R

FRANK PLUMPTON RAMSEY

(22 February 1903–19 January 1930)

Frank Plumpton Ramsey made important contributions to philosophy, economics, logic, and mathematics. The son of a Cambridge mathematician, from an early age he was well known to members of the Cambridge intellectual community. He received a degree in mathematics from Trinity College in 1923, became a Fellow of King's College in 1924, and in 1926 he was made a University Lecturer in Mathematics, the post he held until his untimely death in 1930. Ramsey was an original thinker and no one's disciple, but his work clearly shows the influence of Russell, Keynes, Wittgenstein, Moore, W. E. Johnson, and Peirce. (Biographical information on Ramsey can be found in Mellor 1995, Sahlin 1990, and the introductory sections of Ramsey 1931 and 1990.)

Ramsey's earliest publications include a criticism of Keynes' theory of probability (Ramsey [1922] 1989) and a critical notice on Wittgenstein's ([1922] 1961) *Tractatus*. From 1925 to 1927, he published the philosophical papers "The Foundations of Mathematics," "Universals," "Mathematical Logic," and "Facts and Propositions" (Ramsey 1927). In 1927–1928, he published two influential papers in economics, "A Contribution to the Theory of Taxation" and "A Mathematical Theory of Saving," and his single mathematical publication, in which was introduced what is now known as Ramsey's theorem, "On a Problem in Formal Logic." Shortly after his death, the collected works of Ramsey (1931) appeared, containing all of the aforementioned works except the economics papers and the discussion of Keynes. It also contains writings unpublished until then, including the paper "Truth and Probability," written in 1926, and papers dating from 1928–1929 such as "Theories" and "General Propositions and Causality." Similar collections of Ramsey's work have also been published (Ramsey 1978 [which has the economics papers] and 1990). Two more recent books (Ramsey 1991a, b), contain material from the manuscripts in the Ramsey Collection at the University of Pittsburgh's Archives of Scientific Philosophy. The most comprehensive treatment to date of Ramsey's philosophical work is by Sahlin (1990).

The significance of some of Ramsey's work—for example, his contributions to the foundations of mathematics—was quickly appreciated. But it took time for many of Ramsey's ideas to become widely known and appreciated (on this, see Ramsey 1990, xi–xxiii, and Mellor 1995). As one encounters those ideas, it is worth remembering that they were all produced before his twenty-seventh birthday, which he did not live to see. Some are expressed in papers or notes not meant for publication and not developed to a point that fully satisfied him. It is remarkable how much illumination has been found, and how much can still be found, by studying the work that Ramsey had time to produce.

Logic and *The Foundations of Mathematics*

Ramsey was well acquainted with Whitehead and Russell's (1910) *Principia Mathematica* (*PM*), and with Wittgenstein ([1922] 1961). He commented on and corrected the proofs of the second edition of *PM*, and he was the major contributor to the first English translation of the *Tractatus.* In his lengthy "The Foundations of Mathematics (FM)" and the subsequent paper "Mathematical Logic (ML)," Ramsey strongly argued that the system of *PM* needed serious revision in order to remain true to the project of capturing mathematics within logic (see Russell, Bertrand). He identified three crucial shortcomings of the system that, in his view, undermined both the legitimacy of its fundamental principles and the system's adequacy as a basis for mathematics. As Sullivan (1995) observes, there is a correspondence between the three fundamental problems that Ramsey found and the three problematic axioms of *PM* with which Russell struggled—the axioms of choice, reducibility, and infinity. The upshot of the solutions Ramsey offered was that the formal system of *PM* was drastically reinterpreted but largely preserved; changes were confined to a simplification of its theory of types and the elimination of one of its axioms (reducibility). In the course of doing this, Ramsey drew a distinction that has become a standard way of classifying the various paradoxes that Whitehead and Russell cataloged in *PM.* Only brief indications of Ramsey's criticisms and proposals can be given here. (For background and more thorough discussion, see Sullivan 1995 or Grattan-Guinness 2000; the latter contains an extensive bibliography of further sources.)

At the heart of Ramsey's revisions to the system of *PM* is a move toward extensionality, based on an understanding of logic strongly influenced by Wittgenstein. Ramsey followed the *Tractatus* in taking propositions to be truth functions of atomic propositions. He divorced propositions from the symbolic formulas that express them; a single proposition (truth function) may be expressed by many different formulas, and some propositions may not be expressible at all. The same is true for propositional functions. (In *PM*, propositional functions are, roughly, what yield propositions when all their occurrences of free variables are bound or replaced by names. In Ramsey's conception, they turn out to be functions from individuals to propositions.) Some truth functions with infinitely many arguments can be expressed by use of the quantifiers, which Ramsey understood as convenient ways of writing infinite conjunctions and disjunctions. Given infinitely many atomic propositions, however, many possible truth functions of the set of atomic propositions will not be directly expressible, though they are relevant to the truth or falsehood of universally and existentially quantified propositions.

