Towards an Ontology of the Rainbow

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Abstract

There are some objects of perception that are either too far from us to touch or that cannot be touched at all. Typical examples are the sky and the various phenomena that appear in the sky such as rainbows and sunsets. This paper is concerned with the ontological status of the rainbow. Does it exist when it is not actually perceived? Does it exist even when it is not possibly perceived? My conclusion is that a rainbow is a physical event, and that, although it is recognized as a rainbow by its characteristic visual appearance, it should not be identified with that appearance. I suggest that the case of the rainbow might give us useful hints for the analysis of secondary qualities like colors and sounds.

keywords

ontology, rainbow, existence and perceivability

1

Whenever we discuss perception in philosophy, we tend to talk about things like a desk in front of us, a glass of water on a table, a tree we see from our window, and so on; in general, we talk about the material objects which are not only visible with our own eyes but that are not so far from us that we cannot touch them either. I guess it is because philosophy is mostly an indoors activity that we have such a limited range of examples. Once we leave the room and look around us, we should notice that among the things we see there are many that are either too far from us to touch or cannot be touched at all.

What are those things that we see all the time and yet we cannot touch? They are the sky and the various phenomena that appear in the sky like rainbows and sunsets. The sky, rainbows and sunsets are different from the usual objects in the philosophical discussion of perception in that they can be seen but cannot be touched. They are also different in that they make us uneasy because it is not sufficiently clear what sorts of entities they are. There is little doubt that they

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are "material" in a certain sense; yet clearly they are not "material objects". Then, what sorts of entities are they?

It is too quick, however, to suppose that the sky, rainbows and sunsets are the same sort of entities; they might turn out to belong to different sorts of entities. I will start with rainbows. There are two reasons for doing so. First, great philosophers like Aristotle and Descartes discussed rainbows; as a matter of fact, Descartes is the first who explained the exact mechanism of the formation of rainbows[1]. Second, rainbows do not just provide a paradigm for a variety of phenomena we observe in the sky, but they might also suggest an important class of phenomena, which we may call "physically well-grounded perceptual phenomena" after a term invented by another great philosopher who discussed rainbows in many places in his writings, namely, Leibniz.

2

The Chinese character "虹" that means rainbow belongs to the same character class that includes "蛇" (snake) and "蛙" (frog). The part ("radical") that these characters share, "虫" means insect or worm, among others[2]. This suggests that rainbows were thought to be similar to a certain kind of animals in ancient China. In particular, rainbows were often referred as "big snakes in the sky". One reason why they were compared to the snakes might be that a rainbow seems to follow us when we try to get away from it. The same fact chould explain why rainbows were generally regarded as ill omens in ancient China and other societies that were under its influence[3].

In ancient Greece, the rainbow was represented as the goddess Iris, who was the messenger of the gods. She was sometimes thought to be a messenger of an ominous news, but she was also regarded as a benefactor of people as a ruler of the clouds that bring us the water necessary for the crops[4]

In the Hebraic and Christian traditions, rainbows were symbols of hope and good future. The most famous story about a rainbow is perhaps the one that appears in *Genesis* of the Old Testament.

> And God said, This is the token of the covenant which I make between me and you and every living creature that is with you, for perpetual generations: I do set my bow in the cloud, and it shall be for a token of a covenant between me and the earth. And it shall come to pass, when I bring a cloud over the earth, that the bow shall

[1]For a general history of scientific inquiry on rainbows, see Carl B. Boyer, *Rainbow. From Myth to Mathematics*, 1959, Sagamore Press. Reprinted, 1987, Princeton University Press.

[2]The character "虹" is a typical example of the very large class of Chinese characters that consist of a semantic and a phonetic part. "虫" is the semantic part and refers to a class of animals (mostly invertebrates); "工" is the phonetic part and stood for *gung* in Tang era Chinese, and for *gong* (and variants) and *kou* in modern Mandarin Chinese and Japanese respectively. [I owe this footnote to Lajos Brons.]

[3]Cf. Saijo Toshimi, *The Rainbow: Its Culture and Science* (in Japanese), 1999, Kouseisha-Kouseikaku, pp.17–18 and 31–35.

[4]Boyer, *Op. cit.*, pp.20–23.

> be seen in the cloud: And I will remember my covenant, which is between me and you and every living creature of all flesh; and the waters shall no more become a flood to destroy all flesh. And the bow shall be in the cloud; and I will look upon it, that I may remember the everlasting covenant between God and every living creature of all flesh that is upon the earth. And God said unto Noah, This is the token of the covenant, which I have established between me and all flesh that is upon the earth[5].

In sum, rainbows were associated with certain supernatural agencies in most ancient cultures; either they were identified with supernatural agents themselves, or they were thought to be fashioned or produced by them. Thus, the rainbow's appearances were thought to be those of a goddess in ancient Greece, while the rainbow was likened to some mythical creature such as the dragon (or snake) in ancient China. In contrast, in many cultures, a rainbow was likened to an artifact. As we just saw, in the Old Testament it was a bow put in the clouds by God. The very word "rainbow" contains a bow, and it is well known that in French a rainbow is called "l'arc-en-ciel" (the arch in the sky). In a similar way, a rainbow was sometimes called a "bridge in the sky" in traditional Japanese poetry.

Of course, we know today that a rainbow is not an appearance of a goddess, nor something put in the sky by God. Then, should we dismiss these myths and legends as worthless? Such a reaction is too hasty, for at least two reasons. First, we might be able to derive from these myths and legends some characteristic features of rainbows that the ancients thought of as essential. Even though they are no longer considered essential today, still they might be the features that should be attended to by any satisfactory explanation of a rainbow. Secondly, those things that the ancients thought real and we think only imaginary or fictional can also be subjects of ontological investigation. Its concern is not restricted to what there is. Ontology is not only concerned with what might be or what might have been, but also with what is only thought or imagined to be. For, many impossible things are thought or imagined. Imaginary beings can also be serious subjects of ontology.

Then, let us consider what follow if we take seriously these ancient views about a rainbow according to which we see an appearance of a goddess or a mythical creature when we see a rainbow in the sky? The first question that would occur to a contemporary philosopher is the following. Are there more than two rainbow goddesses or rainbow creatures? In other words, do we see different appearances of the same goddess or the same creature when we see rainbows at different times or places? Or, might we see different goddesses or mythical creatures at different occasions?

