What do we mean by "true" in scientific realism?

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Abstract

A crucial aspect of scientific realism is what do we mean by true. In Luk's theory and model of scientific study, a theory can be believed to be "true" but a model is only accurate. Therefore, what do we mean by a "true" theory in scientific realism? Here, we focus on exploring the notion of truth by some thought experiments and we come up with the idea that truth is related to what we mean by the same. This has repercussion to the repeatability of the experiments and the predictive power of scientific knowledge. Apart from sameness, we also found that truth is related to the granularity of the observation, the limit of detection, the distinguishability of the objects in theory, the simultaneous measurements of objects/processes, the consistencies of the theory and the one-to-one correspondence between terms/events and objects/processes, respectively. While there is no guarantee that we can arrive at the final "true" theory, we have a process/procedure with more and more experiments together with our own ingenuity, to direct us towards such a "true" theory. For quantum mechanics, since a particle is also regarded as a wave, quantum mechanics cannot be considered as a true theory based on the correspondence theory of truth. Failing this, truth may be defined by the coherence theory of truth which is similar to the coherence of beliefs. However, quantum mechanics may not be believed to be a true theory based on the coherence theory of truth because wave properties and particle properties may contradict. Further research is needed to address this problem if we want to regard quantum mechanics as a "true" theory.

Keywords: truth, pessimistic induction, no miracle argument, scientific realism

1. Introduction

Scientific realism tries to establish that the scientific theories are believed to be true so that the aim of science is to discover the truth about the universe. However, scientific realism may regard a model as a theory, and proceed to consider that the model as well as the theory is believed to be true even though this has been regarded as problematic (Chakravartty, 2001). Nevertheless, a crucial aspect of scientific realism is what we mean by "true". And some may relax the criterion to approximately true (Weston, 1987) rather than true, because a true theory or true model implies the accuracy is 100% which is hard to achieve in practice as there are errors due to measurement, idealization, abstraction, approximation, etc. so that the criterion is relaxed to accurate enough for the theory and model. By contrast, according to Luk's theory and model of scientific study (Luk, 2010; 2017), a theory can be believed to be true or false whereas a model is accurate or not. Therefore, we need to clarify what we mean by a true theory (van Fraassen, 1980). The simplest solution is that we say the description or explanation advanced by the theory is accurate. But what do we mean by saying that it is accurate? If it is accurate, we should have some means to measure the accuracy and check whether it is accurate or not. Given that the outcome is accurate, we infer that the theory is considered to be true. If we want to be cautious, we would wait for many different measurements of different explanations that allow us to infer that the same theory is considered to be true. But in this case, what do we mean by the theory is considered to be "true" based on the inference? That is we accept the whole description or explanation (as a system like the Duhem-Quine thesis) is believed to be true if the outcome is as predicted. In this case, we would believe that the physical situation operates as described by the explanation even though we have not actually observed how the situation operates. However, scientists do not necessarily believe that but that is the best knowledge at the time to predict the outcome. So, we have to restrict to the case that when the scientists believe that the theory is true, it means that the explanation and description advanced by the theory is believed to be accurately describing the physical situation operation. The scientists support this belief (a) by finding different lines of evidence (coming from different experiments) for their predictions derived from their scientific knowledge and (b) by following a (statistical) methodology to decide whether to accept such a belief (with a certain level of confidence or risk).

In the rest of this paper, we explore the notion of truth in scientific realism, which happened to take the realist stance. Specifically, the rest of this paper is organized as follows. In Section 2, we discuss the relationships between theory and model, and we explore what we mean by a "true" theory in Luk's sense. In Section 3, we will explore the relationship between "truth" and "sameness". In Section 4, we look at what an electron is since it can be both a particle and a wave according to quantum mechanics, which violates some notion of truth. In Section 5, we explore the issues related to unobservable objects and events, which may lead to underdeterminism that leads to the pessimistic induction. Finally, we draw our conclusion. Note that from here on when we write, for example, that the theory is true, we mean that the theory is believed to be true, in order to keep the flow of the text undisturbed. Similarly, when we write the theory being true, we mean the theory being believed to be true.

