concept does not establish its ontological fundamentality.

On the other hand, a concept can be extraordinarily useful without being fundamental.

For example: Temperature is extremely useful. But at the microscopic level we can understand temperature in terms of statistical properties of enormous numbers of degrees of freedom. So temperature is arguably **emergent**, rather than fundamental.

Likewise:

Classical mechanics → extraordinarily useful but not fundamental.

Thermodynamics → extraordinarily useful but statistical mechanics provides a deeper description.

And perhaps:

spacetime → extraordinarily useful but potentially not fundamental.

This gives us a powerful philosophical hierarchy:

Concept→ Theory→ Reality

The danger is assuming that because a concept appears in a successful theory, it must correspond exactly to an ultimate constituent of reality. That is one of the central philosophical problems in the realism vs. instrumentalism debate in science. In fact, we can say that the realism–instrumentalism distinction provides a useful framework for tying together many of the issues we've been exploring**:** epistemology vs. ontology, objective vs. subjective, form vs. content, and determinism vs. free will.

The common thread is this:

How much of what we call "reality" belongs to reality itself, and how much belongs to the conceptual framework through which we apprehend it?

18. Realism vs. instrumentalism

Scientific realism says, roughly: Our successful scientific theories tell us something genuinely true about a mind-independent reality, including things we cannot directly observe.

If physics says electrons exist, the realist is inclined to say: There really are electrons.

If GR says spacetime has curvature, the realist is inclined to say: Spacetime really is curved.

Instrumentalism takes a more cautious position: A scientific theory is primarily an instrument for organizing observations and predicting outcomes. Its theoretical entities need not correspond literally to fundamental reality.

An instrumentalist might say:

"Electron" is an extraordinarily successful concept for predicting experimental results. Whether an electron exists *as an entity in itself* is a further metaphysical question.

That doesn't mean the instrumentalist believes electrons are fictional. The point is that **successful prediction doesn't logically entail ontological truth**.

19. This maps directly onto epistemology vs. ontology

This is probably the most important connection.

Epistemology asks**:** How do we know? Ontology asks**:** What exists?[7]

Science gives us extraordinarily powerful epistemological structures:

Observations → concepts→ theories→ predictions

But there is a temptation to move directly from:

"This theory predicts reality extremely well" to "Therefore the entities and structures in the theory constitute reality."

That second step is not logically automatic. This is sometimes called the under-determination problem: different theoretical descriptions can potentially account for the same observable phenomena. So you could formulate your position approximately as: Epistemological success does not by itself establish ontological identity.

20. Objective vs. subjective

Here we have another parallel.

Something can be subjective in its conceptual formulation while referring to something objective in reality. For example, temperature. The concept temperature is something humans formulate and mathematically define. But that doesn't mean temperature is merely subjective. There is something objectively different between water at 0^0C and water at 100^0C under specified conditions. So we should distinguish: the subjectivity of representation (art) from the subjectivity of what is represented (a statue of Cinderella).

21. Form vs. content

Think of a scientific theory as having something like: Form + Content

Form is the mathematical/conceptual structure.

Content is what we take that structure to be describing.

For example, in GR: $G_{\mu\nu}=(8\pi G/ c^4)T_{\mu\nu}$

The mathematical structure is extraordinarily precise. But there is a philosophical question:

What exactly is the ontological status of the mathematical objects appearing in this equation?

Is the metric tensor $g_{\mu\nu}$:

1. literally the geometry of reality?
2. our mathematical representation of relations among physical events?
3. an effective description of something deeper?

GR itself doesn't completely settle that philosophical question.

This is where form/content becomes useful. The mathematical form may be extremely successful while questions about its ultimate ontological content remain open.

Concern about spacetime fits perfectly. We've repeatedly questioned whether spacetime should be regarded as fundamental reality or as a conceptual/mathematical framework for organizing observations.

That is essentially a realism/instrumentalism question.

The realist interpretation says: The four-dimensional spacetime structure represented by GR corresponds to something genuinely existing.

A more instrumentalist or structuralist interpretation might say: The mathematical structure captures invariant relationships among physical events, but we shouldn't necessarily interpret the mathematical objects literally as "things."