In the system of *PM*, every class (set whose members all have the same type) is defined by a symbolically expressible propositional function, or defining property. Ramsey's *first criticism* was that this is too restrictive for mathematics, which at least leaves open the possibility of infinite classes not definable by the propositional functions of *PM.* So the system of *PM* misinterprets important mathematical assertions about some or all classes, including the axiom of choice (*PM*'s multiplicative axiom) (*FM,* §II). Given the restricted availability of classes in *PM*, this would be an empirical truth rather than a logical truth, if it is true at all. In Ramsey's reconstruction of *PM*, many classes were available beyond those definable by *PM*'s propositional functions, and he regarded the axiom of choice as an obvious tautology, a necessary truth.

Paradoxes and the Theory of Types

Ramsey's *second criticism* of *PM* is now the one best remembered. Whitehead and Russell had cataloged seven logical contradictions that the system of *PM* must avoid; these included the existence of Russell's class of all classes not members of themselves, the liar sentence, and Richard's construction of a decimal that both is and is not finitely definable. They attributed a common source to the contradictions—"a certain kind of vicious circle"—and they invoked a *vicious circle principle*: "Whatever involves *all* of a collection must not be one of the collection" (*PM,* introduction, Ch. 2). The system of *PM* adhered to this principle through its theory of ramified types.

Ramified type theory arranged propositional functions into a twofold hierarchy of orders and of types within individual orders. The *type* of a propositional function was determined by the members of its domain. Individuals, monadic functions of individuals, monadic functions of monadic functions of individuals, and so on, had distinct and increasing types, which might be labeled 0, 1, 2, and so on. (Types of relations, and of classes defined with them, were more complex.) A function was only meaningful when applied to entities of type one less than itself, and it was not meaningful to say that classes defined by such functions either contain or fail to contain themselves as members. The hierarchy of *orders* of propositional functions was generated by how the functions were defined—specifically, by what quantifications over functions (think of them as quantifications over properties) were used in their definitions. In keeping with the vicious circle principle, the idea was that the definition of a propositional function could not quantify over all functions, or even over all functions of its own type. This restriction generated functions of increasing order: Those whose definition involved no quantification over functions were order zero (Ramsey called these *elementary*), those whose definition involved quantification over elementary functions were first-order, those whose definition involved quantification over first-order functions were second-order, and so on. It was not meaningful to quantify over propositional functions of all orders, and Whitehead and Russell showed that the dual hierarchy of ramified type theory defused the threat posed by the contradictions to the system of *PM*.

But the complications that the hierarchy of orders brought to type theory presented a serious problem for *PM*'s adequacy as a foundation for mathematics. The example Ramsey emphasized most fully in *ML* is crucial to real analysis. The least upper bound of a set of real numbers would be defined in *PM* by a function having an order greater than the order of a function defining the class of real numbers, so that it would fail to be a member of that class, that is, fail to be a real number itself. Whitehead and Russell introduced their *axiom of reducibility* to deal with such problems. It asserted that to each propositional function within a given type, there corresponded an equivalent function of lowest order for that type, so that the same class was defined by both functions. By invoking the axiom, then, real numbers and least upper bounds could be defined by functions of the same (lowest) order. Ramsey forcefully asserted, however, that the axiom of reducibility is far from obvious, and certainly not a principle of logic. Ramsey followed Peano in pointing out that the logical contradictions on Whitehead and Russell's list are dissimilar. (He added to the list Grelling's "heterological" contradiction, which he attributed to Weyl.) Ramsey placed them in two groups—(1) contradictions that could arise within a logical system and (2) contradictions that "cannot be stated in logical terms alone; for they all contain some reference to thought, language, or symbolism, which are not formal but empirical terms" (*FM*, Ramsey 1990, 183). The latter "all involve some psychological term, such as meaning, defining, naming, or asserting. They occur not in mathematics, but in thinking about mathematics" (*ML*, Ramsey 1990, 239). This has come to be known as a distinction between logical paradoxes and semantic paradoxes. Ramsey argued that those in the first group, including the contradictions of Russell's set and Burali's greatest ordinal, can and must be avoided by features of the logical system; in the case of *PM*, the theory of types, without ramification, would do the job. The second group of contradictions included the paradoxes of the liar, the least indefinable ordinal, the least integer not definable in fewer than nineteen syllables, Richard's finitely undefinable decimal, and Grelling's property "heterological." These are what motivated *PM*'s very general vicious circle principle and the ramified theory of types and orders.

