Rudolf Carnap

Philosophical Foundations of Physics

An Introduction to the Philosophy of Science

Edited by

Martin Gardner

Basic Books, Inc.

Publishers

New York, London

Contents

CHAPTER 26

The Ramsey Sentence

SCIENTIFIC THEORY, in the sense in which we are using the term—theoretical postulates combined with correspondence rules that join theoretical and observational terms—has in recent years been intensely analyzed and discussed by philosophers of science. Much of this discussion is so new that it has not yet been published. In this chapter, we will introduce an important new approach to the topic, one that goes back to a little known paper by the Cambridge logician and economist, Frank Plumpton Ramsey.

Ramsey died in 1930 at the age of twenty-six. He did not live to complete a book, but after his death a collection of his papers was edited by Richard Bevan Braithwaite and published in 1931 as *The Foundations of Mathematics.*[1] A short paper entitled "Theories" appears in this book. In my opinion, this paper deserves much more recognition than it has received. Perhaps the book's title attracted only readers interested in the logical foundations of mathematics, so that other

[1] Ramsey, *The Foundations of Mathematics* (London: Routledge and Kegan Paul, 1931), reprinted in paperback, Littlefield, Adams (1960).

important papers in the book, such as the paper on theories, tended to be overlooked.

Ramsey was puzzled by the fact that the theoretical terms—terms for the objects, properties, forces, and events described in a theory—are not meaningful in the same way that observational terms—"iron rod", "hot", and "red"—are meaningful. How, then, does a theoretical term acquire meaning? Everyone agrees that it derives its meaning from the context of the theory. "Gene" derives its meaning from genetic theory. "Electron" is interpreted by the postulates of particle physics. But we are faced with many confusing, disturbing questions. How can the *empirical* meaning of a theoretical term be determined? What does a given theory tell us about the actual world? Does it describe the structure of the real world, or is it just an abstract, artificial device for bringing order into the large mass of experiences in somewhat the same way that a system of accounting makes it possible to keep orderly records of a firm's financial dealings? Can it be said that an electron "exists" in the same sense that an iron rod exists?

There are procedures that measure a rod's properties in a simple, direct manner. Its volume and weight can be determined with great accuracy. We can measure the wave lengths of light emitted by the surface of a heated iron rod and precisely define what we mean when we say that the iron rod is "red". But when we deal with the properties of theoretical entities, such as the "spin" of an elementary particle, there are only complicated, indirect procedures for giving the term an empirical meaning. First we must introduce "spin" in the context of an elaborate theory of quantum mechanics, and then the theory must be connected with laboratory observables by another complex set of postulates—the correspondence rules. Clearly, spin is not empirically grounded in the simple, direct manner that the redness of a heated iron rod is grounded. Exactly what *is* its cognitive status? How can theoretical terms, which must in some way be connected with the actual world and subject to empirical testing, be distinguished from those metaphysical terms so often encountered in traditional philosophy—terms that have no empirical meaning? How can the right of a scientist to speak of theoretical concepts be justified, without at the same time justifying the right of a philosopher to use metaphysical terms?

In seeking answers to these puzzling questions, Ramsey made a novel, startling suggestion. He proposed that the combined system of theoretical and correspondence postulates of a theory be replaced by what is today called the "Ramsey sentence of the theory". In the Ramsey sentence, which is equivalent to the theory's postulates, theoretical terms do not occur at all. In other words, the puzzling questions are neatly side-stepped by the elimination of the very terms about which the questions are raised.

Suppose we are concerned with a theory containing n theoretical terms: "T_1", "T_2", "T_3" . . . "T_n". These terms are introduced by the postulates of the theory. They are connected with directly observable terms by the theory's correspondence rules. In these correspondence rules occur m observational terms: "O_1", "O_2", "O_3" . . . "O_m". The theory itself is a conjunction of all the theoretical postulates together with all the correspondence postulates. A full statement of the theory, therefore, will contain the combined sets of T- and O-terms: "T_1", "T_2", . . . , "T_n"; "O_1", "O_2", . . . , "O_m". Ramsey proposed that, in this sentence, the full statement of the theory, all the theoretical terms are to be replaced by corresponding variables: "U_1", "U_2", . . . , "U_n", and that what logicians call "existential quantifiers"—'$(\exists U_1)$', '$(\exists U_2)$', . . . , '$(\exists U_n)$'—be added to this formula. It is this new sentence, with its U-variables and their existential quantifiers, that is called the "Ramsey sentence".

