**The Presuppositions and Rationality of Science**

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**The presuppositions of science are unprovable assumptions about the physical world and ourselves that have several vital roles. Without a basic understanding of science’s presuppositions, no accounts can be given of how science achieves full disclosure, legitimates its presuppositions, has admissible evidence, justifies any conclusions, and specifies its referents. At stake is the competence of scientists to explain science as a rational activity.**

common sense | PEL model | philosophy of science | presuppositions | rationality

Significance

Scientists can make discoveries and improve technology without being aware of science’s presuppositions. However, scientists cannot uphold the rationality of science without invoking indispensable presuppositions.

**Introduction**

If science is to be regarded as a rational activity, then several questions must be asked and answered.

1. What are the requirements for full disclosure of *all* premises needed to support any scientific conclusions?

2. How can science’s presuppositions be legitimated, even if they cannot be proved?

3. What renders evidence admissible?

4. How can scientific knowledge be justified?

5. What does science talk about, and how are those referents specified?

What these questions have in common is that they all concern presuppositions, although this is explicit in only the second question. The presuppositions of science are unprovable assumptions about the physical world and ourselves that have several vital roles, including that they are needed for science to have any evidence and to reach any conclusions.

Presuppositions are often regarded as a topic for philosophers—and so they are. However, presuppositions are also important for scientists. Indeed, the above questions are pertinent throughout all of the physical, biological, and social sciences.

**Full Disclosure**

What are the requirements for full disclosure of *all* premises needed to support any scientific conclusions?

An answer can be pursued with a simple example. Envision a coin toss and ask, “Did the coin land heads or tails?” There are two hypotheses: “The coin landed heads” and “The coin landed tails.” Suppose that we look and see tails. That evidence can be used in an argument with one premise that “We see tails” and the conclusion that “The coin landed tails.”

 Although that informal argument might seem satisfactory, it is actually incomplete. Symbolize seeing the coin by “*S*” and the coin’s landing tails by “*L*.” Then the argument has the form “*S*; therefore *L*.” Formal expression makes it easier to see that *L* does not follow from *S*: The argument commits the logical fallacy called a *non sequitur*. What is missing?

 Another requirement is the premise that “Seeing implies landing,” or “*S* implies *L*” which links human observation and physical object. Common sense presupposes that seeing is believing, which includes that the physical world exists, our sense perceptions are generally reliable, and human language suffices for discussing such matters. With the addition of the second premise, the argument becomes: “*S*; *S* implies *L*; therefore *L*.” It now follows the valid argument form *modus ponens*.

However, the argument is still incomplete. To achieve full disclosure, the logic used here must itself be disclosed by a third premise declaring that “*modus ponens* is a correct rule for deduction.” Logic is needed to combine information in the premises and thereby to reach the conclusion. Although rudimentary deductive logic suffices for this simple example, scientists utilize deductive logic (including *modus ponens*), inductive logic (including statistics), and many branches of mathematics (1, pp 112–173). The complete argument has three premises and achieves full disclosure.

 Simple Example of Full Disclosure:

Premise 1, Evidence. We see tails.

Premise 2, Presupposition. Seeing implies landing.

Premise 3, Logic. *Modus ponens* is a correct rule for deduction.

Conclusion. The coin landed tails.

 This example illustrates the general principle that every conclusion about the physical world requires premises of three kinds: presuppositions, evidence, and logic. I named this the PEL model of full disclosure for its three components (1, pp 78–84). The PEL model has an intellectual heritage from the *ex suppositione* reasoning of Aristotle, the conditional necessity of Albertus Magnus, the *scientia realis* of William of Ockham, the four rules of reasoning of Sir Isaac Newton, and the symmetry thesis of Thomas Reid (1, pp 41, 46, 74–76, 176–177). The evidence concerns a human perception (sight), whereas the hypotheses and conclusion concern something else, an external physical object (coin); accordingly, presuppositions and logic provide the required link between perception and object.

**Legitimated Presuppositions**

How can science’s presuppositions be legitimated, even if they cannot be proved?

