Scientific realism: historic and contemporary perspectives and problems

What reasons do we have to think of scientific theories as providing a ***true account*** of the world, as opposed to merely useful prescriptions for dealing with the world?

How would we know the difference between having a true picture and merely having useful prescriptions?

What is the ***content*** of the claim that a theory is true, as distinct from the claim that the theory "saves the phenomena"?

Can the history of the sciences help us to answer these questions?

A 20th century movement toward a new way of thinking about the philosophy of science:

A new sense of the importance of the history of science to the philosophical understanding of science;

An emphasis on transformative discontinuities in the history of science, in which older ways of seeing the world— and the nature of science— are swept aside;

An awareness that such changes involve not only the accumulation of new information, but profound re-definitions of fundamental concepts;

A deep engagement with the actual practice of science.

A “ minimal” conception of realism:

Physical theories can do more than predict what we will observe. They can also extend our theoretical knowledge beyond what is immediately observable

Theoretical claims about the unobservable can be meaningful, in the sense of having definite truth conditions

The world can reject our theoretical pictures of it, because it has real physical features that cannot be captured within a given picture,

The replacement of one physical theory by another is, at least sometimes, an enlargement of our understanding of features of the world that are not immediately observable.

Questions:

Separating the question of scientific realism from more general questions: semantic realism, metaphysical realism

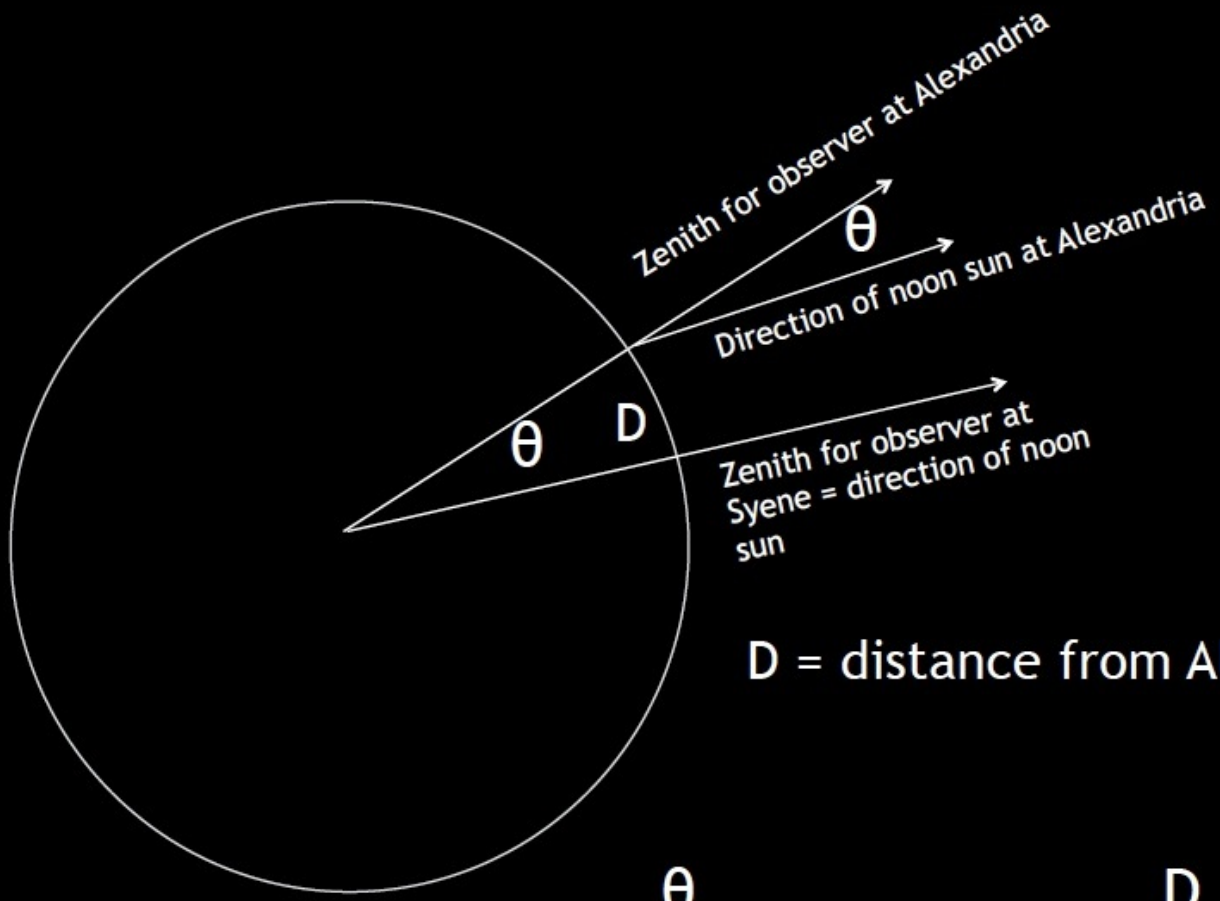
Realism about what? The distinction between realism in general and realism about theoretical entities