To see exactly how this develops, consider the following example. Take the symbol "Mol" for the class of molecules. Instead of calling something "a molecule", call it "an element of Mol". Similarly, "Hymol" stands for "the class of hydrogen molecules", and "a hydrogen molecule" is "an element of Hymol". It is assumed that a space-time coordinate system has been fixed, so that a space-time point can be represented by its four coordinates: x, y, z, t. Adopt the symbol "Temp" for the concept of temperature. Then, "the (absolute) temperature of the body b, at time t, is 500" can be written, "Temp$(b,t) = 500$". Temperature is thus expressed as a relation involving a body, a time point, and a number. "The pressure of a body b, at time t", can be written, "Press(b,t)". The concept of mass is represented by the symbol "Mass". For "the mass of the body b (in grams) is 150" write, "Mass$(b) = 150$". Mass is a relation between a body and a number. Let "Vel" stand for the velocity of a body (it may be a macro- or a microbody). For example, "Vel$(b,t) = (r_1, r_2, r_3)$", where the right side of the equation refers to a triple of real numbers, namely, the components of the velocity in the directions of x, y, and z. Vel is thus a relation concerning a body, a time coordinate, and a triple of real numbers.

Generally speaking, the theoretical language contains "class terms" (such as terms for macrobodies, microbodies, and events) and "relation terms" (such as terms for various physical magnitudes).

Consider theory *TC*. (The "*T*" stands for the theoretical postulates of the theory, and "*C*" stands for the postulates that give the correspondence rules.) The postulates of this theory include some laws from the kinetic theory of gases, laws concerning the motions of molecules, their velocities, collisions, and so on. There are general laws about any gas, and there are special laws about hydrogen. In addition, there are macro-gas-theory laws about the temperature, pressure, and total mass of a (macro-) gas body. Suppose that the theoretical postulates of theory *TC* contain all the terms mentioned above. For the sake of brevity, instead of writing out in full all the T-postulates, write only the theoretical terms, and indicate the connecting symbolism by dots:

(*T*) . . . Mol . . . Hymol . . . Temp . . . Press . . .
Mass . . . Vel . . .

To complete the symbolization of theory *TC*, the correspondence postulates for some, but not necessarily all, of the theoretical terms must be considered. These C-postulates may be operational rules for the measurement of temperature and pressure (that is, a description of the construction of a thermometer and a manometer and rules for determining the values of temperature and pressure from the numbers read on the scales of the instruments). The C-postulates will contain the theoretical terms "Temp" and "Press" as well as a number of observational terms: "O_1", "O_2", . . . , "O_m". Thus, the C-postulates can be expressed in a brief, abbreviated way by writing:

(*C*) . . . Temp . . . O_1 . . . O_2 . . . O_3 . . .
Press . . . O_4 . . . O_m . . .

The entire theory can now be indicated in the following form:

(*TC*) . . . Mol . . . Hymol . . . Temp . . . Press . . .
Mass . . . Vel . . . ; . . . Temp . . . O_1 . . . O_2 . . .
O_3 . . . Press . . . O_4 . . . O_m . . .

To transform this theory *TC* into its Ramsey sentence, two steps are required. First, replace all the theoretical terms (class terms and relation terms) with arbitrarily chosen class and relation variables. Wherever "Mol" occurs in the theory, substitute the variable "C_1", for example. Wherever "Hymol" occurs in the theory replace it by another class variable, such as "C_2". The relation term "Temp" is replaced everywhere (both in the T and C portions of the theory) by a relation variable, such as "R_1". In the same way, "Press", "Mass", and "Vel" are replaced by three other relation variables, "R_2", "R_3", and "R_4" respectively, for example. The final result may be indicated in this way:

$$\ldots C_1 \ldots C_2 \ldots R_1 \ldots R_2 \ldots R_3 \ldots R_4 \ldots ; \\ \ldots R_1 \ldots O_1 \ldots O_2 \ldots O_3 \ldots R_2 \ldots \\ O_4 \ldots O_m \ldots$$

This result (which should be thought of as completely written out, rather than abbreviated as it is here with the help of dots) is no longer a sentence (as T, C, and TC are). It is an open sentence formula or, as it is sometimes called, a sentence form or a sentence function.