2. "True" Theory

According to Luk (2010, 2017), a theory is a set of general statements, which is distinct from a model. So, how are the theory and the model related to each other? First, the theory is related to the model by using the statements (e.g., $F = m.a$) in the theory to build the situation-specific models. Second, the theory makes some theoretical assumptions which are assumed to hold for the models. Third, since the theory is supposed to be more general than the model, the accepted ranges of the parameter values in the theory are supposed to vary more than those in the model. Fourth, a theory may have some term (e.g., energy) which corresponds to more than one term in the model or in the experiment (e.g., electromagnetic radiation and heat). In this case, certain quantity of the theoretical term (e.g., energy) corresponds to some (applied) term in the model (e.g., radiation) and the other quantity of the theoretical term (i.e., energy) corresponds to another (applied) term in the model (e.g., heat). As a result, there can still be a one-to-one correspondence between theoretical terms and (applied) terms in the models and experiments if we take into account about the quantity of the theoretical terms. By contrast, the models may make some model-specific assumptions (e.g., frictionless assumption) to simplify the modeling of the situation, in which case this has no bearing on the theory. The models may abstract the situation choosing certain aspect of the situation not described by the model, which typically is assumed not to affect the theory. The models may idealize the situation in order to simplify the situation for modeling. Again, it is assumed that such idealization has no bearing on the theory. The models may make approximations sometimes for the ease of calculations or derivations and this is assumed that it will not affect the theory. Having clarified the relationship between theory and model, they can be regarded as distinct entities. In this respect, the theory is considered to be true because its theoretical statements are considered as true. By comparison, the model is only considered as accurate or not because it usually makes quantitative predictions, the accuracy of which can be measured. Therefore, one form of scientific realism is about achieving a theory that is considered to be true by scientists because its theoretical statements are believed to be true by scientists.

When a (scientific) theory is considered to be true, basically some scientists mean that the theoretical terms that the theory refers to correspond to the physical objects and the events that the theory refers to correspond to the physical processes (similar to the correspondence theory of truth although ours may apply not only to sentences but to some models/representations or to some technical specifications like formulae or equations) even though some of the objects or processes may be unobservable. While this is the intention of the scientists who believe that the theory is true, how the belief of the scientists comes about is based on the coherence of beliefs (similar to the coherence theory of truth) that came about by statistical tests in experiments. The basic idea is that from experiments the statistical test supports the belief that the theory is true. Further (novel) experiments by statistical tests further support the belief that the theory is true, so that there is a coherence of beliefs that the theory is true. As a result, when the scientists are convinced by the coherence of beliefs (which can be made objective by carrying out statistical tests as discussed in scientific realism in [Luk, 2018a]), they would consider that the terms/events mentioned by the theory correspond to the physical objects/processes, respectively.

Usually, the statements in the theory are applied to build models which make predictions that experiments can measure to see if the predictions are accurate. In this way, the statements in the theory (like conservation of energy) are only tested indirectly. Therefore, when we refer to a theory to be true, we are saying either (a) the terms/events (like energy) of the statements in the theory correspond to those terms (like thermal infrared energy or heat) realized in the physical situation of an experiment, or (b) the terms/events (like energy) of the statements in the theory, which are applied in building the model, correspond to those terms (like momentum) applied in the model describing the physical situation of the experiment. Therefore, the terms/events of the statements in the theory may not directly correspond to the physical objects/processes, but the realized or applied terms/events in the model or the experiment correspond to the physical objects/processes when the theory is true. To maintain a one-to-one correspondence of theoretical terms/events with the physical objects/processes, the quantity of the theoretical terms/events needs to be taken into account so that some quantity of the theoretical term/event corresponds to some applied/realized term and the other quantity of that theoretical term/event corresponds to some other applied/realized term. In the rest of this article, we will not divert into this issue in order to keep the argument simple since this issue can be resolved.