If we follow the mythical conception of the ancient Greeks and believe in the existence of the rainbow goddess, we could think that we see the same goddess whenever and wherever we see a rainbow, because there seems to be only one rainbow goddess, namely, Iris. On the other hand, it is not clear whether there

[5] *Genesis*, IX, 12–17 (King James version).

is only one mythical snake-like creature or heavenly bow; just as there might be many different dragons or bows, there might be many rainbow creatures or heavenly things that appear at different times and places.

We should not jump to conclusions, however, because a goddess is not a person like you and me, and we should not think that a mythical creature or a heavenly being behaves like the ordinary things we know. For example, it is not unlikely that one and the same goddess might appear at different places at the same time as happens frequently in the Homeric epics.

In general, the supernatural agents that were identified with rainbows seem to be different from agents like us in at least three respects. First, as we have remarked just now, they might be ubiquitous, that is, they can exist at different places at the same time. Secondly, they can move from one place to another in an instant, no matter how far the two places are from each other; this suggests that the spatio-temporal continuity is not a necessary condition for their identities. Thirdly, there might be a time in which they cannot be found anywhere in the world. Sometimes they disappear completely from our world before reappearing in it later.

These features suggest that they are not only different from agents like us who have material objects as their bodies, but also different from any object that exists in space and time. Take any ordinary object we know; it occupies more or less the same limited location throughout its existence, its spatio-temporal continuity is essential for its identity, and, of course, it is a thoroughly worldly being, in that it cannot leave the world even for an instant as long as it exists.

In contrast to such ordinary beings including us, although their appearances to us must be in space and time because we are, mythical creatures like goddesses and dragons are not themselves entirely in space and time; they are supernatural beings, because they exist beyond space and time, and hence they cannot belong to our world.

In many cultures, ghosts are like these supernatural agents whose appearances were thought to be rainbows. They are supernatural because they are not entirely in the space and time that constitutes the framework of the nature we are in. Ghosts are supposed to be known to us through their appearances to us, and hence, they sometimes[6] exist in the same space and time as we are, but where are they when they do not appear to anybody? Are there some hiding places for them like the coffin for Count Dracula? No, the vampires and zombies are different from ghosts[7] in that the former are still entirely within our world.

Although this is not true for all supernatural agents, one of their common features is that they can be seen or heard, but cannot be touched; another is that they appear to us only for a short time, and tend to vanish in an instant. It would be interesting to know why these features were frequently believed to be characteristic of supernatural beings, but there is no doubt that rainbows share

[6]Sometimes? It is only for us that ghosts seem to exist sometimes; in reality (?), they exist beyond time.

[7]At least, ghosts in some cultures like that of Japan. Ghosts and other similar imaginary beings should be fascinating subjects for ontological research. An atheist philosopher would say that most of various theological speculations are just that.

these features; they are only seen; we cannot touch them; moreover, their durations are short and they vanish from the sky suddenly. Such observations might have worked towards associating rainbows with supernatural powers in some cultures, and their likening to mythical creatures like goddesses and dragons.

In other cultures, such as the Hebraic one, in which rainbows were thought of as the products by the God, what is emphasized about rainbows seems to be their visual exquisiteness shown in their form and colors, which suggests the work of some superior being. The people may have thought that their arch-like shapes and multi-coloredness could not be produced by mere chance and there had to be some supernatural agent who intentionally created them. Hence, rainbows would have been one more piece of evidence for the existence of some supreme being.

Before leaving this stage of the history of the rainbow, I would like to say something about a certain interpretation of the biblical passage quoted above. According to this interpretation, the passage says that a rainbow appeared for the first time at the end of Noah's deluge and that rainbows had not been seen before[8]. Two entirely different questions may be raised about this claim.

On the one hand, there is a scientific question whether the conditions on Earth before the date when Noah's deluge is supposed to have taken place allowed for rainbows to appear, and almost certainly it will be answered positively. If there is no evidence to hold that the climate on Earth underwent a radical change just before the time of Noah's deluge, then we have no reason to think that no rainbows had appeared before.

Another question, on the other hand, is whether rainbows existed at a time when there were no people or living beings with vision around, and this leads to a more general question whether rainbows exist without anyone perceiving them. This is a question for which you cannot expect any unanimous answer from philosophers, as is the case with any philosophical question. It is one of the main questions in the philosophy of rainbows, and we will be occupied in trying to answer it in the next section.

3

When we turn to Aristotle's *Meteorologica* (Meteorology), we find ourselves in a very different climate than that of the myths and legends we have been discussing so far.

In Book III of *Meteorologica*, after having listed the already known facts about rainbows that need explaining, Aristotle devotes two chapters to rainbows. In the first (Chapter 4), he explains how rainbows are formed and why they have the colors they have. In the second (Chapter 5) he is concerned with the explanation of how the characteristic shape of a rainbow comes about. Throughout all of this, there is absolutely no mention of supernatural agents or powers. Aristotle gives us a completely naturalistic explanation of rainbows.

[8] Boyer, *Op. cit.*, pp.18f.

Rainbows were now considered as a recurring phenomenon with natural causes, which Aristotle sought in "a reflection of sight to the sun" from drops of water in the air[9]. As is well known, Plato held that we see things because light rays emitted by our eyes reach them[10]. It is because Aristotle was following the Platonic conception here that he spoke of the "reflection of sight". Carl Boyer suggested, however, in his book on the history of rainbow that if we are only concerned with the physical causes of rainbows it would not make any difference if we spoke of the reflection of the light instead[11]. If we adopt this suggestion, then we may say that Aristotle was looking in the right direction, namely, he was rightly seeking the causes of rainbows in the interactions between the light from the sun and water drops in the air. Of course, it is true that Aristotle's treatment of rainbows was mostly qualitative and that he made the crucial mistake of thinking that only reflection was involved in the formation of rainbows. These two defects were corrected by Descartes nearly two thousand years after Aristotle, but that is the subject of the next section.

Aristotle's theory of rainbows in its original form seems to imply that the existence of rainbows depends on that of creatures with vision; for, according to this theory, the eyes were essential elements in the formation of rainbows, because it holds that they were produced by the reflection at the water drops in the air of the light rays coming from the eyes of an observer. This immediately raises the same question that we encountered at the end of the previous section, namely, would rainbows exist if there were no creatures with vision to see them?