A practical difference between evidence and presuppositions is that each scientific project requires its own particular collection of evidence, whereas the entire scientific enterprise needs its presuppositions to be disclosed and legitimated but once. The presuppositions of science cannot be proved or disproved by the ordinary means of marshaling evidence because any appeal to evidence has already implicated these presuppositions. However, presuppositions can be legitimated by basing them on our most confident and widespread knowledge about ourselves and our world. Legitimization does not involve learning new and erudite material; rather, it is an exercise in becoming self-aware of our own ongoing experiences and beliefs (1, pp 84–89). There are two steps.

The first step is selection of an exemplar of commonsense knowledge about the world, called a “reality check,” that is as certain and universally known as is anything that could be mentioned. Common sense is the realm of our easiest knowledge—indeed, much of it is known by children only three or four years old. There are many good reasons for starting the journey of human knowledge with common sense (2). Building science on a base of common sense is a plausible and venerable tradition. According to Albert Einstein, “The whole of science is nothing more than a refinement of every day thinking” (3). The following reality check serves as an exemplar of certain and unassailable knowledge that is comfortably within reach of ordinary human endowments and experiences.

Reality Check: It is rational, realistic, true, and certain that “Stepping in front of moving cars is hazardous for pedestrians.”

 *Rationality* is understood here in traditional terms of reason’s double office: to pursue true beliefs and to guide good actions. Belief and action should match. *Realism* asserts that both human thoughts and mind-independent physical objects are real. *Truth* is a property of a statement, namely, that the statement corresponds with reality. *Certainty* is complete confidence without any doubt that a statement is true (or else false, as the case may be), which equates to a probability of truth of 1 (or else 0). Also, *knowledge* is understood here in classical terms as justified true belief: justified by virtue of being based on good reasons and evidence, and true by virtue of corresponding with reality.

 The second step is philosophical reflection on the reality check in order to disclose our presuppositions and to show that they also suffice for science. Michael Polanyi keenly observed that the presuppositions underlying the generation of facts “are not known to us or believed by us *before* we start establishing facts, but are recognized on the contrary *by reflecting on the way we establish facts*” (4, p 162). In order for the reality check to have been established by our experiences of life, the general makeup of the world cannot follow just any conceivable story. Accordingly, those of us who have believed the reality check all our lives since childhood should ask: What have we been presupposing all along about the world and ourselves? A reasonable perspective is that “Science presumes that the things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study” (5, p 25). Likewise, the “search for regularity in the natural world … is predicated on the assumption that the natural world is orderly and can be comprehended and explained” (6, p 16). The following statement offers a concise expression of these basic presuppositions.

Basic Presuppositions: The physical world is real and orderly and we humans find it substantially comprehensible.

 Further reflection on the reality check discloses obvious and yet remarkable things about our world and ourselves. Physical objects have properties and causal powers. For instance, impact from rapidly moving cars can cause harm or death for pedestrians *because* cars have the properties of being heavy and hard relative to humans. Reflection also reveals that humans desire to know and understand. Naturally, we need to know the reality check, and need to teach it to young children in the form “Look both ways before crossing a street,” for its sheer survival value. But humans desire more than mere survival. Elaborating on Aristotle’s *Metaphysics*, Jonathan Lear commented: “Yet it is a remarkable fact about us that we cannot simply observe phenomena: we want to know *why* they occur. We can imagine beings who simply watched the sun set and the moon rise in the heavens: they might come to expect the regular transitions, but they would lack curiosity as to why the changes occur. We are not like that. The heavenly motions cry out (*to us*) for explanation” (7, p 3). Indeed, we know the reality check not merely as a regularity, that being hit by a car is bad over and over again; but rather, we also understand and explain the reality check in terms of properties of objects and causes of events.

An important issue is how deeply science must account for its presuppositions. A shared reality check among scientists enables them to agree *that* science’s presuppositions hold, whereas worldview differences between scientists preclude agreement about the deeper issue of *why* they hold. For instance, theists and atheists can agree that the physical world is real, although they have different explanations for why the universe exists at all. Fortunately, the scientific community only needs to assert *that* science’s presuppositions hold in order for them to function. For instance, in order to conclude that “The coin landed tails” or “Water is composed of hydrogen and oxygen,” one *does* need to assert science’s presuppositions; but one *does not* need to explain why science’s presuppositions hold in terms of the whole story of the universe. One need not know everything in order to know something.

