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A theorist's philosophy of science

Considerations of perception illuminate and reconcile the issue that divides theorist and experimentalist in science, rationalist and empiricist in philosophy, and "airies" and "earthies" in general.

Helier J. Robinson

There is a temperamental difference among thinkers that has produced a spectrum of attitudes among them, in all realms of thought, throughout the history of ideas. This difference is the preference, in the one case, for the concrete over the abstract, and in the other for the abstract over the concrete. In science, this temperamental difference distinguishes experimentalists and theorists; in mathematics it distinguishes applied and pure mathematicians; and in philosophy it distinguishes empiricists and rationalists. Thus experimentalists are concerned with concrete apparatus in the laboratory, or concrete specimens in the field, while the nearest that theorists get to experimenting is the "thought experiment," which cannot be performed in any laboratory. Similarly, although all mathematics is abstract, applied mathematics is less so than pure mathematics; applied mathematicians are concerned with mathematics that relates to the concrete world around them, while extreme pure mathematicians consider such concrete application unimportant at best and an adulteration of mathematics at worst.

The two temperaments are sufficiently important to be named. The obvious names, however, are rather ugly—"concretists" and "abstractists"—so I propose to call them instead by the immediately understood terms *earthies* and *airies*.

Each of these terms should be thought of sympathetically, for the strength it represents, rather than contemptuously, for the weakness it represents. Thus earthies have their feet on the ground and are practical, common-sense people, while airies are impractical and have their heads in the clouds—at least this is the common-sense view of the distinction. We should remember, however, that common sense is itself earthy and so not unprejudiced. In fact, the great strength of common sense is that it is the cumulative practical wisdom of millenia of experience, and so, in general, highly reliable—which seems to give lopsided support to the earthies. However, common sense is not completely reliable, as the history of ideas shows. This history is a history of corrections to common sense, and the corrections have all been made by airies. So credence should always be given to both sides.

It is one of the strengths of science that the temperamental gap between earthies and airies is successfully bridged, and it is one of the weaknesses of philosophy that the gap is not bridged—that it remains a gulf of misunderstanding and mutual contempt. This is important to scientists, in the realm of the philosophy of their work, in that a balanced science should not be backed by an unbalanced philosophy. That is to say, theoretical science is airy and modern philosophy of science is earthy, so as a result, modern philosophy of science cannot do justice to theory. As with other temperamental differences, such as those that separate introverts and extraverts, optimists and pessimists, and radicals and reactionaries, the whole truth must be a combination of both viewpoints. When each side sees the other as perversely wrong, a sterile controversy results or a one-sided majority view dominates—a half-truth rather than a whole truth.

Throughout its history, the philosophy of modern science has been earthy. It has been dominated by empiricists who, claiming that science is exclusively empirical, maintain that philosophy of science must be so also. In the early days of science this attitude was quite reasonable, because no one made the distinction between empirical science and theoretical science. Today, however, it is no longer reasonable, because theoretical science is clearly distinct from empiricial science. The philosophers of science have not yet recognized this, and, like Cinderella's stepsisters, they try to cut theoretical science down to size so that it will fit into the glass slipper of empiricism.

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For example, the predominant philosophy of science in the twentieth century has been logical positivism in various forms, all of which insist that theoretical science is fiction.

In this article I want to correct this historical neglect of theory. To this end I shall first examine some of the differences between earthies and airies, in both philosophy and science. Then I will present evidence that earthies and airies practice two fundamentally distinct kinds of science, which are based on two genuinely different kinds of perception. This will bring us to the ancient philosophical problem of the relationship between object and image, or between observation and theory. While some may be uncomfortable with the solution that I favor, we will see that it does resolve the problem of perception and explain science.

The question of illusion

The basic positions of empiricism and rationalism are frequently expressed by their opponents as caricatures. Empiricism is said to be the doctrine that all knowledge, without exception, is obtained empirically, that is, through the senses. Rationalism is said to be the doctrine that all knowledge—true knowledge, that is, for the empirically known is not really knowledge because of illusion—is known by reasoning about the way the world must be. If these caricatures were true, then no empiricist could allow any generalization of empirical data into empirical law, because no generalizations are known through the senses. And every rationalist would be nothing but an armchair scientist, reasoning *a priori* about the nature of reality without any reference to empirical fact.

These caricatures arise in the first place because each side is wary of the weaknesses of the other side's position and seeks to defend the truth from this weakness. The weakness in the empiricist position stems from the existence of illusion: Not all that we perceive around us is really so. To correct illusion rationally is to replace an empirical observation with a rational

belief—for example, that railroad tracks do not really meet in the distance—which is what the rationalists want to do. The weakness of the rationalist position is that, historically, they disagreed so much among themselves as to what these rational beliefs should be (to say nothing of their weakness for falling back on authority rather than reason) that one cannot help but regard this disarray as evidence of a failure of method.