It should be noted at once that this question arises not because Aristotle had followed Plato and adopted the emission theory of vision. The same question arises also with our conception of vision, according to which we see a rainbow when our eyes receive through a mass of water drops the light rays that originated in the sun. The only difference between the Aristotelian view and ours is in the place of the eyes in the causal process that results in our vision of a rainbow; in Aristotle, they are at the start of the causal process, while they are at its end in our modern conception. Just as the vision of rainbows needs the eyes as the source of the light in the Aristotle of *Meteorologica*, it needs the eyes as the receptor of the light in the modern conception.

If you are actually looking at a rainbow, then undoubtedly your present experience depends on the existence of your eyes, because our having a perceptual experience depends on our having well-functioning sense organs. If a condition that is necessary for having a perceptual experience of a rainbow were also a condition for the existence of a rainbow, then the existence of a rainbow would depend on that of eyes.

But, this is true only on the supposition that a rainbow exists only when it

[9] *Meteorologica*, III, 4, 373b–374b.

[10] Plato, *Timaeus*, 45B–46C.

[11] Boyer, *Op. cit.*, p.325, note 19. In the following paper, S.Kanzaki suggests that Aristotle moved from the "emission theory" of vision to a conception similar to the modern view sometime between *Meteorologica* and *De Anima*: S.Kanzaki, "The outset of Aristotle's philosophy — 'being' as 'power of being acted on' " (in Japanese) *Philosophy* [*Tetsugaku*] No.64 (2013) 58–77.

is actually perceived, and this supposition is not obvious, to say the least. Why cannot a rainbow exist unperceived?

There seem to be certain kinds of things that exist only when they are actually perceived. One example would be occurrences of pain, although it might not be correct to say that pains are things. It is absurd to think that pain can exist without being perceived. Think of a person who insists that there exists a severe pain even though she does not feel it because she is under an anesthetic[12]. We cannot take her words seriously. We might say that the same applies to qualia in general, namely, various sensations like redness, bitterness, smoothness, and so on, again with the proviso that it may not be appropriate to refer to them as "things". These qualia exist only when they are experienced, and it is not difficult to understand why we might think that this is so; such a sensation can exist only as part of a perceptual experience.

Seeing a rainbow is a perceptual event that happens to somebody, but a rainbow itself is not a sensation which is part of a perceptual episode of a person or, more generally, a creature with vision[13]. Still, isn't it true that a rainbow can exist only when it is seen by somebody? Can a rainbow exist unperceived?

Suppose that I am looking at a rainbow with my friend. Nobody will think that this rainbow ceases to exist when I stop looking at it. Is it because my friend is still looking at it? Don't we think that the same rainbow will be in the sky, even if my friend stops looking? Suppose that my friend and I retire to our room and we are no longer looking at the sky. Yet we are sure that the rainbow does not disappear as soon as we stop looking. Is that because we believe somebody else is looking at the same rainbow? Obviously not. We think that the rainbow is still there because anybody would see it if she were situated at a suitable location and looking at the sky.

Again, it seems undeniable that we can easily imagine a rainbow which no one sees; for example, think of a time when Niagara Falls were not yet discovered, and then imagine a rainbow there; you will not find it too difficult to do so. You might object that even before Niagara Falls were "discovered" there had been some creatures with vision there. But it is not difficult to answer to this. Just imagine an ancient rainbow at a time before any creature with vision appeared; we can also imagine a future rainbow at the time when there will be no longer any creature with vision; in short, we can easily imagine a rainbow with absolutely no spectator[14].

There is an old objection against such scenarios, which goes back to Berkeley at least. Although it has a certain power to fascinate some people, I believe it is nothing but a muddle, and I hope to make it as clear as possible why this is so.

The objection runs roughly as follows. Let us take the case of an ancient rainbow at the time before any creature with vision was around; we know that there was a time like that; we may also know that it rained occasionally even at

[12]This used to be a favorite example of late Shozo Ohmori, when he talked about the essence of pain.

[13]For the sake of simplicity, I will omit such a qualification from now on.

[14]I thank Lajos Brons for discussing the points in this paragraph.

that time and that it might have happened that the light rays from the sun hit a mass of drops that had remained in the air after it rained; in short, we may agree that the conditions for a rainbow to appear might have been satisfied at the time; but, it does not mean that there could have been a rainbow; for, a rainbow is a multi-colored arch seen in the sky, and, as there was no creature with vision, there was no color, and hence, no rainbow. There could not be a rainbow when there were no beings who could see it.

Please, compare this argument with the following argument that purports to show that there are no truths about the primitive era that precedes the appearance of a language. —There are two main conceptions of truth; in one, the correspondence theory of truth, truth is a relation between a sentence and some worldly states of affairs, and, in another, the coherence theory of truth, truth is a relation among a group of sentences; in either conception, truth is a concept that makes an essential reference to linguistic entities; hence, we can talk about truth only where there exists a language.

The absurdity of this argument must be obvious. We use sentences and other linguistic devices to talk about things. This argument confuses what is talked about with what we use in order to talk about it[15]. Now we think we know many things about the dinosaurs and the times when they were roaming the earth. Such pieces of supposed knowledge are typically expressed by sentences, and the truths of some of these sentences have been hotly debated. No one has suggested that all these debates are meaningless because the concept of truth cannot be applied to the matters that precede the emergence of language.

Just as we can use sentences to describe the world at a time when there was no language, we can use pictures and movies to depict the world at a time when there were no human beings, as many pictures and movies about dinosaurs testify. We can talk about their truth and falsity just as we talk about the truth and falsity of sentences. Someone who sees a picture of a dinosaur might raise a question whether the color of the dinosaur depicted is correct or not.

Such pictures and movies represent situations by showing us what we would have seen (and heard, in the case of sound movies) if we had been present. In such cases, our ways of taking in the information from our environment such as seeing and hearing are used as the means for making reference to and talking about the things in the world. If we can use sentences to talk about a world in which no language exists, then, in exactly the same way, we can use visual and auditory representations, which are grounded in our way of perceiving the world, to talk about a world in which no visual or auditory experiences as we have now existed. If it were impossible to make a picture of a time when there were no experiences like our perceptual experiences, we would not raise questions like whether the depicted color of a dinosaur is correct or not; instead, we would wonder how it was possible for some person to be at the age of the dinosaurs and to see such a scene. But, usually, we do not wonder such things, showing that

[15]This point was forcefully stated by G. Pitcher, when he ciriticized Berkeley's so-called Master Argument. He argued that Berkeley missed a crucial distinction between "what is conceived *of*" and "what one conceive *with*". See G. Pitcher, *Berkeley*, 1977, Routledge & Kegan Paul, p.113.

we usually think that there is nothing wrong in a picture's depicting a world in which no human experience exists.