 Persons who believe the reality check, “Stepping in front of moving cars is hazardous for pedestrians,” have already adopted all of the presuppositions about our world and ourselves needed for science to flourish. Science requires more experimentation, more data collection, more computation, more thought, and more work than common sense, but requires no further presuppositions. Indeed, any extra presuppositions would restrict science because on pain of circular reasoning, whatever is presupposed cannot also be concluded. For instance, science can investigate the electric charge of electrons because science does not have any presuppositions about electrons. Science’s ability to investigate so much emerges from its presupposing so little.

**Admissible Evidence**

What renders evidence admissible? Because the three components of the PEL model interact deeply, an account of admissible evidence necessarily involves all three.

Presuppositions suitable for science have a dual nature: They are nondiscriminatory and indispensable. First, *nondiscriminatory* means having no bearing either positive or negative on the credibility of any of the competing hypotheses. Appropriate presuppositions are nondiscriminatory precisely because they are shared in common among all hypotheses under consideration. For example, the hypotheses about the coin landing heads or else tails *agree* and presuppose that a physical object such as the coin is real and that humans can observe and discuss a coin flip (even though these hypotheses *disagree* about whether the coin landed heads or else tails). Second, presuppositions are *indispensable* because there must be a link between perception and object in order to assert any of the hypotheses as the argument’s conclusion. Likewise, logic is nondiscriminatory or impartial because it gives neither hypothesis about the coin any advantage or disadvantage, and yet it is indispensable for reaching any conclusion.

 Evidence also has a dual nature: It should be admissible and relevant. First, evidence is rendered *admissible* by presuppositions. Given commonsense presuppositions about the existence of physical objects and the sensory and mental endowments of humans, a report about seeing a coin is admissible. By contrast, without such presuppositions, reports about the physical world could be deemed inadmissible because the world is thought to be illusory, inaccessible, or even nonexistent. Second, evidence should be *relevant* relative to the competing hypotheses, bearing differentially on their credibilities. For example, the hypotheses about the coin *disagree* about whether it landed heads or else tails (even though they *agree* about commonsense presuppositions). Consequently, seeing that the coin landed tails is relevant because it confirms one hypothesis and disconfirms the other.

 The three components of the PEL model are complementary. Presuppositions and logic answer the question: How can I assert *any* of the hypotheses? Evidence answers the question: How can I assert a *specific* hypothesis rather than another one? Both questions must be answered.

 A common opinion is that science is based solely on evidence. However, the concept of evidence is meaningless apart from presuppositions because one of the essential properties of evidence, namely admissibility, depends on presuppositions. It is clear from the PEL model that evidence by itself cannot support a conclusion about the outcome of a coin flip, let alone any conclusion of science. The role of evidence is to discriminate among the competing hypotheses in order to assert a specific one as the conclusion; *but* that role is inoperative without the support of logic and unprovable presuppositions that make it possible to assert any conclusion.

The cost for promulgating an incomplete and simplistic “evidence-based science” is that it simply does not work; it cannot stand up to the scrutiny that the scientific community is bound to receive in the contemporary world. By contrast, the benefit from a presupposition-evidence-logic-based science is that it gives a unified and defensible account of how science functions.

**Justified Knowledge**

How can scientific knowledge be justified?

Besides the reality check, other beliefs could also be deemed certain, such as the outcome that “The coin landed tails.” Similarly, Ludwig Wittgenstein judged “the existence of the apparatus before my eyes” to have the same certainty as “my never having been on the moon” (8, p 43e). Claims of certain knowledge can be justified by extending the reality check’s certainty to other beliefs. For a concrete example, consider the belief that “There are elephants in Africa.”

 A suitable method of justification has three steps (1, pp 91–93). First, denote the reality check that “Stepping in front of moving cars is hazardous for pedestrians” by *A* and assert that: *A* is certain. Second, demonstrate that another belief, “There are elephants in Africa” denoted by *B*, has certainty equivalence with belief *A* by showing three equivalences: Beliefs *A* and *B* have the same presuppositions; they have equally admissible, relevant, and weighty evidence; and they use equally valid logic. Indeed, the same presuppositions are necessary and sufficient to believe *A* or *B*; recent sightings or photographs of elephants in Africa are as admissible, relevant, and weighty as evidence from sightings or photographs of car accidents with pedestrians; and equally valid logic works in both cases: *B* has certainty equivalence with *A*. Third and finally, from these two premises, that *A* is certain and that *B* has certainty equivalence with *A*, infer the conclusion that *B* is certain.