The point of departure between empiricists and rationalists is indeed on the question of illusion. The empiricists believe that what we perceive around us is reality. The rationalists, because of the fact of illusion, believe that what we perceive around us is not necessarily reality, and that to know reality we must substitute rational belief for perception. In consequence, there are two definitions of reality, an earthy one and an airy one. It what follows it will be most important that they be explicit.

Empirical reality is defined as all that we perceive around us—with two provisos. One is that the purely private is not empirically real; it is, rather, a product of the perceiver's unconscious mind, projected into the world. Beauty and sex-appeal in a lover, glory in a hero and evil in an enemy are common examples. Hence we can say that the empirically real must be public. (This includes potential publicity, of course: If what one perceives is private merely because no one else is around to perceive it, this does not mean that it is unreal.) The second proviso is that not everything public is empirically real, because illusions are both public and unreal. During a solar eclipse, for example, the Sun and the Moon appear to be the same size, an appearance that is both public and an illusion. No illusions are real—the stick half-immersed in water is not really bent, for example—so empirical reality is all that we perceive around us, provided that it is public and nonillusory. The reason for calling this empirical reality is that we know it empirically. It is the reality that we know through our senses.

Theoretical reality, on the other hand, is defined as all that exists independently of being perceived. If something continues to exist when no one is perceiving it any longer, or it exists even though no one can perceive it at all, then it is theoretically real. Conversely, if something exists only while perceived—as in a dream or hallucination—then it is unreal. The reason for calling this theoretical reality is that no one can perceive anything existing while unperceived, so such existence is nonempirical, hence theoretical.

These two definitions of reality are usually regarded as equivalent, even though no one has ever been able to prove that they are. However, I shall keep them distinct, at least for the present.

A second major point of disagreement between earthies and airies is on the question of whether or not there are such things as abstract ideas. The notion of an abstract idea was invented to explain our use of abstract language. For each abstract word an abstract idea is supposed to exist, and to be the meaning of that word. A structure of abstract ideas—a proposition—is supposed to be the meaning of an abstract sentence. Those who accept the existence of abstract ideas and propositions are called *conceptualists*, while those who deny their existence are called *nominalists*. Not surprisingly, earthies are generally nominalists and airies are generally conceptualists. (The two most important nominalists of the twenthieth century were David Hilbert and Ludwig Wittgenstein.) In the past, nominalists supposed that the meanings of abstract words were the words themselves: "Words are the counters of the mind" and "All thought is silent speech" were two ways of expressing this. However, this leads to difficulties in explaining such things as abstract synonyms and translation of abstract sentences from one language to another without loss of meaning.

The strength of the earthies' position with regard to nominalism is that one cannot discover abstract ideas empirically—that is, in this case, introspectively. The airies do not worry about this, however. Their view is that we suppose many things to exist even though we cannot have direct empirical experience of them—wavefunctions, for example, or force fields. The reason for supposing such things to exist is that they have great explanatory power.

The earthy–airy preferences are very clear on the question of abstract ideas. If abstract ideas exist then they are abstract *entities*. In the earthy view, no abstract entities exist and nominalism is true (and theories using wavefunctions and force fields are fiction), while in the airy view there is no objection to abstract entities and conceptualism is accepted.

Two kinds of science

When it comes to earthy–airy preferences is science, it might seem at first that the existence of two kinds of science, empirical and theoretical, is due entirely to this temperamental difference among scientists. But this is not in fact so. I am not here siding with the empiricist philosophers, who mostly claim that there is really only one kind of science. Rather, I want to emphasise that there definitely *are* two kinds of science. A particular scientist may favor experimental or theoretical science, according as he is an earthy or an airy, but this is not the reason why there are two kinds of science. There are in fact at least four reasons for distinguishing them. These distinctions are usually denied or discounted by earthy philosophers of science, who regard theories and empirical laws as the same thing, on the supposition that both are generalizations from empirical data; but this is untenable, as the following discussion will show.

Perceptible or imperceptible? The first difference between empirical and theoretical science follows immediately from their descriptions. Empirical science deals with empirical data and theoretical science does not. "Theoretical" means "nonempirical," meaning that the entities of theoretical science *cannot be perceived, by anyone, ever*. We are quite used to believing otherwise on this, because for several centuries many earthy philosophers have been insisting on it. They have been insisting that theoretical science is really empirical and hence, if theoretical entities exist at all, then they are perceptible.