Although there might not have existed any experience of colors and shapes like ours at the age of the dinosaur, we use the colors and shapes we experience as a means to refer to the things and situations that existed at that time, just as we use our words and sentences to talk about the times when no language was present. There is an important difference, however, between colors (shapes, and sounds) and words (and sentences) in that the latter is conventional and may not reflect any property of the thing referred to or described, while the former usually reflects some important aspects of the things represented by them. We might say, using a Gricean terminology[16], that the colors and shapes used in a picture representing a certain situation are non-conventional signs, whereas words and sentences are conventional signs. For example, if we see a red flower in a picture which is supposed to be a realistic depiction of that flower, then we suppose that the object represented in the picture has a surface with a certain composition, which would cause a perception of redness if an appropriate condition were satisfied.

It is the same with imagining. To imagine a scene visually is to imagine what we would see if we were present at the scene; likewise, to imagine something auditorily is to imagine what we would hear if we were in the hearing range at the relevant time. We can easily imagine a tree's blossoming in a mountain no one knows, or the sound of a tree's falling deep in a forest which no one enters. To think that it is impossible to do such imaginings is to commit the mistake of confusing what the imagination is of with what we use in order to imagine it[17].

Still, it may be objected that the perception of a rainbow is different from that of a tree, because a rainbow can only be seen, while a tree can be perceived by any of the five senses. It is not obvious, however, how this makes any difference. It is true that people found the rainbow mysterious because it can only be seen. They found it mysterious also because it seemed either to run away from us when we tried to approach it, or to follow us when we tried to run away from it. For these reasons, in many cultures the rainbow was considered to belong to some supernatural realm, as we saw in the previous section.

But, what is at issue now is whether a rainbow can exist unobserved, and the fact that a rainbow can only be observed visually does not seem to make any difference to the present issue. Suppose that you are looking at the sky with your back to the sun after it rained; if you see no multi-colored arch-like shape in the sky, then you can be sure that there is no rainbow. This fact shows that the perception of a rainbow is different from other cases of perception in an everyday context in at least two respects. First, in the usual cases of perception, we have a variety of evidence from different sense modalities in order to confirm the existence or non-existence of the objects of perception. We may perceive an approaching train by either seeing it or hearing its sound. Secondly, most of the objects of perception are found in various circumstances and we may have to

[16]H.P.Grice, "Meaning" *The Philosophical Review*, 66 (1957) 377–388. Reprinted in H.P.Grice, *Studies in the Way of Words*, 1989, Harvard University Press.

[17]See two footnotes before this one.

call on different sense modalities in different circumstances. If I want to make sure that my friend is beside me in complete darkness, I have to rely on senses other than sight. In contrast, a rainbow can only be seen, and appears in only one sort of circumstances; they must be in daytime and after rain. But this does not make a rainbow any less real than a cloud in the sky; it can be publicly observed, and it may exist even when it is observed by no one.

Thus, we may conclude that a rainbow can exist without being actually perceived by anyone. But, if being actually perceived by someone is not a necessary condition for the existence of a rainbow, then when does a rainbow exist? An answer to this question was implicit in our consideration at a few pages back. Why are we sure that a rainbow remains in the sky after we stopped looking at it? Of course, we may be wrong and the rainbow may have disappeared at the same time as we stopped looking it, but we will think that it is just a coincidence. We believe that our stopping looking it does not cause the disappearance of the rainbow, and that, if we were still looking at the sky, we would see it, unless some significant changes took place since.

The use of such a counterfactual conditional is essential for making sense of the supposition that the objects of perception exist even when no one observes them. There is nothing absurd in supposing that at just this moment a cherry tree is in full bloom on a certain mountain without anyone observing it; what we understand when we hear this amounts to something like this: if someone were now near the tree, she would see it covered with pink blossoms.

So, roughly speaking, for a rainbow to exist now, it is at least sufficient if anyone who were now looking at the sky would see it. But, this is only a rough characterization. If we wish to be more precise, we should say something like the following.

> For a rainbow to exist at a time t and a location l, it is sufficient that the following counterfactual conditional holds.
>
> > (C) if someone with normal vision were looking at the sky at t and at an appropriate location within l, she would see a multi-colored arch-shaped figure.

I put a qualification "with normal vision" in order to exclude some exceptional cases like seeing an illusion of a rainbow. Another qualification "an appropriate location within l" is there for the obvious reason that if you want to see a rainbow you have to locate yourself in some suitable place and look in the right direction.

As the sufficient condition for the existence of a rainbow is expressed in the form of a counterfactual conditional (C), it allows a rainbow to exist even if no one actually sees it. What is needed for the existence of a rainbow is not the actuality of its perception, but merely the possibility of its perception.

A counterfactual conditional like (C), however, looks suspicious to some people. Their suspicion seems to be motivated mainly by two reasons. Of these, one is usually not a good reason but just a product of a simple misunderstanding,

although sometimes it needs our consideration; the other is a much better reason and we will see that in dispelling the doubts this raises to counterfactuals we will be led to an important point.

Some people may be suspicious of a counterfactual in general, because they think that a counterfactual supposition involves a contradiction. Suppose we are explaining to one of them why there might be sounds which no one hears; we begin with asking her to suppose that there is a big forest into which no one has entered and into which no one will enter; next we ask her to consider a counterfactual conditional "if someone were now in that big forest and a huge tree fell, she would hear the sound of the falling". At this point she would object and argue like this. —You started with the supposition that there is a big forest into which no one has entered and will enter. But then you say that someone is there after all. Isn't this an obvious contradiction?

One source of confusion is missing the distinction between *de re* and *de dicto*. If we say "someone is in a forest which no one has entered and will enter", it is, of course, a contradiction. But, in the counterfactual conditional in question, "that big forest" is used *de re*, namely, it refers to the forest that was introduced at the outset. This forest was introduced into a discourse by the property of no one's entering it, but it is an accidental property, and hence, it is perfectly possible to suppose that this same forest lack this property. In the antecedent of the conditional, we are presenting a possible situation in which there is someone in this very forest. As this is a counterfactual conditional, such a possible situation should be just the same as the situation which is supposed to be actual in this story except for the fact that there is someone in that forest and other facts this change should entail.