 The method of justification is easily extended from certain to probabilistic knowledge claims, such as weather forecasts. For example, let belief *R* be “It will rain tomorrow” with a probability of 70%. Assertion of the reality check, adoption of the basic presuppositions, and insistence on valid logic remain the same. However, *R* has less certainty than *B*, so *R* is asserted with a probability.

 Most science is relatively routine. Nevertheless, “Scientific ideas not only influence the nature of scientific research, but also influence—and are influenced by—the wider world of ideas as well. For example, the scientific ideas of Copernicus, Newton, and Darwin … altered the direction of scientific inquiry and influenced religious, philosophical, and social thought” (6, p 24).

Appropriate presuppositions are especially crucial for scientific arguments that bear on the wider world of ideas, that is, that have worldview import. When evaluating such arguments, it is important to realize that a statement’s *content* is not the only relevant consideration; its *logical role* also matters (1, pp 107–108). For instance, it is easy to grasp the difference between opposing claims such as “The universe is purposeless” and “The universe is purposeful.” However, “The universe is purposeless” asserted in the logical role of a presupposition and this same “The universe is purposeless” asserted in the logical role of a conclusion are two vastly different claims.

If a controversial worldview claim—such as life is purposeful (or else purposeless)—is adopted as a presupposition, then that claim loses eligibility to become an argument’s conclusion.

If a worldview claim appears as both a presupposition and a conclusion within a given discourse, then the result is empty circular reasoning.

However, if a worldview claim emerges as a conclusion from an argument having appropriate presuppositions, admissible and relevant evidence, and standard logic, then the argument merits consideration. Support for the favored worldview can come entirely from informative, empirical, public evidence precisely because these appropriate presuppositions are nondiscriminatory and this standard logic is impartial.

Consequently, clarity about the logical role of worldview claims is essential. Awareness of the PEL model can help scientists to discern the merits and structure of worldview arguments. For example, some scientists and scholars insist that science’s presuppositions must include more than the recommended basic presuppositions, even much more, namely their own favored worldview. An oft-quoted statement by Richard Lewontin insists that the scientific community must adopt materialism or atheism as a “prior commitment … to materialism” and “*a priori* adherence to material causes” because commitment to “materialism is absolute, for we cannot allow a Divine Foot in the door” (9). The expanded presuppositions become, “The physical world is real and orderly and we humans find it substantially comprehensible; and materialism is the true worldview.” People who defend and promote their own worldview by presupposing it should realize that this move is equally available to adherents of *any* worldview, so the value of this move is questionable.

**Specified Referents**

What does science talk about, and how are those referents specified? That seemingly simple question is surprisingly complex and controversial.

 The character or nature of scientific knowledge can be approached in a concrete manner by considering typical knowledge claims in scientific journals. For instance, the 24 August 2018 issue of *Science* has information on interplanetary small satellites, ancient human DNA, biodiversity in the ocean, spread of a deadly virus disease of pigs from Africa to China, self-cleaning properties of titanium dioxide, and mutations that cause immune deficiency and inflammation in humans.

 Obviously, physical objects and events are what that literature is about: humans, pigs, and oceans are typical referents of scientific literature. Equally obviously, science is done by humans, so scientific articles express human ideas and knowledge claims by means of words and images. Hence, science has a dual context of physical objects and human beliefs. Significantly, our most rudimentary knowledge has the same dual context: The reality check’s referents are physical objects, namely moving cars and human pedestrians; and human endowments are presumed and displayed by our having acquired the knowledge expressed in its text. Accordingly, scientific literature resonates with the basic presuppositions recommended here that “The physical world is real and orderly and we humans find it substantially comprehensible.” Also, given the dual context of physical objects and human beliefs, the correspondence theory of truth is applicable and meaningful: A statement is true if it corresponds with reality, but is false if it does not correspond. For instance, a statement that loss-of-function mutations in the receptor-interacting serine/threonine-protein kinase 1 (*RIPK1*) gene cause immune deficiency and inflammation in humans is true if and only if that is the case for these physical objects, namely *RIPK1* mutations and human bodies. Furthermore, the truth of this claim matters: It has practical consequences for mitigation of serious human diseases.