The distinction between realism about theoretical entities and realism about the objects of “common sense”

(Democritus), Aristotle, Hume)

The relation between scientific reasoning and “common sense” reasoning— is science “an extension of common sense”?

How Eratosthenes measured the earth (240 B.C.E.)



D = distance from Alexandria to Syene

$$\frac{\theta}{360} = \frac{D}{\text{circumference of the earth}}$$

(252,000 stadia, roughly 40,000 km)

Osiander:

For it is the duty of an astronomer to compose the history of the celestial motions through careful and expert study. Then he must conceive and devise the causes of these motions or hypotheses about them. Since he cannot in any way attain to the true causes, he will adopt whatever suppositions enable the motions to be calculated correctly from the principles of geometry for the future as well as for the past. The present author has performed both these duties excellently. For these hypotheses need not be true nor even probable. On the contrary, if they provide a calculus consistent with the observations, that alone is enough.

Text

Copernicus:

And so, after postulating movements, which, farther on in the book, I ascribe to the Earth, I have found by many and long observations that if the movements of the other planets are assumed for the circular motion of the Earth and are substituted for the revolution of each star, not only do their phenomena follow logically therefrom, but the relative positions and magnitudes both of the stars and all their orbits, and of the heavens themselves, become so closely related that in none of its parts can anything be changed without causing confusion in the other parts and in the whole universe. Therefore, in the course of the work I have followed this plan: I describe in the first book all the positions of the orbits together with the movements which I ascribe to the Earth, in order that this book might contain, as it were, the general scheme of the universe.

Kepler, ***Astronomia Nova Αιτιολογητος*** (1609):

It was demonstrated in the previous chapter that…to the extent that a planet is farther from the point which is taken as the centre of the world, it is less strongly urged to move about that point. It is therefore necessary that the cause of this weakening is either in the very body of the planet, in a motive force placed therein, or right at the supposed centre of the world.

Now it is an axiom in natural philosophy…that of those things which can occur at the same time and in the same manner, and which are always subject to like measurements, either one is the cause of the other or both are effects of the same cause….Thus, either that weakening will be the cause of the star's motion away from the centre of the world, or the motion away will be the cause of the weakening, or both will have some cause in common. But it would be impossible for anyone to think up some third concurrent thing which would be the cause of these two, and…it will become clear that we have no need of feigning any such cause, since the two are sufficient in themselves.

Newton’s “instrumentalist” talk”

I likewise call Attractions and Impulses, in the same sense, Accelerative, and Motive; and use the words Attraction, Impulse, or Propensity of any sort towards a centre, promiscuously, and indifferently, one for another; considering those forces not Physically, but Mathematically: wherefore the reader is not to imagine, that by those words I anywhere take upon me to define the kind, or the manner of any Action, the causes or the physical reason thereof, or that I attribute Forces, in a true and Physical sense, to certain centres (which are only Mathematical points); when at any time I happen to speak of centres as attracting, or as endued with attractive powers.