A theory is more general than a model so that a lot of the situation-specific constraints (e.g., model-specific assumptions) are not present in the theory. The statements in the theory are supposed to hold. Typically, controlled experiments are used to validate these statements so that they can be considered as true. For example, the validity of the famous equation, $E = mc^2$, is being validated by Rainville et al. (2006) in a controlled experiment to explore the precision of this equation. By contrast, a model is a situation-specific description. It may or may not be applied to a controlled experiment. Typically, a model uses abstraction and idealization to combat the complexity of the modeling process so that a simplified description can be drawn up to make predictions. Because severe abstraction and/or idealizations may be used, some may consider the model cannot be true (Chakravartty, 2001). However, because the statements in the theory (like $E = mc^2$) have been applied to build the model and when the model makes accurate predictions, scientists would consider that the accurate predictions support the theoretical statements even though the model is not considered to be true. In this case, the scientists would consider that the theory is true because a successful model is built to make predictions even though the model is not considered to be true. Obviously, scientists do not look at just one model but different models that the same theory generates. If all these models make accurate predictions even though all these models are not considered to be true, scientists would consider the theory generating all the different models to be true in the sense that there is a (strong) coherence of beliefs. Such (strong) coherence of beliefs accompanied by controlled experiments showing that the statements in the theory are supposed to hold may overwhelm the scientists, convincing them to believe that the theory is true in terms of the correspondence theory of truth.

3. “Truth” and “Sameness”

Suppose that the theory is believed to be true based on the correspondence theory of truth as the scientists are overwhelmed by the coherence of beliefs that the theory is true. If the theory only refers to a single object or a single event, then it is just a matter of naming the object or naming the event. However, scientific theories refer to a group of objects and a group of processes. For example, a scientific theory that refers to an electron means for all the objects that are called electrons, we expect that the electrons will behave identically in the same condition. So, the problem is that the theory in science refers to objects in a group that are supposed to be the same or refers to a group of processes that are supposed to be the same. It is precisely that the group of objects or processes that are supposed to be the same, that experiments on the same objects or processes produce the same results (This is assumption 7 in the theory of scientific study by Luk [2017]). That is why we have repeatability in our experiments, thereby supporting our suggested notion of truth. Therefore, the problem about what we mean by “true” theory is how do we regard objects or processes to be the same.

We cannot arbitrarily regard different objects to be the same or different processes to be the same. They must have the property that under the same condition, they will behave the same. That is why science has predictive power. However, can we require all possible behavior to be the same for the same objects? That may require an infinite amount of time and resources. Usually, what is done is to label the object to belong to certain class and then find objects that belong to that class because they have the same behavior as the original object. For example, we find a particle that is called an electron with one elementary charge and a mass of 1/1836 of a proton. Then, we proceed to find other particles with these properties and call them electrons. Some of these particles may indeed be electrons if you test them with all the procedures but some may not because the distinguishing test has not been discovered yet. If it had been discovered, then we might add a feature (or intrinsic property?) to those particles to distinguish them, for example, particle+ and particle- (or say a colored particle).

So, how do we know if any two electrons are of the same kind? We can measure their mass and their electrical charge, and those measurements are the same. But how do you know they are exactly the same kind? Let us engage in a thought experiment. Suppose one electron has a string orbiting around it but the other electron has none. Suppose the string cannot be detected by us, so the observable electron includes the string orbiting around it. Our measurements of the two observable electrons have no difference because the string is undetectable. So, if we just consider the mass and charge measurements, then the two electrons are the same (within measurement errors), so our theory is true. Note that we believe it is true but according to our hypothetical observation it is not because the two electrons are different, one having a string orbiting around it and the other hasn't. Suppose now we fire the two observable electrons to hit some object and they behave differently. So, we may than conclude that these observable electrons are different. Scientists may hypothesize that one observable electron has something different from the other and proceed with more experiments. They may not know that there is a string orbiting one electron but they label one observable electron as having a positive spin and the other as a negative spin. So, is the scientific theory true or not? The description is not accurate any more since an (observable) electron does not spin. But the description serves the purpose to distinguish one observable electron from the other.

In practice, the sameness issue is even more problematic because usually science deals with probability and statistics. Suppose you fire a group of electrons to hit an object and the electrons are scattered in all different directions. Was it because the electrons are inherently different leading them to be scattered differently or because the electrons hit the object at different angles leading them to be scattered differently or both? Scientists are faced with such difficult questions. They have to make more observations in different experiments in order to answer the difficult questions. Moreover, some of the theory may be probabilistic in nature so that the theory predicts that the electrons will be scattered by the object even if the electrons are regarded as identical, hitting the object at the same angle, so that you don't know from the theory whether the electrons are the same or not.