One way they justify this is with a doctrine of "indirect perception." It is supposed that to perceive an effect directly is to perceive its cause indirectly. "Directly" here means to be directly conscious of it. Thus, to perceive a table directly is to be directly conscious of its color, shape, number of legs, and so on, and indirectly conscious of the molecules that cause these direct perceptions. If we put a piece of paper over a magnet and sprinkle iron filings on it, then we are directly conscious of a pattern to those filings and hence indirectly conscious of the magnetic field that causes the pattern. Again, if we directly perceive forces of weight or of inertia, then we indirectly perceive mass, and if we directly perceive sensations of warmth or see thermometer readings, then we indirectly perceive molecular kinetic energy. Thus, if theoretical entities are indirectly perceived, then they are perceived, in which case they are empirical.

A little thought shows, however, that we never perceive molecules, force fields, mass, kinetic energy or any other theoretical entity. The doctrine of indirect perception is a camouflaged description of belief. To say that we indirectly perceive the magnetic field when we directly perceive the iron filings means that as we see the filings we *believe* that there exists a magnetic field that causes the pattern. Similarly, we *believe* in the existence of molecules, mass and all the other accepted entities of theoretical science. Belief is a substitute for perception. Whenever our perception fails us, for any reason

whatever—horizons, darkness, unconsciousness, limitations of our sense organs, and so on—we substitute a belief. We believe in these theoretical causes of empirical effects because they *explain* these effects, as I will show shortly.

The fact that we believe (at best) in the existence of theoretical entities proves their nonempirical status. That the doctrine of indirect perception is a doctrine of disguised belief is shown by the fact that as beliefs change, so do the things supposedly indirectly perceived. If there really is indirect perception, then we have to say that medieval astronomers indirectly perceived angels guiding the planets in their orbits and the alchemists indirectly perceived phlogiston whenever they saw fire. The distinction here is quite sharp: Everything empirical is perceived by someone, sometime, and nothing theoretical is perceived by anyone, ever.

The sharpness of this distinction is frequently denied by means of a doctrine of "degrees of perception." The fewer causal steps between the object and its perceptible effects, the more directly the object is supposed to be perceived. Thus, things are seen most directly with the naked eye, less directly through a microscope or telescope, less directly still through an electron microscope, and quite indirectly as tracks in bubble chambers or as pointer readings; and all of these are rendered even less direct if they are seen in the form of photographs or television pictures. Given this doctrine, everything theoretical is empirical to some degree, provided that there is some empirical evidence for it. In fact, however, it makes no difference whether indirectness of perception is a two-valued property or is a matter of degree: This doctrine of perception remains a circumlocution for belief in a strictly imperceptible cause.

Description or explanation? The second difference between empirical and theoretical science arises from the well-known distinction that empirical science describes the world and theoretical science explains it. Explanation is causal. To describe a cause is to explain its effect. This is putting it very simply, of course, because most effects are complex, and result from complex causes. Philosophers tend to speak of causes and effects as single events, while scientists speak in terms of processes. However, a process is a complex series of events, so the difference in approach is not fundamental. Theoretical science, then, describes the causes of what empirical science describes. This is emphasized by another well known saying: Theoretical science explains by describing the *underlying* causes of phenomena, which is to say, by describing imperceptible causes.

A third well-known saying seems to disagree with this: Explanation is deductive. This needs a little explication, for which an actual example is best. In empirical science, data are formulated and, if the formulas warrant it, they are generalized into empirical laws. Boyle's law and Charles's law are well-known examples. They are combined into the ideal gas law, $PV = nRT$, where P is the pressure, V the volume, n the mass of the gas in moles, R the universal gas constant and T the absolute temperature. (The law is only approximately true, but we can ignore that.) The quantities P, V, n, R and T are measured, empirical quantities. This law is explained in statistical mechanics by assuming that gases consist of a statistically significant number of molecules that obey the laws of mechanics. The quantity V is then defined as the volume occupied by these molecules, T as their average kinetic energy and P as the average force of reaction as they bounce on their container. It is then possible to deduce, within this theory, that $PV = nRT$. When an empirical law is deduced within a theory in this way, the theory is said to have explained the law. Although this seems to contradict the earlier claim that all explanation is causal, it does not in fact do so, as I will show later. It is worth mentioning, however, that a widely accepted empiricist doctrine that all explanation is deductive in this way—it's called the doctrine of *covering law explanation*—stands or falls on whether deductive explanation is not, or is, a special case of causal explanation.

Laboratory or armchair? The third difference between empirical and theoretical science lies in their methods. Philosophers of science have long been fascinated by scientific method, for the simple reason that science is spectacularly successful, so that if this success is due to method, then specification of the method should allow its application in other fields—with equal success. Various analyses have been undertaken; the best known was that by John Stuart Mill, resulting in the famous Mill's Methods. These are all various

ways of discovering empirical correlations which, if they warrant it, may be generalized into empirical laws.