What Huygens claimed to have explained about the action of gravity:

So I have explained, with one hypothesis that contains nothing impossible, why terrestrial bodies tend to the centre; why the action of gravity cannot be prevented by any known body; why the parts within each body all contribute to its gravity; and finally why falling bodies constantly increase their velocity in proportion to the times. Such are the properties of gravity as we have distinguished them so far.
There still remains one property…namely that bodies weigh as much in one place on earth as they do in another.

Newton's reply to Huygens' objection to the argument for universal gravitation, and the speculative extension of Law III to gravitational attractions:

What that great man Huygens has remarked on my work is acute…But… since all the phenomena of the heavens and of the sea follow accurately, so far as I am aware, from gravity alone acting in accordance with the laws discovered by me, and nature is most simple; I myself have judged that all other causes are to be rejected and that the heavens are to be stripped as far as may be of all matter lest the motions of the planets and comets be impeded or rendered irregular. But if meanwhile someone explains gravity together with all its laws by the action of some subtle matter, and shows that the motions of the planets and comets will not be disturbed by this matter, I shall be far from objecting. (From a letter to Leibniz)

Newton's distinction between mathematical theory of gravity, vs. what we actually know about gravity:

"that it must proceed from a cause that penetrates to the very centres of the sun and planets, without suffering the least diminution of its force;

that it operates not according to the quantity of the surfaces of the particles upon which it acts (as mechanical causes use to do), but according to the quantity of the solid matter which they contain;
that it propagates its virtue on all sides to immense distances, decreasing always in the duplicate proportion of the distances…

….in receding from the sun [it] decreases accurately in the duplicate proportion of the distances as far as the orb of Saturn, as evidently appears from the quiescence of the aphelions of the plants; nay, and even to the remotest aphelions of the comets; ***if those aphelions are also quiescent."*** [Emphasis added]

But hitherto I have not been able to discover the cause of those properties of gravity from phaenomena, and I frame no hypotheses; for whatever is not deduced from the phaenomena is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferred from the phenomena, and afterwards rendered general by induction. Thus it was that the impenetrability, the mobility, and the impulsive force of bodies, and the laws of motion and of gravitation, were discovered. And to us it is enough that ***gravity does really exist***, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our sea. [Emphasis added]

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Laplace on the instrumental character of Newton's theory:

The theory of gravity, which, by so many applications, has become a means of discovery, as certain as by observation itself, has made known to him several new inequalities, in the motions of the heavenly bodies, and enabled him to predict the return of the comet of 1569, whose revolutions are rendered very unequal, by the attractions of Jupiter and Saturn. He has been enabled, by this means, to deduce from observation, as from a rich mine, a great number of important and delicate elements; which, without the aid of analysis, would have been forever hidden from his view: such as the relative values of the masses of the sun, the planets and satellites….. (Mécanique céleste).

Berkeley on the relation between idealism and natural philosophy (*Principles*):

Sixthly, You will say there have been a great many things explained by Matter and Motion: Take away these, and you destroy the whole Corpuscular Philosophy, and undermine those mechanical Principles which have been applied with so much Success to account for the Phænomena. In short, whatever Advances have been made, either by ancient or modern Philosophers, in the study of Nature, do all proceed on the Supposition, that Corporeal Substance or Matter doth really exist. To this I answer, that there is not any one Phænomenon explained on that Supposition, which may not as well be explained without it, as might easily be made appear by an Induction of Particulars. To explain the Phænomena, is all one as to shew, why upon such and such Occasions we are affected with such and such Ideas. But how Matter should operate on a Spirit, or produce any Idea in it, is what no Philosopher will pretend to explain. It is therefore evident, there can be no use of Matter in Natural Philosophy. Besides, they who attempt to account for Things, do it not by Corporeal Substance, but by Figure, Motion, and other Qualities, which are in truth no more than mere Ideas, and therefore cannot be the Cause of any thing, as hath been already shewn.