Another source of confusion perhaps lies simply in that people tend to find it difficult to keep track of what is supposed to be actual and what is supposed to be possible but non-actual. In a philosophical discussion such as this, which is concerned with what holds in general, it frequently happens that a mere possible situation is temporally regarded as "actual", the difficulty is stronger. In our example of the big forest, it is supposed that no one has entered or will enter it in the "actual" world, and that there is some other "possible" world in which someone is in the forest. There is no possible world in which no one is in the forest and at the same time someone is in it.

Thus, some people's suspicion that a counterfactual supposition involves a contradiction is mostly groundless. But, it is not true that all counterfactual suppositions are free from contradictions.

A case in point is the case of imagining a scene on primitive Earth when there was no life yet. We might see a picture of such a scene in some book on geology. As it is a picture, it depicts what Earth would be like if someone with sight had been at that time. What kind of a situation is that in which someone like us existed on Earth at a time when there was no life yet? If this person was there as a result of a natural course of events, then almost all of our science should be revised so that such a possibility is allowed. If it is not feasible, we should think such a person existed there because of some miracle, which might be a result of divine intervention, an operation of a time machine

which defies the known physical laws, or whatever. Moreover, it may turn out that it is metaphysically impossible that any god exists, or that it is physically or even logically impossible that a time machine exists. But then, is it coherent to imagine a situation in which such an impossibility holds?

Though this seems to constitute a serious objection, it is not necessarily the case that we have no answer to it. Those counterfactual conditionals whose antecedents involve impossible situation are sometimes called "counterpossible conditionals", or simply "counterpossibles", because their antecedents are not only contrary to facts but also contrary to possibilities. There are two things we can say about those counterpossibles. First, they are usefully employed in both theoretical discourses and ordinary conversations. Secondly, there exist a variety of accounts which give systematic semantics of them[18]. So, I believe that we have a good prospect of showing that there is semantically nothing wrong with counterfactual conditionals, including counterpossible conditionals, and hence, that they make perfect sense.

Now, let us turn to the other reason some people give for doubting the legitimacy of counterfactual suppositions. It is the seeming difficulty of giving satisfactory answers to two closely related questions that naturally arise with such suppositions. They are: (1) how can we know whether a given counterfactual conditional is true or not? (2) if a counterfactual conditional is true, then what grounds its truth?

As you see, the first question is epistemological, while the second is ontological. (1) seems to be difficult to answer because we don't know how to verify or falsify a counterfactual conditional. How can we find out whether it is true that I would have seen a rainbow if I had been near Tokyo station at 3 o'clock in the yesterday afternoon? As I was not near Tokyo station at 3 o'clock in the yesterday afternoon, it is impossible to know whether I would have seen a rainbow at that time and place. The reason why (2) seems to be unanswerable is that we don't know any fact that we can point to as the one that makes a given counterfactual conditional true. Unless you believe that other possible worlds are as real as the actual world like David Lewis does[19], a counterfactual situation is not any part of reality because it is a situation that did not exist or does not exist.

Although we must admit that it is very difficult to give an account that uniformly applies to counterfactuals in general and answers these questions, fortunately, for the sort of counterfactuals for which we need to make sense of the idea of the unobserved existence of perceivable objects, we have some good idea about what such an account should be.

Take a statement "if a lump of sugar were put in water, it would dissolve". It has the form of counterfactual conditional. Although it is not true as it stands, if it is reformulated with some qualification as "if a lump of sugar were put in some suitably prepared water in an appropriate circumstances, it would dissolve", we

[18]Most of these accounts employ the concept of an impossible world. For example, see the following. D.Nolan, "Impossible worlds: a modest approach" *Notre Dame Journal of Formal Logic* 38 (1997) 535–72.

[19]D.Lewis, *A Plurality of Worlds*, 1986, Blackwell.

will agree that it is true. There may be various reasons why we agree; it may be because we have observed in the past many cases of the sugar's dissolving in water, or it may be because we know that sugar is a water-soluble material but there are some circumstances that are not favorable for dissolving sugar in water, or it may be because we have enough chemical knowledge about sugar and water to tell apart the favorable and unfavorable conditions for dissolving sugar in water.

As this example shows, the truth of some counterfactual conditionals is based on the observed regularities, which, in turn, are based on the nature of the things involved; and sometimes we succeed to discover the scientific laws that govern these observed regularities. Usually such laws not only explain the regularities but also tell us when and why the seemingly exceptional cases occur.

It is the same with our counterfactual (C). By the time of Aristotle, rainbows had been known to be recurring phenomena in nature, and the search for their causes had already started.

A rainbow is seen in highly specific circumstances. In order to find out what causes a rainbow, we should know much more about the factors that make our perceptual experience of a rainbow possible. They are two in kind: there are factors relating to our vision, and there are those relating to the physical environment consisting of the mass of water drops in the sky and the sun. (C) contains two expressions "normal vision" and "appropriate location", just as the reformulated counterfactual about sugar and water contained "appropriate circumstances". They are intentionally left to be vague, because it is the task of scientific research to replace them with precise conditions.

It is not unreasonable to think that some scientific laws exist behind our counterfactual (C). In fact, some parts of scientific research can be regarded as efforts to get at such laws, and the history of the research on rainbows from Aristotle to Descartes is just the history of the discovery of such laws. And as one of its results, the vaguely expressed qualifications in (C) should be replaced by a detailed and precise specification.

So far,we have been defending the thesis that not an actual perception of the rainbow but its possible perception is sufficient for the existence of a rainbow. Is it also necessary?

This amounts to asking whether it is possible that there exists a rainbow which is either impossible for anyone with normal vision to see, or for which there is no appropriate location to be able to see it. It seems very difficult to come up with such possibilities, and I suspect that it is because a rainbow is recognized as such only through its appearance to us, more specifically, its particular visual appearance.

Once the laws that govern the formation of a rainbow are known, however, it might become possible to know the existence of a rainbow without recourse to our perceptual experience of it. If that happens, our criterion for the existence of a rainbow may need to be revised. We are going to see whether such a case can be made in the next section.

4

Now we come to Descartes, who gave us "the single greatest contribution in the story of the rainbow"[20]. This contribution was published in one of the three *Essays* appended to the famous *Discourse on the Method*, and it was published in 1637. Descartes's theory of the rainbow is the centerpiece of his essay on meteorology (*Météores*) indicating that he was very proud of it, and he had every reason to be so.

Descartes's greatness lies in that he did not try to explain the rainbow in terms of the reflections of the light at the drops in the air alone, nor of their refractions alone, as many people before him had done, but he thought that both the reflections of the light rays that occur inside the drops and the refractions that occur when the rays come out from them are essential to the formation of a rainbow, and confirmed his idea by theoretical calculations and experiments[21].