The second step, which transforms the open sentence formula into the Ramsey sentence, ^{R}TC, consists of writing in front of the sentence formula six existential quantifiers, one for each of the six variables:

$$(^{R}TC) \quad (\exists C_1)(\exists C_2)(\exists R_1)(\exists R_2)(\exists R_3)(\exists R_4)[\ldots C_1 \\ \ldots C_2 \ldots R_1 \ldots R_2 \ldots R_3 \ldots R_4 \ldots ; \\ \ldots R_1 \ldots O_1 \ldots O_2 \ldots O_3 \ldots R_2 \ldots \\ O_4 \ldots O_m \ldots]$$

A formula preceded by an existential quantifier asserts that there is at least one entity (of the type to which it refers) that satisfies the condition expressed by the formula. Thus, the Ramsey sentence indicated above says (roughly speaking) that there is (at least) one class C_1, one class C_2, one relation R_1, one R_2, one R_3, and one R_4 such that:

(1) these six classes and relations are connected with one another in a specified way (namely, as specified in the first or T part of the formula),

(2) the two relations, R_1 and R_2, are connected with the m observational entities, $O_1, \ldots, O_m$, in a certain way (namely, as specified in the second or C part of the formula).

The important thing to note is that in the Ramsey sentence the theoretical terms have disappeared. In their place are variables. The variable "C_1" does not refer to any particular class. The assertion is only that there is at least one class that satisfies certain conditions. The meaning of the Ramsey sentence is not changed in any way if the variables are arbitrarily changed. For example, the symbols "C_1" and "C_2" can be interchanged or replaced with other arbitrary variables, such as "X_1" and "X_2". The meaning of the sentence remains the same.

It may appear that the Ramsey sentence is no more than just another somewhat roundabout way of expressing the original theory. In a sense, this is true. It is easy to show that any statement about the real world that does not contain theoretical terms—that is, any statement capable of empirical confirmation—that follows from the theory will also follow from the Ramsey sentence. In other words, the Ramsey sentence has precisely the same *explanatory and predictive power* as the original system of postulates. Ramsey was the first to see this. It was an important insight, although few of his colleagues gave it much attention. One of the exceptions was Braithwaite, who was Ramsey's friend and who edited his papers. In his book, *Scientific Explanation* (1953), Braithwaite discusses Ramsey's insight, emphasizing its importance.

The important fact is that we can now avoid all the troublesome metaphysical questions that plague the original formulation of theories and can introduce a simplification into the formulation of theories. Before, we had theoretical terms, such as "electron", of dubious "reality" because they were so far removed from the observable world. Whatever partial empirical meaning could be given to these terms could be given only by the indirect procedure of stating a system of theoretical postulates and connecting those postulates with empirical observations by means of correspondence rules. In Ramsey's way of talking about the external world, a term such as "electron" vanishes. This does not in any way imply that electrons vanish, or, more precisely, that whatever it is in the external world that is symbolized by the word "electron" vanishes. The Ramsey sentence continues to assert, through its existential quantifiers, that there is something in the external world that has all those properties that physicists assign to the electron. It does not question the existence—the "reality"—of this something. It merely proposes a different way of talking about that something. The troublesome question it avoids is not, "Do electrons exist?" but, "What is the exact *meaning* of the term 'electron'?" In Ramsey's way of speaking about the world, this question does not arise. It is no longer necessary to inquire about the meaning of "electron", because the term itself does not appear in Ramsey's language.