Tenthly, It will be objected, that the Notions we advance, are inconsistent with several sound Truths in Philosophy and Mathematicks. For Example, The Motion of the Earth is now universally admitted by Astronomers, as a Truth grounded on the clearest and most convincing Reasons; but on the foregoing Principles, there can be no such thing. For Motion being only an Idea, it follows that if it be not perceived, it exists not; but the Motion of the Earth is not perceived by Sense. I answer, That Tenet, if rightly understood, will be found to agree with the Principles we have premised: For the Question, whether the Earth moves or no, amounts in reality to no more than this, to wit, whether we have reason to conclude from what hath been observed by Astronomers, that if we were placed in such and such Circumstances, and such or such a Position and Distance, both from the Earth and Sun, we should perceive the former to move among the Choir of the Planets, and appearing in all respects like one of them: And this, by the established Rules of Nature, which we have no reason to mistrust, is reasonably collected from the Phænomena.

Berkeley on “mechanical vs “metaphysical” principles” (*De Motu*):

The mechanical principles and universal laws of motions, or of nature, happily discovered in the last century and treated of and applied with the aid of geometry, have cast a remarkable light on philosophy. But metaphysical principles and the real efficient causes of the motion and existence of bodies or of corporeal attributes in no way pertain to mechanics and experiments, nor can they shed any light on them, except in so far as by being known beforehand they may serve to set the limits of physics, and so to remove foreign difficulties and questions…

Motion never meets the senses without corporeal mass, space, and time. However, there are some who desire to contemplate motion as a certain simple and abstract idea, and separated from every other thing….And also of this kind is the definition of a famous man in recent times, who asserts that "there is nothing real in motion beyond a momentary something which must consist in a force striving toward change.” Again, it is agreed that the authors of these and similar definitions had it in mind to explicate the abstract nature of motion, apart from any consideration of time and space, but I do not see how this abstract quintessence of motion (as I may call it) can be understood.

'Force', 'gravity', 'attraction', and words of this sort are useful for reasonings and computations concerning motion and bodies in motion, but not for understanding the simple nature of motion itself, or for designating so many distinct qualities. As for attraction, it is clear that this was employed by Newton, not as a true and physical quality, but only as a mathematical hypothesis. And indeed Leibniz, in distinguishing elementary nisus or solicitation from impetus, confesses that these things are not to be found in things themselves in nature, but must be made by abstraction….

Because these things are not sufficiently understood, some un justly repudiate mathematical principles of physics, evidently on the pretext that they do not assign the true efficient causes of things. When in fact it is the concern of the physicist or mechanician to consider only the rules, not the efficient causes, of impulse or attraction, and, in a word, to set out the laws of motion: and from the established laws to assign the solution of a particular phenomenon, but not an efficient cause.

Berkeley on absolute space:

Furthermore, since…the motion of the same body varies, and indeed any thing can be said to be moved in one respect, and at ,rest in another: for determining true motion and true rest, by which means ambiguity is eliminated and the mechanics of those philosophers who contemplate a wider system of things is furthered, it would suffice to take the relative space enclosed by the fixed stars, regarded as at rest, instead of absolute space. Indeed motion and rest defined by such a relative space can conveniently be applied in place of the absolutes, which cannot be discerned by any mark. For however forces may be impressed, whatever conatus there may be, we admit that motion is to be distinguished by actions exerted on bodies; but never will it follow that there is this absolute space, and location, and the change of this is true motion.

The laws of motions and effects, and the theorems containing the calculations of the same for different figures of the paths, as well for accelerations and diverse directions, and for more or less resistant media, all these hold without the calculation of absolute motion. Just as it is plain from the fact that, according to the principles of those who introduce absolute motion, it cannot be known by any mark whether the entire frame of things is at rest or moved uniformly in a right line, it is evident that the absolute motion of no body can be known.