Descartes established that a rainbow is formed in the following manner[22].

1. When the light rays from the sun hit the surface of the raindrop, part of them are reflected at it, but another part of them are refracted entering the surface of the drop, reflected off the back of the drop, and again refracted as they come out of the drop.
2. If we calculate the paths of the light rays that come out of the raindrops after having entered them using the refractive index of water, we see that these rays converge on a certain particular angle, which is called the "rainbow angle". This can be confirmed by experiments.
3. The light rays coming from all such raindrops in the air make a rainbow.

With such an explanation of rainbows, we can give the precise content to "an appropriate location" in our counterfactual (C), and together with the description of how the information carried by the light rays that enter through the eyes are processed in the brain, we can hope to make clear the laws that are supposed to lie behind (C).

One way of characterizing a rainbow ontologically is to identify it with a certain event which takes place in an extended space for a certain short duration; its essential constituents are the aggregate of rain drops in the air, the light rays from the sun, and an observer with well-functioning vision. Moreover, it is an extremely complex event that consists of an innumerable number of the refractions and reflections at or inside of a raindrop, which are events themselves.

[20] Boyer, *Op. cit.*, p.200.

[21] For the roles of experiments and theory in Descartes's explanation of the rainbow, see the following. Daniel Garber, *Descartes Embodied. Reading Cartesian Philosophy through Cartesian Science*, 2001, Cambridge University Press, Chapter 5.

[22] It is well known that Descartes's attempt to explain the colors of a rainbow was a failure, and that the satisfactory explanation was first given by Newton. This part of the story of the rainbow, however, is not our concern here.

Such a characterization of a rainbow accords well with our ordinary usage of the expression "the same rainbow"; if my friend tells me that she saw a rainbow when she was near Tokyo station at 3 o'clock in the afternoon yesterday, I might say that I saw the same rainbow when I was in the same place and at around the same time. In this usage of "the same rainbow", it is obvious that if two people are looking at a rainbow side by side, then they are looking at the same rainbow. However, it is said that in the same situation two people are looking at different rainbows. Not only there are famous lines of a poem that says no two people can see the same rainbow, but also you will find such an observation is almost routinely repeated in many popular articles and books about the science of the rainbow.

Why can't two people see the same rainbow even when they are very close to each other and looking up at the sky at the same time? We will be told that it is because a person sees the rainbow by receiving the light rays which were refracted and reflected by the aggregate of raindrops, and as any two persons cannot be at the same location at the same time, two people receive different rays which came through different aggregates of raindrops, implying that they are looking at different rainbows.

This is a very poor argument, however. Think of a case of seeing a desk. We also see a desk by receiving the light rays that were reflected at its surface; even if two people are looking at the same desk at the same time, the light rays they receive are different and were reflected at different parts of the desk, because they cannot be at exactly the same place at the same time. Does this make it impossible for two people to see the same desk? Obviously not. Or at least, it is not our way of talking.

Another argument for the impossibility of two people seeing the same rainbow is this. Suppose two people are looking at a rainbow side by side. Further suppose that one person moves to the right and another person moves to the left. They will find that the rainbow they see moves in the same direction as their own movements; but the same thing cannot move in contrary directions at the same time. Hence, the rainbows they see must be different from each other.

To answer this objection, let us remind ourselves of the fact that a perception of an event is perspectival as every perception is perspectival. Thus, when we observe an event which is extended in space and time, what we observe at a given time from a given location is only its partial stage observed from that particular location. It is the same with a rainbow, which is an event extended in space and time; at any given instant, each of us sees only a very small portion of the entire event. Which part of an event we observe at any moment depends on the moment and our location at that moment, just as what part of a material object we observe at any moment depends on our location at that moment. But, if we observe a partial stage of an event from a certain location, then we observe the event itself, just as we see a desk itself when we see a part of a desk which can be seen from our location. At any instant we see only a momentary stage of an event if it is temporally extended, and if it is extended in space as well, what we see at that instant is a partial view of that momentary stage from the place we are located at the instant.

If we recognize the essential perspectivity of our perception of an event, it is not difficult to reply to the objection above. When you move while seeing a rainbow, you will see successively different spatial and temporal parts of that rainbow, as we are now supposing that a rainbow is a complex event extended in both time and space. But it is almost impossible for us not to see the changes in what we see as the movements of one and the same arch-shaped figure given the nature of our visual sense[23]. A person moving to the right watching a rainbow see a series of consecutive parts of the rainbow, while another person moving to the left see another series of parts of the same rainbow; they are not looking at different rainbows.

This shows that our own movements also contribute to our perceptual perspectives, and hence, the manner of our own movements influences them, just as the place from which we see an object or event does. Two people moving in contrary directions while watching a rainbow have different perceptions, not because their objects of perceptions are different, but because their perspectives towards the same object of perceptions are different.

Still, it is almost certain that this reply is insufficient. Because it will be objected that it is obviously wrong to identify a rainbow with a complex event consisting of numerous smaller events. Because anybody would say that a rainbow is a multi-colored and arch-shaped figure you see in the sky, and that its extension cannot extend beyond that figure.

It is indeed true that, if you do not see a multi-colored arch-shaped figure in the sky, then you do not see a rainbow. In reality, however, at any moment you see only a part or a stage of a rainbow when you see a multi-colored arch-shaped figure in the sky. The same rainbow could be seen by another who is located at another location, and the multi-colored arch-shaped figure she sees is another part of the same rainbow as I see. Each person sees one and the same rainbow from her own perspective. Moreover, our way of talking confirm that this is part of our view of the rainbow, for, we might exclaim at the sight of a rainbow and invite others to see it, or we might ask others whether they see the rainbow that we see. In short, a rainbow is a public sight.

To repeat, each person sees one and the same rainbow from her own perspective. But, a rainbow is different from other objects and events that can be perceived from different perspectives in that the difference of perspectives does not seem to make a change in the phenomenal content of its perception. For example, if you go around a desk, your perception of the desk changes as you move; the look of the desk changes as the relative position between you and the desk changes. There are objects such as a perfect sphere whose apparent shape remains constant no matter what angle you see it from; but, even in such a case, its apparent size differs according to its distance from you. A sphere looks smaller if you move away from it, and larger if you move towards it. A perception of a rainbow is different. When you see a rainbow, the shape you see does not change no matter how you move, and, more remarkably, its apparent

[23]Even when we remain in the same place when we watch a rainbow, we successively receive a series of light rays coming from different aggregates of water drops in succession, because they are constantly falling down. But, of course, we are not aware of this fact.

size does not change; whether you go forward or backward, its size does not change, and that is the reason why a rainbow seems to recede from us when we try to approach it and follow us when we try to get away from it.