It is quite significant that Mill ignored theoretical science entirely. This was not merely because he was an earthy—he was, in fact, one of the most extreme of all empiricists—but because no one has ever been able to formulate a method for theoretical science. The reason for this is quite simple. Theoretical science is *invented*, and this requires creativity, for which there is no known method. A major theory in science, just like a major work of art, requires creativity to produce it. A computer can discover correlations but it cannot be creative. This is the difference in method between empirical and theoretical science, according to Mill's analysis.

Even more significant than Mill's neglect of theory is the fact that empirical science does not in fact consist of the blind groping after correlations that Mill's Methods make of it. As Karl Popper has pointed out, empirical science is almost always a matter of testing theories. Whenever a theory predicts something novel, an experiment is required to test the prediction. Such experiments have to be designed, and their design requires as much creative genius as does the invention of theories. Strictly speaking, then, neither empirical nor theoretical science has a formal method. Nonetheless, they do differ in their methods, in a fashion that is obvious once it is pointed out. Empirical science takes place in a laboratory, an observatory or in the field, and theoretical science does not. Theories can be created anywhere, even in an armchair. Hence, theoretical science could be called armchair science, without any disrespect, while empirical science definitely is not armchair science.

Repetition or novelty? Fourth, empirical and theoretical science differ in the kind of predictions they make. Empirical science makes predictions of repetition and theoretical science makes predictions of novelty. Empirical predictions result from the fact that empirical laws are generalizations of empirical formulas, and this generalization includes generalization into the future—which is prediction. Thus, if $PV = nRT$ is true now, then it will be true tomorrow.

Theoretical science, on the other hand, predicts not only this, but also experimental results never before perceived. Sometimes these predictions are spectacular, as in the case of Maxwell's equations leading to Hertz's discovery of radio and Einstein's $E = mc^2$ leading to atomic energy. Most of the time, however, theoretical predictions of novelty are predictions of new empirical data that, when tested by experimentalists, serve either to verify or to falsify the theory. Indeed, this kind of interaction between theory and experiment is the mark of sophisticated science. It is also the supreme example of successful cooperation

between earthies and airies in science, a cooperation whose success is shown by major advances in the sciences that manage to achieve it. So successful is the cooperation in these sciences, that *all* research experiment is concerned with testing theories and *all* theories must be empirically testable to be theories. Physics and chemistry are examples of such successful sciences.

A second point about prediction of novelty is the curious fact that only mathematical theories are capable of it. The theory of evolution, for example, although an excellent theory, is not a mathematical theory and does not make predictions of novelty. The theory does predict that, given time, new species will arise; but this is only generalization into the future, from the fact that in the past new species have evolved. This is prediction of repetition, not prediction of novelty in the sense of predicting precisely what the new species will be.

Thus, philosophers of science have a problem. It is, in my opinion, the most important problem in all of philosophy of science. What do the mathematical theories of science (and nothing else that we know of) have that enables them to predict empirical novelty, successfully and often? Poets cannot do this nor astrologers nor soothsayers nor prophets nor think tanks nor biologists nor social scientists nor empirical scientists. Mathematical theories must have some special relationship to reality that enables them to predict successfully, and it is an exceedingly interesting question to ask what this relationship is. We will return to this later.

Two kinds of perception

I have said enough, I believe, to show that empirical science and theoretical science are distinct, and that earthy philosophers of science either discount or deny this distinction. Let us turn next to the question: Why are there two kinds of science? This question is important because it concerns a duality that is one facet of a much more general duality. Other facets are some of the dualities that we have already met, and that we may equally question. Why are there two kinds of reality, empirical and theoretical? Why is there the distinction between description and explanation? Why are the entities of empirical science always perceptible and the entities of theoretical science always imperceptible? Why are there two kinds of prediction—of repetition and of novelty? Why are there two methods in science—experimental and armchair? There is also a duality of two kinds of publicity. The Moon is public, according to common sense, because we all perceive the *one* Moon, whereas the contents of newspapers are public because all copies of one edition have the same contents. The first is publicity by singularity and the second is publicity by similarity—a distinction that will be relevant later.

Why are there all these dualities? The answer is that all of these dualities are caused by a more general one: the duality between two kinds of perception. These may appropriately be called empirical and theoretical perception. As one might expect, earthies prefer to view perception as being empirical perception, and airies prefer to view it as being theoretical perception.

Before explaining these two kinds of perception, we should note that perception, and the philosophic problems of perception, are bound to come into any sound philosophy of science. Not only is science observer-dependent and so perception-dependent, but its foundation on the authority of empirical data is a foundation on perception.

Empirical perception is perception as we all know it from experience. In it we are directly conscious of material objects around us. *Theoretical perception* is the scientific explanation of empirical perception, in terms of reflection and refraction of light, acoustical vibrations, diffusion of olfactory molecules, and neural physiology. In theoretical perception a reproduction, image or representation of the external object is conveyed into the brain of the perceiver. Theoretical perception thus has a duality of object and image. The object is external to the head of the perceiver, theoretically real (because it continues to exist when unperceived), public and material (as opposed to mental). The image is internal and mental, hence not theoretically real (because it exists only while perceived) and not public.