From what has been said it is clear that in investigating the true nature of motion, it will be of greatest avail first, to distinguish between mathematical hypotheses and the nature of things; second, to beware of abstractions; third, to consider motion as something sensible, or at least imaginable, and to be content with relative measures. Which things, if we do them, will at once leave untouched all the famous theorems of the mechanical philosophy, through which the recesses of nature are opened up and the system of the world is subjected to human calculation, while the consideration of motion will be freed from a thousand minutiae, subtleties, and abstract ideas.

Kant's "empirical realism":

Our exposition therefore establishes the reality, that is, the objective validity, of space in respect of whatever can be presented to us outwardly as object, but also at the same time the ideality of space in respect of things when they are considered in themselves through reason, that is, without regard to the constitution of our sensibility. We assert, then, the empirical reality of space, as regards all possible outer experience; and yet at the same time we assert its transcendental ideality in other words, that it is nothing at all, immediately we withdraw the above condition, namely, its limitation to possible experience, and so look upon it as something that underlies things in themselves.

Helmholtz on the status of Euclidean geometry:

…The recent mathematical investigations… as to wider kinds of geometry have established the following propositions:

(1) Kant's proof of the a priori origin of geometrical axioms based on the assumption that no other space-relations can be mentally represented, is insufficient, the assumption being at variance with fact.
(2) If, in spite of the defective proof, it is still assumed hypothetically that the axioms are really given a priori as laws of our space-intuitions, two kinds of equivalence of space-magnitudes must be distinguished: (a) Subjective equality given by the hypothetical transcendental intuition; (b) Objective equivalence of the real substrata of space-relations, proved by the equality of physical states or actions, existing or going on in what appear to us as congruent parts of space. The coincidence of the second with the first could be proved only by experience; and as the second would alone concern us in our scientific or practical dealings with the objective world, the first , in case of discrepancy, must be discounted as a *false show*.

Helmholtz on the reality underlying the appearances:

Now we find, as a fact of consciousness, that we think we perceive objects occupying determinate positions in space. If anobject appears thus in one particular part of space and not inanother, this must depend on the kind of real conditions that evoke the presentation. We must conclude that other real conditions might have existed fitted to produce a perception of the like objects in a different position. In the world of realitythere must be some causes or aggregates of causes determining at what particular place in space an object shall appear to us.These I will designate, for shortness, ***topogenous moments***, i.e.,circumstances determining space-perception. We know nothiingof their nature; we know only that the occurrence of spatially different perceptions involves a difference of topogenous moments. Also there must be different causes in the sphere of the real, when at the same place we think we perceive substances with different qualities. I will call these ***hylogenous moments***, i.e., circumstances determining the perception of material things. New names are chosen in both cases, to avoid the misleading associations of current expressions.

Helmholtz, continued:

If now we perceive and affirm anything that involves space-relations, the real meaning of our words no doubt is nothing more than that between certain topogenous moments, the nature of which is unknown to us, a certain relation holds, whose nature also is unknown. Hence Schopenhauer and many followers of Kant have been led to the improper conclusion that there is no real content at all in our space-perceptions, that space and its relations are purely transcendental and have nothing corresponding to them in the sphere of the real. We are, however, justified in taking our space-perceptions as signs of certain otherwise unknown relations in the world of reality, though we may not assume any sort of similarity between the sign and what is signified.