It is important to understand—and this point was not sufficiently stressed by Ramsey—that Ramsey's approach cannot be said to bring theories into the observation language if "observation language" means (as is often the case) a language containing only observational terms and the terms of elementary logic and mathematics. Modern physics demands extremely complicated, high-level mathematics. Relativity theory, for instance, calls for non-Euclidean geometry and tensor calculus, and quantum mechanics calls for equally sophisticated mathematical concepts. It cannot be said, therefore, that a physical theory, expressed as a Ramsey sentence, is a sentence in a *simple* observational language. It requires an *extended* observational language, which is observational because it contains no theoretical terms, but has been extended to include an advanced, complicated logic, embracing virtually the whole of mathematics.

Suppose that, in the logical part of this extended observation language, we provide for a series $D_0, D_1, D_2, \ldots$ of domains of mathematical entities such that:

(1) The domain D_0 contains the natural numbers (0, 1, 2, . . .).

(2) For any domain D_n, the domain D_{n+1} contains all classes of elements of D_n.

The extended language contains variables for all these kinds of entities, together with suitable logical rules for using them. It is my opinion that this language is sufficient, not only for formulating all present theories of physics, but also for all future theories, at least for a long time to come. Of course, it is not possible to foresee the kinds of particles, fields, interactions, or other concepts that physicists may introduce in future centuries. However, I believe that such theoretical concepts, regardless of how bizarre and complex they may be, can—by means of Ramsey's device—be formulated in essentially the same extended observation language that is now available, which contains the observational terms combined with advanced logic and mathematics.[2]

On the other hand, Ramsey certainly did not mean—and no one has suggested—that physicists should abandon theoretical terms in their speech and writing. To do so would require enormously complicated statements. For example, it is easy to say in the customary language that a certain object has a mass of five grams. In the symbolic notation of a theory, before it is changed to a Ramsey sentence, one can say that a certain object No. 17 has a mass of five grams by writing, "Mass (17) = 5". In Ramsey's language, however, the theoretical term

[2] I have defended this view at greater length, and with more technical details, in my paper, "Beobachtungssprache und theoretische Sprache," *Dialectica,* 12 (1958), 236–248; reprinted in W. Ackermann et al., eds., *Logica: Studia Paul Bernays dedicata* (Neuchâtel (Switzerland): Éditions du Griffon, 1959), pp. 32–44.

"Mass" does not appear. There is only the variable (as in the previous example) "R_3". How can the sentence "Mass (17) = 5" be translated into Ramsey's language? "R_3 (17) = 5" obviously will not do; it is not even a sentence. The formula must be supplemented by the assumptions concerning the relation R_3 that are specified in the Ramsey sentence. Moreover, it would not be sufficient to pick out only those postulate-formulas containing "R_3". *All* the postulates are needed. Therefore, the translation of even this brief sentence into the Ramsey language demands an immensely long sentence, which contains the formulas corresponding to all the theoretical postulates, all the correspondence postulates, and their existential quantifiers. Even when the abbreviated form used earlier is adopted, the translation is rather long:

$$(\exists C_1)\ (\exists C_2)\ \ldots\ (\exists R_3)\ (\exists R_4)\ [\ldots C_1 \ldots$$
$$C_2 \ldots R_1 \ldots R_2 \ldots R_3 \ldots R_4 \ldots ; \ldots R_1 \ldots$$
$$O_1 \ldots O_2 \ldots O_3 \ldots R_2 \ldots O_4 \ldots O_m \ldots$$
$$\text{and } R_3(17) = 5].$$

It is evident that it would be inconvenient to substitute the Ramsey way of speaking for the ordinary discourse of physics in which theoretical terms are used. Ramsey merely meant to make clear that it was *possible* to formulate any theory in a language that did not require theoretical terms but that said the same thing as the conventional language.

When we say it "says the same thing", we mean this only so far as all observable consequences are concerned. It does not, of course, say *exactly* the same thing. The former language presupposes that theoretical terms, such as "electron" and "mass", point to something that is somehow *more* than what is supplied by the context of the theory itself. Some writers have called this the "surplus meaning" of a term. When this surplus meaning is taken into account, the two languages are certainly not equivalent. The Ramsey sentence represents the full *observational content* of a theory. It was Ramsey's great insight that this observational content is all that is needed for the theory to function as theory, that is, to explain known facts and predict new ones.