Suppose now that technology advanced, we are able to detect the string orbiting around the electron. Then, we have to revise our theory that the electron has spins to give a more accurate description (since scientific knowledge is only the best at the time). Therefore, if we have more advanced technology that can probe into nature more deeply, then we may revise our theory for advancement. However, suppose we do not have the advanced technology and suppose that there is a fundamental limit in measuring space that does not allow us to detect the string orbiting around the electron. In this case, we would have to settle on the theory that the electrons have spin and we do not know that the theory is not accurate but it is believed to be true. So, has science advanced to a true theory? We can amend the description of spin to the description that we don't know why the electrons are different but there is something undetectable to distinguish electrons with positive spin and those that have negative spin (so spin is just a label rather than a description of the mechanism of difference). At last, we can make the theory to be true given that we cannot observe the mechanism of the spin of the electron. Therefore, scientists need to be more careful with their wordings when they want their theory to be true or explain more carefully (e.g., what they mean by the spin of an electron if the mechanism of the spin is undetectable [yet]).

4. What is an electron?

Is an electron a point-like object? Is it a cloud of strings? A point is only a concept. A point has no length, no width, etc. An electron is a point-like object only in terms of the level or granularity of observation. At the particular level of measurement that we can make, an electron appears as a point-like object. This is perhaps a better description because the measurements only allow us to describe the object as point-like. Effectively, we do not know what the object looks like because the measurement cannot support such observation. In quantum mechanics, actually an electron can be considered as a wave (function) which we will discuss further later. If we have better instruments, we may be able to look at the surface of an electron in which case the electron may not appear as point-like anymore. The electron may be an irregular surfaced object for example. Then, no two electrons may appear similar with their irregular surfaces. Therefore, when we refer to objects that are treated as the same, they are the same only in certain sense (in this case, only up to the level or granularity of measurements). In other subjects like biology, two dogs are the same so far as we recognize them as dogs in general. Their genes are different but similar in some sense and they may react to germs or viruses differently even though they are categorized as the same kind of dogs. So, "sameness" is a convenience to our mind so that we can treat these objects as the same, but whether they are or not, may depend on the granularity of observation as well as what do we mean by the "same". Therefore, if we want to specify a true theory, we may need to explicitly state the conditions in which we treat the objects/events as the same or indistinguishable.

The indistinguishability of particles is actually a postulate in quantum mechanics. This postulate is supported by quantum statistical mechanics experiments (involving the Fermi-Dirac distribution or the Bose-Einstein distribution for example). Therefore, the particles are identical in theory which is supported by experiments. However, quantum mechanics is only the best theory so far to explain the quantum phenomena, as some problem is found with the Heisenberg uncertainty principle by Ozawa (1988). We may also have the possibility that some higher power microscope may be invented that can make finer observations of particles, which may reveal more details about whether the descriptions (e.g., spin) are true or not. On the other hand, if quantum mechanics is the final theory, then in theory the conceptually same elementary particles are identical and there is no issue about the granularity of observation as quantum mechanics is the limit. However, physicists need to remind us that the intrinsic properties are just labels to distinguish the particles rather than suggestive mechanisms of the behavior of particles to avoid the theory to be inaccurately describing the particles.