Think of the image of the world in a convex mirror.... the images are diminished and flattened in proportion to the distance of their objects from the mirror.... Yet every straight line or every plane in the outer world is represented by a straight line or a plane in the image. The image of a man measuring with a rule a straight line from the mirror would contract more and more the farther he went, but with his shrunken rule the man in the image would count out exactly the same number of centimetres as the real man. And, in general, all geometrical measurements of lines or angles made with regularly varying images of real instruments would yield exactly the same results as in the outer world, all congruent bodies would coincide on being applied to one another in the mirror as in the outer world, all lines of sight in the outer world would be represented by straight lines of sight in the mirror. (Helmholtz 1870)

“If it were useful for any purpose, we might with perfect consistency look upon the space in which we live as the apparent space behind a convex mirror with its shortened and contracted background....Only then we should have to ascribe to the bodies which appear to us to be solid, and to our own body at the same time, corresponding distensions and contractions, and we should have to change our system of mechanical principles entirely.... Thus the axioms of geometry are not concerned with space-relations only but also at the same time with the mechanical deportment of solid bodies in motion.”

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Van F. on Helmholtz:

“The reflection in the mirror is a perfect image of what is reflected. If we do not look at any relation of these two sides to ourselves (or any third object or background in which they are located) then they have precisely the same structure. Thus this example illustrates an isomorphism. Two objects that are isomorphic are mathematically no different from each other. We may overlook this if we, very naturally, think of the two as parts of a larger structure (or as related to ourselves as onlookers). In that larger context such parts may indeed be distinguishable, namely by their relations to other parts or to the whole. But if we are dealing with the world as a whole and a model of the world--as in a theory of physical space--then we have no such recourse.”

In short I do not see how men in the mirror are to discover that their bodies are not rigid solids and their experiences good examples of the correctness of Euclid's axioms.

But if they could look out upon our world as we can look into theirs, without overstepping the boundary, they must declare it to be a picture in a spherical mirror, and would speak of us just as we speak of them; and if two inhabitants of the different worlds could communicate with one another, neither, so far as I can see, would be able to convince the other that he had the true, the other the distorted, relations. Indeed I cannot see that such a question would have any meaning at all, so long as mechanical considerations are not mixed up with it. (Helmholtz 1870)

Poincaré on the conventionality of structural frameworks:

Space is another framework which we impose on the world. Whence are the first principles of geometry derived? Are they imposed on us by logic? Lobatschewsky, by inventing non-Euclidean geometries, has shown that this is not the case. Is space revealed to us by our senses? No; for the space revealed to us by our senses is absolutely different from the space of geometry. Is geometry derived from experience? Careful discussion will give the answer—no! We therefore conclude that the principles of geometry are only conventions; but these conventions are not arbitrary, and if transported into another world (which I shall call the non-Euclidean world, and which I shall endeavour to describe), we shall find ourselves compelled to adopt more of them. In mechanics we shall be led to analogous conclusions, and we shall see that the principles of this science, although more directly based on experience, still share the conventional character of the geometrical postulates.

Poincaré (continued) on conventions vs true relations:

So far, nominalism triumphs; but we now come to the physical sciences, properly so called, and here the scene changes. We meet with hypotheses of another kind, and we fully grasp how fruitful they are. No doubt at the outset theories seem unsound, and the history of science shows us how ephemeral they are; but they do not entirely perish, and of each of them some traces still remain. It is these traces which we must try to discover, because in them and in them alone is the true reality.

Poincaré on definitions in mechanics:

The principles of dynamics appeared to us first as experimental truths, but we have been compelled to use them as definitions. It is by definition that force is equal to the product of the mass and the acceleration; this is a principle which is henceforth beyond the reach of any future experiment. Thus it is by definition that action and reaction are equal and opposite. But then it will be said, these unverifiable principles are absolutely devoid of any significance. They cannot be disproved by experiment, but we can learn from them nothing of any use to us; what then is the use of studying dynamics? This somewhat rapid condemnation would be rather unfair. There is not in Nature any system perfectly isolated, perfectly abstracted from all external action; but there are systems which are nearly isolated. If we observe such a system, we can study not only the relative motion of its different parts with respect to each other, but the motion of its centre of gravity with respect to the other parts of the universe. We then find that the motion of its centre of gravity is nearly uniform and rectilinear in conformity with Newton's Third Law. This is an experimental fact, which cannot be invalidated by a more accurate experiment. What, in fact, would a more accurate experiment teach us? It would teach us that the law is only approximately true, and we know that already. Thus is explained how experiment may serve as a basis for the principles of mechanics, and yet will never invalidate them.