It is true that physicists find it vastly more convenient to talk in the shorthand language that includes theoretical terms, such as "proton", "electron", and "neutron". But if they are asked whether electrons "really" exist, they may respond in different ways. Some physicists are content to think about such terms as "electron" in the Ramsey way. They evade the question about existence by stating that there are certain observable events, in bubble chambers and so on, that can be described by certain mathematical functions, within the framework of a certain theoretical system. Beyond that they will assert nothing. To ask whether there really *are* electrons is the same—from the Ramsey point of view—as asking whether quantum physics is true. The answer is that, to the extent that quantum physics has been confirmed by tests, it is justifiable to say that there are instances of certain kinds of events that, in the language of the theory, are called "electrons".

This point of view is sometimes called the "instrumentalist" view of theories. It is close to the position defended by Charles Peirce, John Dewey, and other pragmatists, as well as by many other philosophers of science. From this point of view, theories are not about "reality". They are simply language tools for organizing the observational phenomena of experience into some sort of pattern that will function efficiently in predicting new observables. The theoretical terms are convenient symbols. The postulates containing them are adopted because they are useful, not because they are "true". They have no surplus meaning beyond the way in which they function in the system. It is meaningless to talk about the "real" electron or the "real" electromagnetic field.

Opposed to this view is the "descriptive" or "realist" view of theories. (Sometimes these two are distinguished, but it is not necessary to delve into these subtle differences.) Advocates of this approach find it both convenient and psychologically comforting to think of electrons, magnetic fields, and gravitational waves as actual entities about which science is steadily learning more. They point out that there is no sharp line separating an observable, such as an apple, from an unobservable, such as a neutron. An amoeba is not observable by the naked eye, but it is observable through a light microscope. A virus is not observable even through a light microscope, but its structure can be seen quite distinctly through an electron microscope. A proton cannot be observed in this direct way, but its track through a bubble chamber can be observed. If it is permissible to say that the amoeba is "real", there is no reason why it is not permissible to say that the proton is equally real. The changing view about the structure of electrons, genes, and other things does not mean that there is not something "there", behind each observable phenomenon; it merely indicates that more and more is being learned about the structure of those entities.

Proponents of the descriptive view remind us that unobservable entities have a habit of passing over into the observable realm as more powerful instruments of observation are developed. At one time, "virus" was a theoretical term. The same is true of "molecule". Ernst Mach was so opposed to thinking of a molecule as an existing "thing" that he once called it a "valueless image". Today, even atoms in a crystal lattice can be photographed by bombarding them with elementary particles; in a sense, the atom itself has become an observable. Defenders of this view argue that it is as reasonable to say that an atom "exists" as it is to say that a distant star, observable only as a faint spot of light on a long-exposed photographic plate, exists. There is, of course, no comparable way to observe an electron. But that is no reason for refusing to say it exists. Today, little is known about its structure; tomorrow a great deal may be known. It is as correct, say the advocates of the descriptive approach, to speak of an electron as an existing thing as it is to speak of apples and tables and galaxies as existing things.

It is obvious that there is a difference between the meanings of the instrumentalist and the realist ways of speaking. My own view, which I shall not elaborate here, is that the conflict between the two approaches is essentially linguistic. It is a question of which way of speaking is to be preferred under a given set of circumstances. To say that a theory is a reliable instrument—that is, that the predictions of observable events that it yields will be confirmed—is essentially the same as saying that the theory is true and that the theoretical, unobservable entities it speaks about exist. Thus, there is no incompatibility between the thesis of the instrumentalist and that of the realist. At least, there is no incompatibility so long as the former avoids such negative assertions as, ". . . but the theory does not consist of sentences which are either true or false, and the atoms, electrons, and the like do not really exist".[3]

[3] An illuminating discussion of the two or three points of view on this controversy is given by Ernest Nagel, *The Structure of Science* (New York: Harcourt, Brace & World, 1961), Chapter 6, "The Cognitive Status of Theories."