There's an important middle position here: structural realism. We may not know what the ultimate "stuff" of reality is, but our successful theories capture genuine structural relationships in reality - that is especially attractive in modern physics.

22. Quantum mechanics makes the distinction even sharper

Quantum mechanics gives us an extreme example.

The wave function is: $\psi(x,t)$. But what is ψ? There is no universally accepted answer. Depending on interpretation, it might represent:

- a physically real quantum state,
- information about a system,
- knowledge or expectations,
- a real field-like entity,
- or something else.

Yet the mathematical machinery works extraordinarily well. So we have: Predictive success = unique ontology. That is perhaps one of the most important lessons of modern physics.

23. Determinism vs. free will

Here's where the broader philosophical framework becomes particularly interesting.

Suppose physics provides a deterministic equation: $S_{t+1}=F(St)$. That is, given F at time t, we know S at a later time t+1.

It is tempting to conclude: "The universe is deterministic." But notice the philosophical move. The equation describes the evolution of a state representation. The deeper ontological question is: Does the mathematical determinism of the model entail that reality itself is metaphysically deterministic? Not necessarily. Additional assumptions are needed. This gives us: Epistemological determinism**.** Our model allows us to calculate one state from another. Versus Ontological determinism**:** Given the complete physical state of reality, only one future is genuinely possible. Those are not identical claims.

24. Quantum mechanics complicates the issue

Suppose the quantum formalism gives probabilities: $P(x) = |\psi(x)|^2$. Does this mean that reality is fundamentally indeterministic? Not necessarily. It depends upon interpretation. Some interpretations have fundamentally probabilistic ontology; others retain deterministic underlying dynamics.

So again:

Indeterminacy in our description = ontological indeterminacy

Although the reverse possibility also exists:

Ontological indeterminacy ⇒ epistemic limitations

This is precisely where the idea of **irreducible epistemic limits**[8] becomes philosophically interesting.

25. Free will provides the mirror image

Suppose someone says: "Everything is determined by prior physical causes: therefore, free will is an illusion." There is a hidden assumption here. They have moved from a causal description of physical events to a metaphysical conclusion about agency. But determinism and free will aren't necessarily logical opposites. A compatibilist says: Free will doesn't require being causally unconditioned. It requires that actions arise from the person's own reasons, preferences, deliberations, and intentions rather than external coercion. So causation is not coercion and determination is not absence of agency.

26. Reality Vs Theory

Consider the following:

Reality

There is something that exists independently of us.

Epistemology

We encounter that reality through perception, measurement and conceptualization.

Concepts

We impose categories and structures that allow us to reason about what we encounter.

Mathematics

We develop formal structures capable of representing relationships.

Theory

We connect mathematical structures to observations.

Ontology

We then ask: What, if anything, in this structure corresponds to the fundamental furniture of reality?

That gives us: Reality → experience → concepts→ mathematics → theory.

But the arrow shouldn't automatically be interpreted as: Theory = reality. Rather, theory is a representation of reality, and the philosophical question is how faithful that representation is.

27. There is a position between realism and instrumentalism: structural realism

We may not know the ultimate nature of the entities underlying reality, but the hope is that successful scientific theories capture real structural relationships. For example, perhaps we shouldn't insist: "Spacetime is literally a four-dimensional substance." But we can reasonably say: "Whatever reality ultimately consists of, the relationships represented by the metric and Einstein field equations capture something objective about it." This allows us to distinguish ontology of things from ontology of relations/structure**.**

Putting all the various interests together, we could formulate the central idea approximately like this:

Reality is objective, but our access to it is epistemically mediated by conceptual and mathematical structures. The success of those structures gives us reason to believe that they capture genuine features of reality, but does not justify identifying the representation with reality itself.

Then add our concern about limits: **Our descriptions may therefore contain both objective information about reality and epistemic structures contributed by the observer.**

That gives a middle ground between: Objective reality + subjective/conceptual access = human knowledge.

And that connects remarkably well with the intuition that **the universe may have objective structure while our descriptions of that structure necessarily have epistemic limits**.

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