Poincaré on “true relations”:

The ephemeral nature of scientific theories takes by surprise the man of the world. Their brief period of prosperity ended, he sees them abandoned one after another; he sees ruins piled upon ruins; he predicts that the theories in fashion to-day will in a short time succumb in their turn, and he concludes that they are absolutely in vain. This is what he calls the bankruptcy of science. His scepticism is superficial; he does not take into account the object of scientific theories and the part they play, or he would understand that the ruins may be still good for something…

The differential equations are always true, they may be always integrated by the same methods, and the results of this integration still preserve their value. It cannot be said that this is reducing physical theories to simple practical recipes; these equations express relations, and if the equations remain true, it is because the relations preserve their reality. They teach us now, as they did then, that there is such and such a relation between this thing and that; only, the something which we then called motion, we now call electric current. But these are merely names of the images we substituted for the real objects which Nature will hide for ever from our eyes. The true relations between these real objects are the only reality we can attain, and the sole condition is that the same relations shall exist between these objects as between the images we are forced to put in their place. If the relations are known to us, what does it matter if we think it convenient to replace one image by another?

Poincaré on “true relations”:

Numerous theories of dispersion have been proposed. … But, what is remarkable, is that all the scientists who came after Helmholtz reached the same equations, starting from points of departure in appearance very widely separated. I will venture to say that these theories are all true at the same time, not only because they make us foresee the same phenomena, but because they put in evidence a true relation, that of absorption and anomalous dispersion. What is true in the premises of these theories is what is common to all the authors; this is the affirmation of this or that relation between certain things which some call by one name, others by another. (1902)

Carnap on “the character of philosophic problems”:

Philosophers have ever declared that their problems lie at a different level from the problems of the empirical sciences. Perhaps one may agree with this assertion; the question is, however, where should one seek this level. The metaphysicians wish to seek their object behind the objects of empirical science; they wish to enquire after the essence, the ultimate cause of things. But the logical analysis of the pretended propositions of metaphysics has shown that they are not propositions at all, but empty word arrays, which on account of notional and emotional connections arouse the false appearance of being propositions.

Carnap on ontological commitment:

Recently the problem of abstract entities has arisen again ifi connection with semantics, the theory of meaning and' truth. Some semanticists say that certain expressions designate certain entities, and among these designated entities they include not only concrete material things but also abstract entities, e. g., properties as designated by predicates and propositions as designated by sentences. Others object stiongly to this procedure as violating the basic principles of empiricism leading back to a metaphysical ontology of the Platonic kind.

It is the purpose of this article to clarify this controversial issue. The nature and implications of the acceptance of a language referring to abstract entities will first be discussed in general; it will be shown that using such a language does not imply embracing a Platonic ontology but is perfectly compatible with empiricism and strictly scientific thinking. Then the special question of the role of abstract entities in semantics will be discussed. It is hoped that the clarification of the issue will be useful to those who would like to accept abstract entities in their work in mathematics, physics, semantics, or any other field; it may help them to overcome nominalistic scruples.

(“Empiricism, semantics, and ontology”, 1950)

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Carnap on ontological commitment:

Are there properties, classes, numbers, propositions? In order to understand more clearly the nature of these and related problems, it is above all necessary to recognize a fundamental distinction between two kinds of questions concerning the existence or reality of entities. If someone wishes to speak in his language about a new kind of entities, he has to introduce a system of new ways of speaking, subject to new rules; we shall call this procedure the construction of a framework for the new entities in question.