Consequently, ordinary beliefs about a real, external, and mind-independent physical world that is accessible to human observation and comprehension—which is expressed in the recommended basic presuppositions—comports with typical science. This view is called scientific realism. It is sensible and prevalent, but not uncontested.

 Imagine that the contemporaries George Berkeley, David Hume, Immanuel Kant, and Thomas Reid were together and they flipped a coin to decide between two pubs for having lunch (1, pp 36–49, 74–78, 93). All four would report the same experience of a coin, but their interpretations of that experience would differ. Berkeley would say that the coin does not exist as a mind-independent physical object, but only as a mind-dependent idea of a coin (a position called idealism). Hume would say that science should concern our experiences or perceptions of the coin, whereas science cannot and need not know whether the coin exists. Kant would say that we know about the coin and phenomenal world as it appears to us, but not about the noumenal world as it actually is in itself. Reid would say that philosophy and science should follow common sense with a confident and cheerful certainty that the physical coin does exist. Likewise, imagine stepping two millennia further back and seeing Plato and his student Aristotle purchasing their lunch with a coin. For Plato, the coin would be but an illusory and fleeting shadow of its inaccessible but thoroughly real Form. But, for Aristotle, the coin itself would be completely real. This ancient and still ongoing debate is not about the sensory data. Rather, it is about the interpretation of the data. The debate is entirely about presuppositions concerning what is real and knowable.

 Nevertheless, despite their philosophical differences, Berkeley, Hume, Kant, Reid, Plato, and Aristotle could all agree that “The coin landed tails.” There is agreement about the perceptions or appearances, although not about the referents and causes behind these sensory perceptions. The philosophical terms for what these otherwise diverse perspectives have in common is that they are “empirically equivalent” or they “save the appearances.”

Accordingly, willingness to assert that “The coin landed tails” is a true observation, with no deeper commitment to some metaphysics of coins, could be considered sufficient for science. Philosophical diversity within the scientific community can be accommodated by specifying alternative presuppositions that suffice for science, but carry fewer metaphysical commitments than do the basic presuppositions. The adjusted procedure for disclosing and legitimating the alternative presuppositions would still begin with assertion of the reality check, “Stepping in front of moving cars is hazardous for pedestrians.” However, different presuppositions than the commonsense ones would be disclosed by philosophical reflection on the reality check, such as “The perceptions of humans are real and we find substantial agreement about them.” After that adjustment, the PEL model operates as usual. All three of its resources are still required to reach conclusions, but different presuppositions mean that the hypotheses and conclusions pertain to different referents than those in ordinary science. Reid and Berkeley could agree about the outcome of a coin flip, although they disagree about whether the coin is an object or an idea. Likewise, scientific realists and others can agree on water being composed of hydrogen and oxygen, although they disagree about water’s metaphysical status.

Having accommodated a latitude of understandings of science, still there is much to be said in favor of ordinary, commonsense, workaday, garden-variety realism. Anything else seems odd. For example, imagine reading an article by an idealist following Berkeley that began, “To be clear, by ‘pigs’ I do not mean physical animals that eat physical food and breathe physical air, but rather I mean our ideas that we call ‘pigs’ since only minds and ideas exist.” Or imagine that an empiricist or skeptic following Hume wrote: “This article concerns human perceptions of oceans, but only perceptions and not physical objects.”

 The objection could be raised that much contemporary science is extremely weird and bizarre, so that tame examples of pigs and oceans bias this discussion in favor of realism. Instead, if wilder examples were taken from quantum mechanics, cosmology, and relativity, then realism would seem misleading or simplistic. For instance, seemingly solid objects are actually mostly empty space. Perhaps our “common sense” works against, rather than for, our ability to see things as they really are, so the commonsense basic presuppositions are defective. Granted, science has given us many surprises relative to commonsense expectations. However, those surprises are conclusions of science, not presuppositions. Indeed, “Although through our theories, and the instrument-aided observations they lead to, we can go beyond and correct some of the pre-theoretical picture of the world we have by virtue of our being human, there is always going to be a sense in which all our knowledge and theory is based on elements in that picture. … More theoretical knowledge of the world is always going to have some connection, however remote, with the humdrum level if it is to count as science fact rather than science fiction” (10, pp 95–96). Also, the supposed erosion of common sense by bizarre discoveries should not be overstated: Scientific knowledge of strong interactions between neighboring atoms in the solid state only confirms, rather than contradicts, that cars are solid objects when probed by macroscopic objects such as fingers, which is what common sense talks about. For these reasons, the surprising *conclusions* of science provide no basis for inferring that the *presuppositions* of science need to be different from those of common sense.