Going back to particle-wave duality, this represents a problem for claiming the physics theory (i.e., quantum mechanics) to be "true" as well as other problems (e.g., Kosso, 2000; Norris, 2000). This is because we have two descriptions or labels for the same object: a particle and a wave. A theory to be qualified as a true theory should be able to map a label to an object in a one-to-one way (i.e., an injective function according to Luk [2010]). However, because there are two labels for the same object in particle-wave duality, such an injective mapping from labels to objects cannot be sustained and the physics theory (i.e., quantum mechanics) at present cannot be considered to be "true" even though its predictions are accurate. Therefore, the claim for realism in physics theory needs to be considered. One way to resolve this issue is not to consider the quantum entity as literally a wave but as a particle with different probabilities at different locations since the squared modulus of a wave function is interpreted as the probability density of a particle being detected at a given place. However, the particle would exhibit wave properties, and we do not know whether the wave properties contradict with the particle properties (under the same condition) because even though there is the complementary principle by Bohr that the particle and wave properties will not be found simultaneously, relatively recently this principle has been challenged (Rabinowitz, 2013). The inconsistencies between wave properties and particle properties would prevent us from claiming that the theory is true according to the coherence theory of truth which scientists may fall back on if the correspondence theory of truth is not viable, because the coherence of beliefs may translate into the coherence theory of truth when the beliefs are translated into propositions with true values where true means the propositions are believed to be the case. Another way to resolve this problem is to invent a new name like "wavicle" (Eddington, 1928) instead of using the label: particle or wave. However, we have to make sure that the particle properties and the wave properties do not contradict with each other similar to the previous solution (otherwise there is a consistency problem in the theory which violates the basic principle of theoretical consistency in Luk [2017]). Also, we have the problem of describing what these (quantum) objects are like in natural language for our understanding. Having said that, Luk (2018b) mentioned that it may not be possible for us to understand the phenomenon by analogy with our everyday experience or in natural language, so the object may just be a mathematical entity defined by the mathematical properties that it exhibits. This may turn out to be the case if there is some fundamental limit in which we can probe reality and this is an open research question.

The objects regarded as mathematical entities which are defined by mathematical properties (or numerical quantities) are supposed to be measurable in terms of those properties or quantities. Therefore, when we claim that a theory is true, it means that the objects and processes are defined by some mathematical properties which can be measured directly or indirectly to ascertain whether the theory is true or false. In practice, we cannot make all these measurements simultaneously (may be due to the Heisenberg uncertainty principle although it may become open to debate after Ozawa [1988]). We just use some properties to infer that these objects are indeed as expected. For example, an electron beam is based on accelerating electrons using an anode to attract electrons. It may be that apart from electrons there are other negatively charged particles (which have similar mass and charge) that can be accelerated from the cathode. However, these negatively charged particles have not been discovered yet and they are being mistaken as the electrons. Then, we proceed to consider that the electrons hit some particles and the electrons are deflected in different directions but in fact some charged particles are deflected in one way and the electrons are deflected in another way. However, our theory may predict that some electrons are deflected the same as the unknown charged particles with certain probability and the electrons are deflected in another direction with another probability. Then, we regarded our theory as a success because of its correct predictions and claimed that our theory is true. However, we have to perform more experiments of different kinds so that the different lines of evidence would suggest our theory is true because we did not make simultaneous measurements of all the objects and processes in the experiments to ascertain the theory is true in the prediction. Therefore, to accept that a theory is true, statistical tests are needed to help us to decide whether the theory is true based on various kinds of experiments that support the same theory (Luk, 2018a). Having said that, there is still risk in accepting or rejecting the claim that the theory is true but that is the current acceptable methodology to make a risky decision.

5. Unobservable Objects and Events

How can scientists believe that terms about unobservable objects or processes (Russo, 2006) correspond to reality since there are no direct measurements of the objects or physical processes? If the scientists believe that the theory is true, then they believe the existence of the unobservable objects/processes by indirect measurements and predictions, or they believe that the unobservable objects/processes are convenient tools for modeling or theorizing. If the theory is true, then the model supported by the theory should be able to make accurate predictions. Scientists also try to find and isolate the unobserved objects/processes in the successful theory as a way to support or falsify the theory. In general, scientists do not just rely on a single prediction in an experiment to declare that the theory is true. Instead, multiple lines of evidence are gathered before scientists hold the belief that the theory is true. Since scientists know that making such a belief is a risky decision, scientists follow statistical procedure or methodology to make this risky decision so that they know how risky the decision is (like specifying the level of confidence or risk).