I emphasize these four differences between object and image to demonstrate that the duality is a genuine one rather than merely verbal. The point is important because empirical perception does not have this duality. When we empirically perceive objects, qualities or relations around us, we are directly conscious of objects only, not of objects and images.

Thus theoretical perception has a duality and empirical perception does not, so they are two distinct kinds of perception. There have been many attempts to identify them. These all involve describing a duality within empirical perception and claiming that it is identical with that of theoretical perception. The most common is the claim that a memory is an image of a perceived object and so is the image of theoretical perception. Another is duality of object of perception and act of perception. Another is that of object and belief about that object. None of these works, for a very simple reason: In theoretical perception the object is theoretical and the image is empirical. This means that the object is imperceptible and the image is perceptible. But in empirical perception it is the object that is perceptible. If the two kinds of perception are to be combined, then that of which we are conscious must be the same in each case, meaning that the object of empirical perception must be the image of theoretical perception. However, we have just seen that the first is external, real and public while the second is internal, unreal and private. What has gone wrong?

The problem

We are here involved in an ancient philosophical problem. Long before there was a scientific theory of perception there was a theory that postulated a duality of object and image. This theory arose because of the simple fact of illusion. We know of illusions because they are contradictions between different sensations or between present sensations and normal experience. For example, the half-immersed stick is bent to the sight and straight to the touch, and visual size diminishes with distance from the perceiver, contrary to our general experience of the world.

A contradiction is a necessary falsity, and illusions are thus false perceptions. There is only one possibility of explaining false perceptions, namely, the false perception is an image of reality, and false insofar as it is dissimilar to that reality. Dissimilarity is a matter of degree, varying from perfect dissimilarity, or complete falsity, to perfect similarity, or complete truth. Because we do not know of anything empirically perceived that is completely and wholly nonillusory, we have to say that everything empirically perceived is an image, or a copy or a representation or a reproduction—the actual term used to describe it does not matter. This Representational Theory of Perception, as it is called, goes back at least as far as Plato and the fifth century BC.

The modern scientific theory of perception—theoretical perception—includes the representational theory within it. Indeed, theoretical perception explains most illusions in considerable detail, but always in terms of images that are dissimilar to reality. The basic logic here is simple: Dissimilarity cannot be reflexive, it must have a duality. One thing cannot be dissimilar to what it is. Because illusions are dissimilar to reality, perception must consist of a duality of reality and image of reality.

We can now state our problem more clearly. We have three things: the theoretical object, which is wholly nonillusory; the theoretical image, which is (usually) partly illusory; and the em-

pirical object, which is also partly illusory. Put in this way, it is clear that the empirical object must be the theoretical image, and cannot be the theoretical object. However, this is contrary to all our beliefs, and also leads to the quadruple contradiction between theory and observation, where the empirically perceived object is internal, private, unreal and mental, as well as external, public, real and material. This may be more clear if it is stated as follows. What we empirically perceive is very clearly *outside* our heads, as opposed to the images inside, and so is real. But what we empirically perceive is also partly illusory, and so is an unreal image. How can it be both?

As we will see later, the difficulty here is due to two earthy common-sense beliefs that are false. This has happened often before in the history of ideas, and improved beliefs have usually resolved the problem. However, the resolution always involved bitter controversy between the advocates of the new and the defenders of the old. Copernicus's heliocentric theory and Darwin's theory of evolution are the most notable examples. In the present case, however, the adjustment to established belief is considerably more difficult than Copernicus or Darwin required.

The solution to the problem is so difficult that most people do not even suspect that it exists, even though it is highly probable that Plato taught it in his Academy, Gottfried Wilhelm Leibniz (co-inventor of the calculus) published it in the seventeenth century and Bertrand Russell published it again in this century. To be sure, Plato, having witnessed the death of his teacher Socrates (condemned for corrupting the youth of Athens), did not make the solution explicit in his published works—although they contain a fair amount of evidence that he knew of it. Leibniz, aware that Giordano Bruno had only recently been burned at the stake, and that Galileo had been condemned to house arrest for life—because they published theories upsetting to established belief—was careful not to draw attention to the solution in his published works, although it is there for all to see. (In this vein, it is worth noting that both Copernicus and Darwin cautiously postponed publishing their theories for as long as possible.) In fact, no one noiticed Leibniz's solution until early in this century, when Russell published his own version of it and acknowledged Leibniz's priority. Unfortunately, Russell's early version used a six-dimensional space, which very few of his readers understood. By the time he published a later version in 1948, almost all philosophers had consigned his theory to limbo.