It is a remarkable fact about a rainbow that it is publicly observable, and yet it apparently moves in various strange ways that are never found in the cases of ordinary objects surrounding us. It must have been a mystery how this could be true. The Cartesian theory of the rainbow finally solved this mystery. When the air is full of water drops as it happens after rain, if a person is standing with her back to the sun at an appropriate place, she will receive the light rays that refracted and reflected inside the water drops and concentrated on a certain angle (the rainbow angle), and this is the true nature of the rainbow. If the aggregate of water drops is sufficiently big, the area where a person can get the light rays that cause the perception of a rainbow can be very big; anybody with normal vision in this area standing (or sitting, or whatever) with her back to the sun will see the rainbow. As for the strange movements of the rainbow, they are explained by the fact that the light rays that cause the perception of a rainbow always come from a constant angle, namely, the rainbow angle, and this means you always see the rainbow at the same distance and in the same direction no matter how you move.

Another thing that is frequently remarked about the rainbow is that it has only a front and no sides nor back.

First, if a rainbow is identified with a complex event consisting of numerous refractions and reflections at water drops, then it does not have a front either. We cannot meaningfully speak of the front of an event such as a traffic accident and a baseball game, and the same applies to speaking of the sides or back of an event. This does not mean, however, that the rainbow is not spatially extended. Just as a traffic accident or a baseball game is a spatially extended event, an event which is a rainbow takes place in a certain extended space; it is a space defined by the aggregate of water drops and the paths of the light rays that refracted and reflected by those water drops.

Secondly, although a rainbow as an event has a three-dimensional extension, it is not the same as the part of space where its perception can occur. As it was remarked before, a rainbow can be seen only by a person with her back to the sun, and hence, it is seen in the area that is between the sun and the mass of water drops in the air. It may be easier to consider the case of a rainbow you see at a fountain. You can see a rainbow only from the side where you can stand with your back on the sun. Suppose you walk to the other side of the fountain. Now you don't see the rainbow. Still you are now at the other side of the rainbow at the fountain, if it is considered as an event as we are doing now. You are now "behind" the rainbow, and in seeing the rising and falling water you are seeing an event which is a rainbow.

In sum, a rainbow is an event, and should not be identified with its visual appearance to us, although it is recognized as such by its characteristic appearance, namely, that multi-colored and arch-like shape. This means that a rainbow itself can exist without appearing to us. In the previous section, I argued that a rainbow exists even when no one actually is seeing it, if it is possible to be

seen. I left it undecided then whether the possibility of being seen is a necessary condition for the existence of a rainbow. Now I am claiming that a rainbow can exist even when it is not possible to be perceived. Isn't it going too far?

A physical object like a desk can exist even in circumstances that make its perception impossible. For example, a desk can exist even when we cannot see it because there are no lights. If you object that it can still be touched in the dark, then suppose that it moves away whenever you try to touch it so that you could not feel it; in this way, you can imagine a desk that cannot be perceived at all. It is the same with any physical event or state except those that underlie perceptions themselves. An event of a ball falling to the ground or a state of a ball staying still can happen or hold even when there is no possibility of being observed. Those which are excluded as exceptional cases are perceptions themselves. Consider your seeing a desk; there must be a certain physical event underlying this episode of perception; roughly, it somehow starts with the reflection of lights on the surface of the desk and ends with the change in your brain-state; it is obvious that the existence of this event is not independent of perception, simply because it itself is part of a perceptual event.

The present claim is that a rainbow is a physical event, which exists independently of any possibility of being perceived. To this, you may object that anyone knows that a rainbow cannot be seen in the dark, because the lights from the sun are essential for the existence of a rainbow.

But, in the case of a rainbow, the light rays from the sun are essential for its generation and not for its perception. As we have emphasized, a rainbow is in reality a complicated event consisting of numerous smaller events of refractions and reflections and its participants are the mass of water drops in the air and the light rays from the sun. A perception of a rainbow is also an event, but it is not the same event as the event which is a rainbow; for a perception of a rainbow to occur, a perceiving subject is essential, but it is not so for a rainbow to occur.

If a rainbow is one thing and its perception is another, then does it follow that there is no necessary connection between the two? If there is no necessary connection between them, then each of the following situations should be possible.

1. A rainbow might appear as a perceptual phenomenon that totally differs from the visual phenomenon we are used to.
2. A visual phenomenon we know as the appearance of a rainbow might be caused by some event that is not a rainbow.

Let us start with the first case. There will be little difficulty in imagining such a possibility. The easiest way to do so is to imagine some creature which reacts to light rays but not in the way humans do. For example, we can imagine a creature which perceives lights of different wavelengths as sounds of different pitches. Such a creature would "hear" a rainbow. And, if you can accept such a way of talking without much resistance, than it gives a certain support for our claim that a rainbow should not be identified with its visual appearance.

Or, we can imagine some complicated arrangement for a certain creature, which encodes any refraction and reflection that occurs at the mass of water drops and turns them into signals that are to be received by the creature's brain. In this case again, it would not be too unnatural to say that such a creature perceives a rainbow in an unheard-of way. Thus, what is essential for an experience to be a perception of a rainbow is that it is caused by the same physical event that causes the visual appearance of a rainbow in us, and the visual appearance itself is not essential; it might appear as sounds, or in some sense modality that is alien to us.

It is also easy to imagine a case in which we see a multi-colored arch-shaped figure in the sky that is not caused by the refractions or reflections of the light rays at water drops in the air. In such a situation, would we say that we see a rainbow? This time the answer might not be so straightforward as in the first case. Would we say that we do not see a rainbow but a mock-rainbow? Or, would we say that we have found out that there are two kinds of rainbows? It seems that the answer depends on the circumstances.

Suppose that some new development in technology in the future will make it possible to manufacture an artificial "rainbow" at any time during the day whether it is after a rain or not. In this case, probably we would say that the artificial "rainbow" is not a real rainbow, but an imitation of a rainbow. Of course, the most likely name for it would be "artificial rainbow".