Some may argue that the theory may be underdetermined as there are unobserved objects/processes so that for the same experiment(s) there may be multiple theories that are applicable (speculating different unobserved objects/processes). However, scientists may develop new experiments or find new phenomena that may weed out the unsuccessful theories. So, it is possible that at certain time, multiple theories in science may exist that explain the phenomenon. However, over time, a surviving theory will be identified as science progresses. Therefore, underdetermined theories may occur but it is believed that scientific progress will find the desired one in the future even though there is no guarantee that a final "true" theory will be found in science, but there is a process or procedure that directs the investigation towards a final "true" theory because the aim of scientific study partly targets to produce good quality, general scientific knowledge (according to Luk [2017]). It may be argued that there may be many underdetermined theories speculating wildly about unobservable objects and processes. However, before these theories come into the attention of other scientists, the proposers for such theories need to make successful predictions in the existing experiments, or provide alternative explanations to those experiments or explain why they cannot test the theory. Given this kind of filtering, not many wild underdetermined theories are left to consider in mature scientific disciplines. Also, as science progresses, there are more and more lines of evidence that the scientists need to accumulate to claim the wild theory is the better one than the existing theory as the wild theory needs to make no worse predictions than the existing ones (Luk, 2019) and to succeed in predicting the outcomes of novel situations that existing theory fails. As the number of experiments to test the theories mounts, the likelihood of a wild theory succeeding in these cases is less so that there is possibly something like a probability convergence. Therefore, science progresses not just by having better theories but by more experiments to test the theories and models. Having said that, new theories may be published because they are very novel, they may be mathematically sophisticated and they may be judged by other scientists to be very significant. Therefore, wild theories (like multiverse theory) may get to the stage of publication, but over time, we believe they may be established or falsified. If they are established, they will become scientific theories.

As there is no guarantee that the final "true" theory will be found, newer and newer theory will suggest that more and more past theories are incorrect. According to pessimistic induction (Lauden, 1981; Sankey, 2017; Park, 2017) based on observing the failure of past theories, the most recent theory is likely to be incorrect. The pessimistic induction is based on a rather crude prediction model of the success of the next theory. In fact, if we consider that there is only one "true" theory and we may try over 1 million times to arrive at the final "true" theory, then the probability of getting to the "true" theory is approximately 1 over 1 million. Since this probability is small, it is likely that the next theory is indeed incorrect. However, we do not decide the success or failure of a theory based on such a crude prediction model. Instead, scientists look at how well the theory succeeds in predicting the outcomes of various relevant experiments. For the current winning theory, it is most likely that it can predict successfully for all the current relevant experiments. So, a better prediction model of whether the current theory is a success or not is to estimate the probability that a new experiment may falsify the current best theory. If such falsifying, novel experiment is found, then a new or modified theory is desired. This probability is a better estimate of whether we arrive at the final "true" theory, instead of the coarse survival rate of theories, because the sampling is done at the finer level of experiments of a theory rather than attaching a coarse (survival) probability to a theory. As newer successful theories can successfully predict the outcome of more experiments, the newer theories have higher success rates to predict the outcome of a novel experiment than the older theories. This corroborates with our intuition that the newer successful theory will be more likely to survive (so it is more likely to be the correct one).

Do scientists rely on the no miracle argument (Putnam, 1975; van Fraassen, 1980) for claiming that the theory is "true"? Hoyningen-Huene (2018) used curve extrapolation as an example to illustrate the weakness of the no miracle argument for scientific realism. However, some scientists are not relying on the no miracle argument to declare their theory is "true". The scientists are relying on a statistical methodology to make risky decisions. So, scientists know that when they accept a theory being "true", it is provisional and they acknowledge that the theory may be wrong in the future. Scientists do not need to rely on the no miracle argument to declare that the theory is "true" because scientists are unlike some philosophers who just use arguments to convince others. Therefore, the no miracle argument is a non-issue to most scientists today who use evidence and statistical procedure to make risky decisions, in addition to formulating arguments to convince others rather than based solely on arguments. As scientists acknowledge that their theory can be wrong, there is no surprise that the analogy with curve extrapolation that the fitted curve (representing a scientific theory) can be wrong with a novel point or observation (representing the result of a novel experiment).