The solution

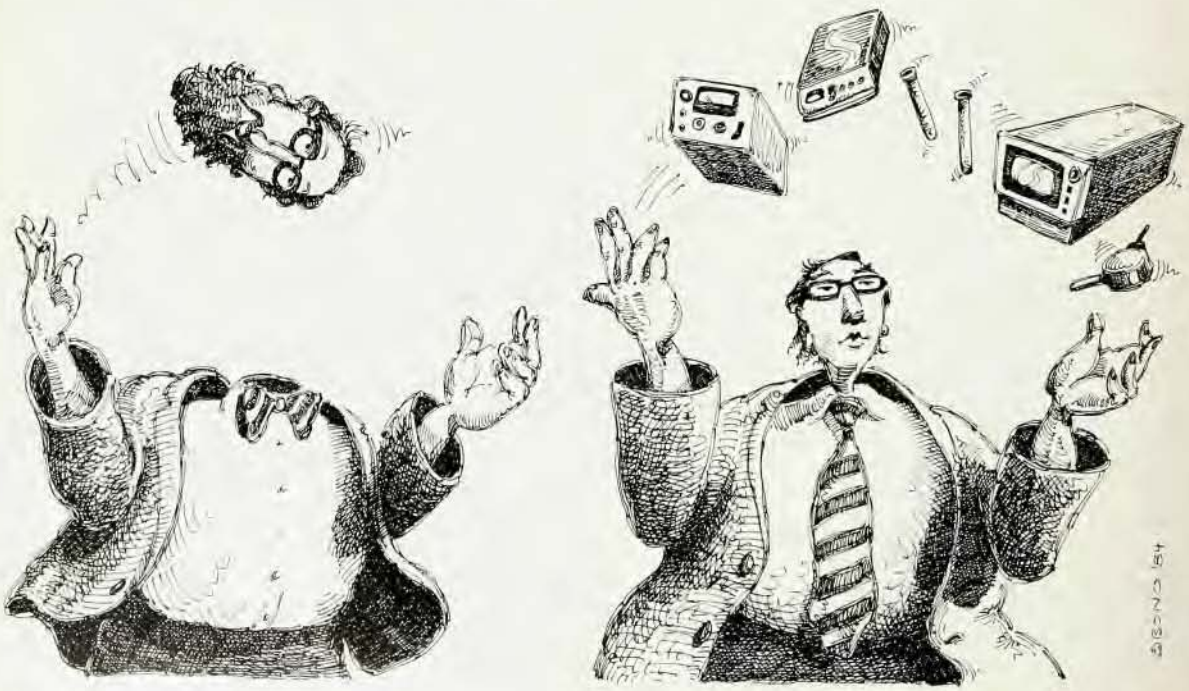
This problem is not logically difficult, it is only psychologically difficult. There are two incompatible propositions, and we want both to be true. What we perceive directly in empirical perception is

- outside our heads, and therefore real objects

- partly illusory, and therefore unreal images, inside our heads.

Earthy common sense has its cake and eats it on this question by stating that when we perceive illusions we perceive images, and that otherwise we perceive real objects. We are so used to thinking this way that we do not normally recognize its inconsistency. In empirical perception *everything* we perceive is outside our heads and therefore real, while in theoretical perception *everything* we perceive is an image. Therefore, if we perceive a mixture of reality and images of reality, both of these accounts of perception are false. Earthies usually avoid this problem by using the empty concept of "projection," in which we "project" illusory images onto real objects. This concept is empty because it is a metaphor that cannot work. The word "projection" has three meanings: mechanical, optical and geometrical, and none can apply here. Furthermore, how can private mental content be projected into public space and remain private?

We do want both empirical perception and theoretical perception to be true. Empirical perception is the foundation of science, and without theoretical perception illusions are impossible. How, then, can what we perceive be both inside our heads and outside? We can consider the possibility of this most easily with an analogy. Suppose we are told that the apple is in the box and also that the apple is outside the box. The only way to make both of these true at



once is to allow two apples or two boxes or both. Thus we can have one box, with an apple inside it and an apple outside it; or two boxes, one inside the other, with the apple inside the outer and outside the inner; or both of these—for example, two boxes, one inside the other, with an apple between them and an apple outside both. In the same way, when we want the empirical object to be both outside and inside the head, we must allow either two objects—object and image—or two heads—empirical head and theoretical head—or both. As it turns out, the facts of perception require that we have both. Indeed, it is the understanding of one key point here that leads to the Leibniz–Russell solution.

Suppose everything empirical is an image of a theoretical reality, as theoretical perception requires. Then one very special empirical object that each of us knows is his own head. One's own empirical head is thus an image of one's own theoretical head. This simple observation has extraordinary and far-reaching consequences. The most striking of these comes from asking *where* this theoretical head is. The answer is simple: Because everything empirical is an image inside one's theoretical head, it follows that this theoretical head must be outside everything empirically perceived. This means that beyond the limits of your empirical perception—that is, beyond the blue sky on a clear day or beyond the dome of visible stars on a clear night—is the inside surface of your own theoretical skull.