Quine on ontology:

As an empiricist I continue to think of the conceptual scheme of science as a tool, ultimately, for predicting future experience in the light of past experience. Physical objects are conceptually imported into the situation as convenient intermediaries-not by definition in terms of experience, but simply as irreducible posits comparable, epistemologically, to the gods of Homer. Let me interject that for my part I do, *qua* lay physicist, believe in physical objects and not in Homer's gods; and I consider it a scientific error to believe otherwise. But in point of epistemological footing the physical objects and the gods differ only in degree and not in kind. Both sorts of entities enter our conception only as cultural posits. The myth of physical objects is epistemologically superior to most in that it has proved more efficacious than other myths as a device for working a manageable structure into the flux of experience.

G.E. Smith on Newton's method:

In Newton's hands force is a flagrantly theoretical quantity. The principal problem Newton's mathematical theories address is to find ways to characterize forces….

The propositions from Books 1 and 2 that become most important to the overall *Principia* are of two types. The first type consists of propositions that link parameters in rules characterizing forces to parameters of motion. The historically most significant example of this type is Newton's "precession theorem" for nearly circular orbits under centripetal forces….This proposition and others of its type thus enable ***theory-mediated measurements*** of parameters characterizing forces to be made from parameters characterizing motions. The propositions laid out earlier relating centripetal forces to Kepler's area rule, and their corollaries, provide another example of this type in which areal velocity yields a ***theory-mediated measure*** of the direction of the forces acting on a body.

Demopoulos on Poincaré on the molecular hypothesis:

In ‘Hypotheses in physics,’ Poincaré took his analysis of the value of atomistic theories as possibly suggestive guides for future research a step further, and argued that the question of the atomic constitution of matter concerns “an indifferent hypothesis,” meaning by this that it is a hypothesis whose assumption is at best a heuristic aid which complements the cognitive style with which some theorists approach their calculations. But in his (1912a) Poincaré came to recognize that, in assigning this methodological status to the atomic hypothesis, he had conflated the question of whether we might dispense once and for all with continuity with the more restricted question of whether the molecular and atomic hypotheses can ever achieve the status of scientific fact. By its very formulation, the former question seems to invite a picture of unstable vacillation between alternative resolutions. But Poincaré argued that this is not the situation with the latter question in light of the justification the molecular hypothesis acquired with the recent discovery of appropriate relations. The principal one among these relations is the identity of the mean kinetic energies of the Brownian particles and the molecules comprising the fluid in which they are suspended. It afforded a means of empirically determining the values of molecular parameters that had previously been lacking.

Demopoulos on Poincaré's realism:

The basis for Poincaré's mature view of molecular reality was the same as Perrin's: once it could be shown to be epistemically accessible by robust theory-mediated determinations of the properties of molecules, molecular reality was on the path to being secured. But this is a justification of the molecular hypothesis that can be maintained in the face of serious questions about the truth of our theories of molecular reality. It would therefore be a mistake to represent Poincaré as having mounted a defense of science that was a pre-echo of scientific realism. Poincaré's view is more nuanced than this and combines both realist and non-realist aspects. It is realist in so far as it fully supports the reality of entities that transcend observation; but it does so on the basis of experimental and theoretical advances within science that are related to measurement. By not resting on the supposition that the predictive success of theories would be miraculous were they not at least approximately true, Poincaré's position differs from standard conceptions of scientific realism.

Demopoulos on Poincaré (continued):

It is however important to emphasize that his methodological remarks avoid certain aspects of realism without falling victim to the then emerging positivist consensus—represented perhaps most prominently by Mach—that theory should be reduced to observation….
….And to the extent that for Poincaré the value of theories is "instrumental," this must include their instrumental value in revealing relations which guide us to a representation of the constitution of a reality that lies hidden from observation.

Cf. Stein: "First of all, instruments for what?…..The instrumentalist's claim can be read as: A theory is 'nothing but' an instrument for representing the phenomena…I turn to the realist and ask, what 'more' should a theory provide than a representation— in a suitable sense correct, and in a suitable sense adequate— of phenomena?"