On the other hand, some scientists may believe in the existence of miracles instead of no miracles. For example, scientists who have the Christian faith hold that Jesus Christ can perform miracles which are outside the physical laws of the universe. However, some scientists believe that God, in general, does not intervene in the human affairs so that no miracles are normally observed, or that God intervened in human affairs in an undetectable way. Consequently, not all scientists believe that there are no miracles. As a result, the success of science to be explained by no miracles may not be accepted by all scientists. For example, we do not know whether any (famous) scientists prayed (Valdesolo, 2013) to God to help them to create a new theory, model or experiment, and whether God helped them to do so by emerging an idea in their mind, which the scientists cannot say that the idea is coming from God or not. Note that we still have (limited?) free will as we can choose to act by ignoring the idea. Obviously, the scientists cannot state that God helped them in the paper if they want the paper to be accepted, so it is very hard to find evidence, unless they confess to the public that they prayed for such knowledge (like Srinivasa Ramanujan confessing to obtain mathematical knowledge from his family Goddess). However, to generalize that there are no miracles in the success of scientific knowledge may be premature.

6. Conclusion

I think from this argument it is clear that some science may possibly finally arrive at the "true" theory depending on how we regard objects and events are the same or are under the same category, as well as depending on the level of granularity of observation, or whether the theory specifies the objects are the same. The description and explanation may have to acknowledge what is undetectable and therefore cannot speculate any mechanism about the label (e.g., say spin) even though the label suggests some kind of mechanism or feature that distinguishes the objects or events. Adding to this complexity is the potential that undetectable objects or events may become detectable in the future. Even if we have a fundamental limit on measurement, that limit may only be our best knowledge at present, leaving us with uncertainty which we are certain about. Scientists combat this uncertainty by following statistical methodology to make risky decisions that may be revised in the future, but yet they may have confidence about their scientific knowledge.

According to the Duhem-Quine thesis, when the scientists make a risky decision to accept the theory or model by some statistical methodology, they accept the whole knowledge system to be applicable to the experiments. However, some scientists may believe that the unobservable objects in the knowledge system may truly exist while some scientists may consider the unobservable objects as convenient tools for theorizing or modeling. Some scientists may not believe that the whole knowledge system is an accurate description even though the statistical tests support the knowledge system, because the scientists may only accept the knowledge is the best so far but not good enough to put their personal belief at stake. Some scientists have the additional option to design experiments that confirm or falsify the existence of the unobserved objects/processes so that they may not be too hasty to believe that the unobserved objects exist or not. Therefore, to say that the theory is true implies that some (knowledgeable) scientists (some example scientists found in [Hoyningen-Huene, 2018]) believe that the unobservable objects/processes in the knowledge system are manifested somewhat in part or in whole in the physical process as there may be difficulties to pinpoint the exact manifestation of the unobserved objects/processes.

For quantum mechanics, we have the additional problem that quantum objects have two descriptions or labels (i.e., waves and particles) so that quantum mechanics cannot be regarded as a "true" theory for realism as the mapping is not one-to-one if we consider truth according to the correspondence theory of truth. While this can be resolved by thinking of the wave function as a way to derive the probability density of a particle detected at a given place or by inventing a new label like wavicle, it is necessary to check whether particle properties contradict with wave properties (under the same condition). Therefore, checking for contradictions of wave and particle properties helps realists to claim quantum mechanics as a "true" theory according to the correspondence theory of truth. In the case that such a correspondence theory is not viable for quantum mechanics, realists can still claim quantum mechanics is a "true" theory based on the coherence theory of truth, which is implied by the coherence of beliefs where the beliefs are translated into propositions with true values. However, if the correspondence theory of truth is not viable because the wave and particle properties contradict, then the coherence theory of truth for quantum mechanics is also not viable. Therefore, either quantum mechanics is not a "true" theory or some other theory of truth needs to be applied to quantum mechanics in order to make it a "true" theory in some new sense of "truth". In addition, a good natural language description of quantum objects is still desired for our understanding of the phenomenon. Further research is needed to resolve this issue which may or may not be resolvable depending on whether we hit any fundamental limit in the physical world. Even though scientific realism is not completely resolved, we have now a better understanding of what do we mean by "true" and a methodology to resolve (scientific) realism.

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