Many people find this so emotionally appalling that they react to it as creationists do to evolution, with passionately closed minds. However, a willing suspension of disbelief will quickly show the value of the Leibniz–Russell theory. Its value lies in resolving the problem of perception and in explaining science.

Thus, everything you empirically perceive, including your own body, is an image of parts of the theoretically real world. As such, it is partly similar and partly dissimilar to that reality—that is, it is partly true and partly illusion. Insofar as it is true, it is empirically real. Insofar as other people have similar images, what is empirically perceived is public by similarity. And these images are outside the image of your own body. Thus, what is empirically perceived is external, real and public—as empirical perception requires. At the same time, all these images are inside your theoretical skull, so they are theoretically unreal and private. Thus, what is theoretically perceived is internal, unreal and private—as theoretical perception requires. These seeming contradictions are resolved because what you empirically perceive is external to your empirical head but internal to your theoretical head, empirically real but theoretically unreal, and public by similarity but private by plurality.

The significance of all this for science is considerable. I propose to examine only three consequences here. There are many others, which I have dealt with in my *Renascent Rationalism*.[1]

Consequences for science

The first consequence is the obvious relationship between empirical and theoretical science. Empirical science tries to describe the true features of empirical worlds, and theoretical science tries to describe the theoretical world. This is why the content of empirical science is perceptible and the content of theoretical science is strictly imperceptible, or "underlying." Because the theoretical world is the cause of empirical worlds, theoretical science describes the cause of what empirical science describes. However, to describe a cause is to explain its effect, so theoretical science explains empirical science.

The second consequence of the Leibniz–Russell theory concerns the criteria for good empirical science. The most important of these are:

- The scientist must be objective.
- Data should be quantitative rather than qualitative.
- Experiments should be repeatable.

These are all explained in terms of publicity. We saw that publicity, or potential publicity, of empirical worlds is a necessary condition for their content being true. That is, publicity is a necessary condition for empirical reality (by definition) and empirical reality is the truth of empirical worlds (truth by the similarity between each person's empirical world and the theoretical world). It follows that if empirical science concentrates on public data then it has the best chance of being true, in the sense of similarity to the theoretical world.

That objectivity in science is attention to the public is obvious as soon as it is realized that subjectivity is attention to the private. What the scientist does in being objective is exclude from consideration everything private—such as prejudice, personal wishes and vanity.

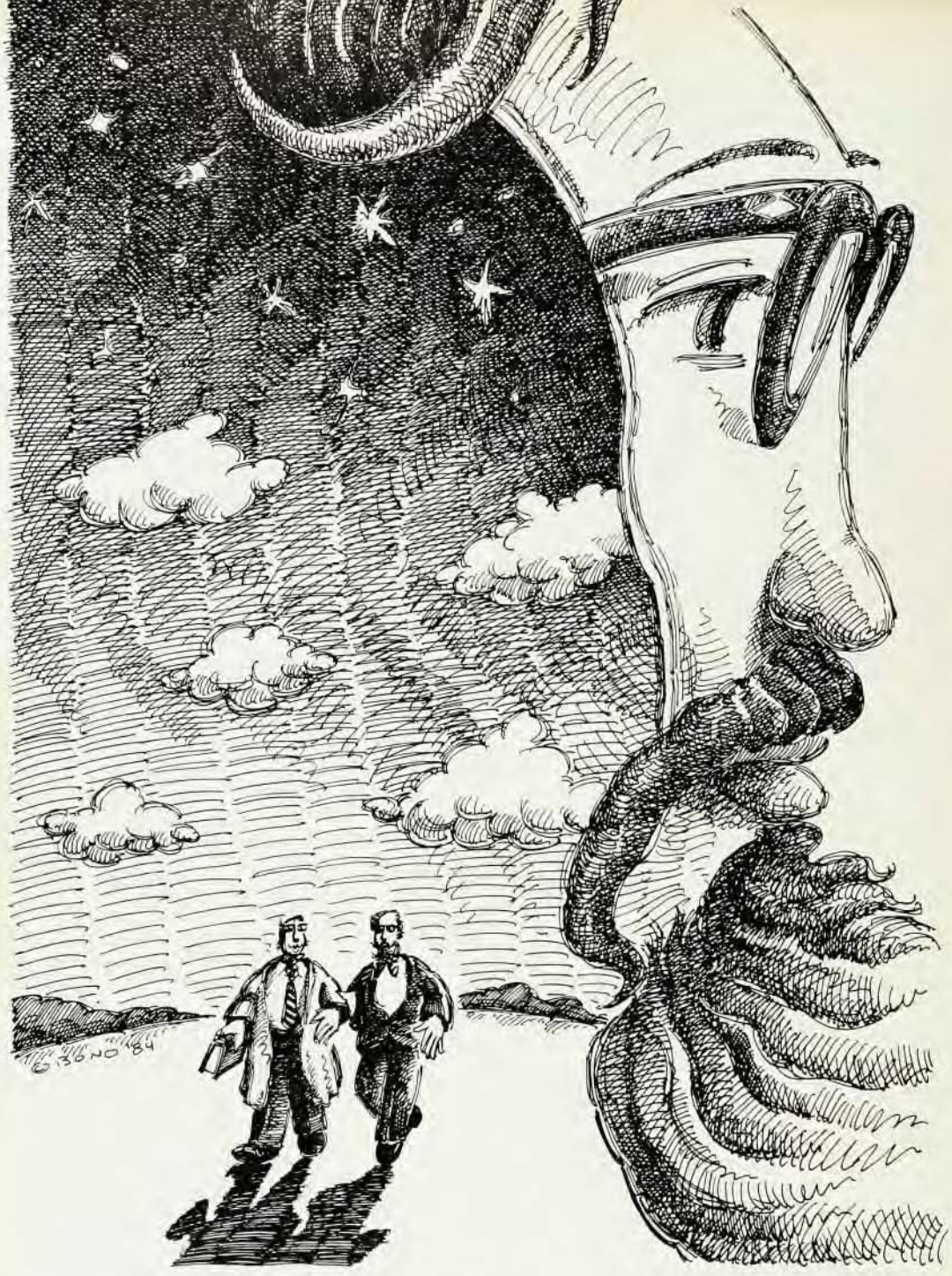
That quantitative data are more public than qualitative data is shown by the fact that all qualitative data are a matter of what Galileo and John Locke called *secondary qualities*. These are qualities, such as color, that are produced by the sense organs at the earliest and so are unreal in the sense of existing only when perceived. When we ask if the grass is really green, the answer is that the green we see when we look at grass is empirically real insofar as it truly represents the molecular structure of the theoretical grass, but it is not theoretically real, because it is a secondary quality. Although the color is widely believed to be public, this cannot be properly established because we cannot compare, interpersonally, our color sensations. Properly obtained quantitative data, on the other hand, are thoroughly public.