The following is a contrasting case. Incredibly, it has been found that some cases of seeing the multi-colored arch-shaped figure after rain in the direction in which a rainbow usually occurs are not caused by an optical mechanism, but caused by a certain hitherto unknown interaction between the light rays and certain particles the raindrops carry. Further suppose that it is impossible to tell whether a given case of seeing the characteristic shape in the sky has the usual optical cause or not if you are not a scientist fully equipped with many instruments. In this case, isn't it likely that we would say that there are two kinds of rainbow?

This might not be the final outcome, however. For, it is also likely that each kind of rainbow will eventually get its own name such as "optical rainbow" and "X rainbow". If this is the most plausible scenario, then it shows again that the decisive factor is not the visual appearance but the physical cause.

We started with trying to defend a thesis that a rainbow exists without being actually perceived. Then, we proceeded to examine whether it exists even when there is no possibility of being perceived. Our considerations suggest that its visual appearance of a rainbow is not a necessary property of a rainbow. Although we recognize a certain sort of natural phenomena as a rainbow through its characteristic appearance to us, it is just an accident that it appears to us in the way it does. Thus, once a rainbow is seen as a natural event which exists independently of us, it becomes obvious its existence does not depend on our perception.

Does it mean that a rainbow has nothing to do with our perception? I think not. Even though a rainbow as an event exists independently of us, it comes to have its identity as an event because it is an event comprised of smaller optical

events united by reference to our perception. But for our system of vision, there would be no point in grouping these smaller events and making them to constitute one complex event. The world exists independently of us, but what part or aspect of the world we take an interest in, of course, depends on us.

5

It seems that, uncharacteristically for him, Leibniz did not make any significant contribution to our scientific knowledge about rainbows. In Boyer's detailed history of scientific research on the rainbow, Leibniz's name appears only a few times, and in an almost accidental way. However, the rainbow had the most important place in Leibniz's philosophy of matter. He held that a material body is both a phenomenon and an aggregate of substances, and cited the rainbow as a paradigm case of a phenomenon which is an aggregate of substances[24]. Most pertinent to our discussion in this paper is his distinction between nominal and real definitions of rainbows. According to Anthony Saville[25],

> When Leibniz characterizes the rainbow in the 'Art Magna' as an appearance of a colored bow in the sky, if that is a definition, it is no more than a nominal one. And by Leibniz's reckoning that does no more than record the marks by which we find we can reliably recognize cases of the definiendum. (...) By contrast, a real definition tells us what the thing in question is: and, just as important, it shows us how the definiendum is possible. In natural cases it answers the latter task by telling us how the thing in question is generated or caused. So, in the case of the rainbow, a real definition will incorporate the information that the appearance of a bow in the sky is caused by the refraction of sunlight through raindrops.

At first sight, the rainbow might be considered a strange choice for a paradigm of material things, but once we learn that Leibniz singled out the rainbow because it gives us the clearest case of the gap between appearance and underlying reality, we may begin to understand his intention. We come to know the material world through our senses; we recognize the things by their sensible properties like colors, shapes, sounds, texture, smells and tastes. For most of the time, they are reliable marks to identify the things in the material world, because they are not arbitrary products of our minds, but are grounded in the things themselves; they are the causes of those colors, shapes, etc. we receive.

Just as there is a great difference between the rainbow's appearance to us, which is the multi-colored arch-shaped figure, and its reality, which is a complex

[24]For the role of the rainbow in Leibniz's philosophy of matter, I learned much from the following. R.M.Adams, *Leibniz: Determinist, Theist, Idealist*, 1994, Oxford University Press, Chapter 9; Anthony Saville, "The rainbow as a guide to Leibniz's understanding of material things" in M.Carrara, A.M.Nunziante and G.Tomasi (eds.), *Individuals, Minds and Bodies: Themes from Leibniz*, 2004, Franz Steiner Verlag. pp.193–202.

[25]Saville, *op.cit.*, p.195. I have omitted references to the literature.

optical event, there is a great difference between what the things are as they appear to us and what they are by themselves[26]. Our efforts to understand the material world may have started with believing that it is as it appears to us, but soon we realize that most of those appearances are grounded in the reality that is independent of us, although there are some appearances like dreams that have no reality apart from our minds. Leibniz called the former "well-founded phenomena" and distinguished them from the latter. The rainbow was for him the prime example of a well-founded phenomenon.

Leibniz seems to have tried to analyze the entire material world as a well-founded phenomenon. I don't know whether it is a feasible project, but it is worth trying to analyze sensible properties like colors and sounds as well-founded phenomena, or what I propose to call more restrictedly as "physically well-founded perceptual phenomena".

Colors and sounds are similar to rainbows in the following respects; they are recognized as the objects of certain kinds of perceptual experiences. Although some philosophers identify them with perceptual experiences themselves, we could argue that they should be identified with their causes, and hence, they are not mental entities but entities that exist outside us.

Many of the issues that arose with rainbows will also arise with them, and, as Leibniz thought, the rainbow and its explanation may provide us with some of the clues necessary to a satisfactory analysis of them[27].

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[1] R.M.Adams. *Leibniz: Determinist, Theist, Idealist*. 1994, Oxford University Press.

[2] Carl B. Boyer. *Rainbow. From Myth to Mathematics*. 1959, Sagamore Press. Reprinted 1987, Princeton University Press.

[3] Daniel Garber. *Descartes Embodied. Reading Cartesian Philosophy through Cartesian Science*. 2001, Cambridge University Press.

[4] H.P.Grice. "Meaning". *The Philosophical Review* 66 (1957) 377–88. Reprinted in H.P.Grice, *Studies in the Way of Words*. 1989, Harvard University Press.

[5] Kanzaki, Shigeru. "The outset of Aristotle's philosophy—'begin' as 'power of being acted on' " (in Japanese). *Philosophy (Tetsugaku)* No.64 (2013) 58–77.

[26] It is not surprising that in *The Critique of Pure Reason*, Kant illustrated his distinction between appearance and things in themselves by the rainbow (A45/B63). Of course, Kant was very critical of Leibniz's optimism about the prospect of our finding out how things are in themselves.

[27] I thank Lajos Brons again for valuable comments and numerous suggestions for improving my English. Although I do not have time and space enough to respond to many of his queries and objections now, I hope to do that in the future.

[6] David Lewis. *A Plurality of Worlds*. 1986, Blackwell.

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[10] Saijo, Toshimi. *The Rainbow: Its Culture and Science* (in Japanese). 1999, Kouseisha-Kouseikaku.