However, extreme doubt can undermine science’s presuppositions and rationality. Human knowledge, from antiquity to the present, has been challenged by various forms of skepticism that profess extensive to pervasive doubt (11). For example, eliminative materialism claims that physical things such as atoms and neurons are real, whereas human rationality, consciousness, and personhood are illusory (10, pp 202–210). But this variant of materialism places itself in the peculiar position of proclaiming arguments that are made by illusory persons who have illusory rationality, and are directed to other illusory persons who have illusory consciousness. More generally, any philosophical position that denies human rationality and consciousness needs to answer a charge of incoherence.

 Scientist’s perceptions of what philosophers say about knowledge and science affect the scientific community’s perspective on science and its referents. Although some philosophers have exotic views that are potentially disturbing, such views are not as common as many scientists might fear. Actually, most philosophers’ beliefs are congenial to science’s basic presuppositions and scientific realism. Recently the first extensive survey of philosophy faculty was conducted, which obtained 931 responses (12). Regarding the existence of an external world, 81.6% of philosophers held non-skeptical realism, 4.8% skepticism, 4.3% idealism, and 9.2% other. Regarding science more specifically, 75.1% of philosophers held scientific realism, 11.6% scientific anti-realism, and 13.3% other. Consequently, scientists who are inclined toward scientific realism should realize that most philosophers agree with them, and they should not feel that the most sophisticated view of science is automatically deeply skeptical or hostile. Philosophers are more knowledgeable than scientists about the arguments for and against realism, and they are better trained to evaluate these arguments, so it is significant that philosophers mostly adopt realism.

Scientific realism, which is rooted in science’s basic presuppositions, provides the ideal context for science to operate with vigor and confidence. Significantly, if electrons and soybeans truly are real physical objects with properties such as a negative electric charge and protein-rich seeds, then these physical referents endow scientific realism with otherwise unapproachable explanatory depth and power.

**Conclusions**

 This article seeks to prompt those readers who since childhood have always believed and acted upon the reality check to become more self-aware of what they have been presupposing all along about the world and themselves—and even to understand that these simple beginnings of intellectual life have profound and strategic implications for science. That might seem easy, but it is not. Indeed, Einstein said that the physicist cannot possibly proceed with “examination of the concepts of his own specific field … without considering critically a much more difficult problem, the problem of analyzing the nature of everyday thinking” (3). Although Einstein mentioned physicists, his remark applies equally to all scientists. Substantial and wonderful aspects of scientific and everyday thinking are simply inaccessible apart from self-awareness of one’s own presuppositions and their vital roles. “Our presuppositions are always with us, never more so than when we think we are doing without them” (10, p 54).

This article upholds science as a rational activity. To preclude misunderstanding, however, it does not argue that *only* science finds real and public knowledge, which is a posture called scientism (13, 14). Certainly, the rudimentary commonsense presuppositions recommended here express nothing that is distinctively or exclusively scientific. In contrast to scientism, a modest and sensible perspective on science is that: “The method of natural science is not the sole and universal rational way of reaching truth; it is one version of rational method, applied to a particular set of truths” (15, p 134). Likewise, “rationality should not simply be identified with it [science],” but rather “science itself stands in need of a rational underpinning” (16, p 5).

 Some key ideas capture the essence of this article. After scientists appreciate the importance of the questions posed here, they can learn much from rigorous thought about the outcome of a coin toss. Appropriate presuppositions plus empirical evidence plus standard logic equal public conclusions; hence, what works is presupposition-evidence-logic-based science. The best way to assure the proper influence of evidence is to understand the accompanying roles of logic and presuppositions. Any discussion or defense of science’s rationality that ignores presuppositions is provably incomplete and necessarily inadequate. Competence to make scientific discoveries and improve technology is wonderful; but far better is competence to do those things *and* to uphold the rationality of science.

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