Finally, that experiments must be repeatable is quite clearly a requirement that their results be publicly verifiable.

There are two further significances of publicity in science. One is that if we ask about the most public content of minds (as opposed to empirical worlds) then the answer is rational thought—logic and mathematics. That these are necessary in science hardly needs to be said. Second, Einstein's principle of relativity, from which the special and general theories of relativity were derived, is the principle that all the basic laws of science must be true for all observers, no matter how they are moving relative to one another. This requires no more than that these laws be public to all observers.

The third consequence of the Leibniz–Russell theory is that we can now explain that most important feature of theoretical science: its frequent and successful prediction of empirical novelty. There are two main features in the process of successful prediction: making the prediction, and its coming true. The key to understanding these features is the concept of necessity. Nominalist earthies tend to discount necessity because it is an abstract thing. They claim that it is merely a property of language, or else a name for what is empirically always so. But it is more than both of these. Necessity can be defined as *singular possibility*. Whenever, in a given situation, the next possibility is the only one, then that possibility *must* occur, which is to say that it is necessitated by that situation. We are familiar with two kinds of necessity, logical and causal. Thus logically the outcome of adding two and two is the singular possibility, four; and the outcome of accelerating an electric charge is the singular possibility, electromagnetic radiation. We use logical necessity to make the prediction: We deduce the prediction within the theory. The theoretical world causally necessitates the prediction coming true: It comes true because theoretical reality makes it do so. These two necessities are related in that they are similar. As we have seen, such similarity between the theory and theoretical reality is truth.

Thus, this explanation of prediction works only if three conditions are fulfilled: The theory is true, logical necessity enables the prediction to be



deduced and causal necessity in the theoretically real world makes it come true. Other explanations are possible—the predictions come true by a long series of coincidences, or miraculously, by God who is testing our faith or by Satan who is trying to deceive us—but none of them is plausible. This explanation does require the Leibniz-Russell distinction between empirical realities and theoretical reality, because, as David Hume pointed out long ago, there are no empirical necessities: We never perceive necessity around us.

Finally, we can account for the fact that only mathematical theories succeed in predicting novelties. Because prediction of novelty requires a theory to be true by similarity to reality, mathematical theories must succeed because reality is mathematical. "All is number," as Pythagoras said two and a half millennia ago. This airy claim was endorsed by Plato, Galileo, Descartes, Spinoza, Leibniz and Newton, to name only the most famous.

Thus we have an outline of an airy philosophy of science, the result of giving theoretical science, and, in particular, theoretical perception, its due.

Reference

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