How did Ramsey deal with the semantic paradoxes (which he described as "epistemological") and dispense with reducibility? Consider reducibility first. Ramsey agreed that a propositional function's type, determined by the members of its domain, was a real feature of it. But he thought of *PM*'s orders as features of the particular symbolic expressions that point to functions, rather than as features of the functions themselves. Since the functions themselves served to define classes, there was no need to regard their orders as relevant to the definitions of classes, and so no need for the unwanted axiom of reducibility. In taking this direction, Ramsey departed from *PM*'s strict observance of the vicious circle principle, which he regarded as much too broad. He treated definitions as ways of specifying particular functions and classes, rather than as ways of constructing them. It can be acceptable, in the course of successfully specifying what an entity is, to refer to the whole of a class of which that entity is a member. Whatever circularity is involved need not be vicious. This approach relies, of course, on the idea that the entities are already somewhere out there to be selected by the specifications. The Platonistic flavor of his account led Carnap (1931) to label it "theological mathematics," in contrast to the "anthropological mathematics" of the intuitionists. Ramsey later moved away from the account and this particular aspect of it.

What, then, about the semantic paradoxes? They all exploit the relation of *meaning* between symbols and propositional functions they express. Orders are no longer features of functions themselves and no longer play a role in defining classes, but it does make sense to think of orders as features of symbolic expressions that reflect levels of quantificational complexity—over individuals, or over functions (properties or relations) of individuals, or over functions of functions of individuals, and so on. In a move resembling later treatments that developed hierarchies of languages, Ramsey argued that relation(s) of meaning (and so of definability) are ambiguous for symbolic expressions of different orders. The meaning relation that holds for an elementary function is distinct from the meaning relation that holds for a first-order function, and so on up the hierarchy of orders. He further argued that when one keeps track of the distinct meaning relations, each of the semantic paradoxes can be shown not to yield a real contradiction (*FM*, §III).

Impredicative Functions, Infinity, Abandonment of Logicism

Ramsey pushed the extensionality of his system quite far. As mentioned earlier, he arrived at the point of regarding propositional functions as functions from individuals to propositions, rather than as open symbolic expressions. Ramsey called all propositional functions that are truth functions of atomic propositions *predicative* functions (this is not the same meaning that Whitehead and Russell gave the term). Predicative functions include more than just functions of individuals; Ramsey shows that all of the propositional functions of *PM* are predicative in his sense. But in Ramsey's extensionalization of *PM*, there are more propositional functions than this: *Impredicative* functions are those among the mappings from individuals to propositions that cannot be built up as truth functions of atomic propositions. In Ramsey's system, quantification over propositional functions is understood to range over all *functions in extension*, predicative and impredicative.

Ramsey's *third criticism* of *PM* was directed at its treatment of identity. In *PM*, identity was defined by appeal to a principle of indiscernibility of elementary properties. But it is no truth of logic, Ramsey said, that two things cannot share all elementary properties. He instead took *sameness of individual* as a primitive nonlogical idea, and made use of the rich collection of functions in extension to give an account of the propositional function $x = y$. The proposition that *PM* interpreted as saying that indiscernible individuals are related by '=' was instead interpreted as saying that '=' holds between individuals that share all functions in extension, predicative or impredicative. The latter include all mappings from individuals to propositions, however arbitrary, and this amounts to saying that '=' holds among individual(s) that are the same. In this interpretation, the assertion $(\phi_e)(\phi_e\, x \equiv \phi_e\, y)$, where ϕ_e ranges over functions in extension, does turn out to be a tautology exactly when $x = y$, and Ramsey took it, so understood, to be the defining condition for $x = y$. Ramsey applied this account to *PM*'s axiom of infinity, which, in Whitehead and Russell's interpretation, asserted that there are infinitely many individuals distinguishable by predicative functions (in Ramsey's sense of 'predicative'). Ramsey regarded that as at best an empirical claim. Since his reconstruction included functions in extension, his interpretation of the axiom just amounted to the assertion of the existence of an infinity of individuals, whether distinguishable by predicative functions or not. Ramsey acknowledged that this may still appear to be an empirical claim, but he used his account of identity to argue that, though the axiom is unprovable, it is a tautology (necessary) if it is true. At the end of *FM* he advocated adopting it, both on these grounds and because it is indispensable to mathematics.

This is still not an entirely satisfactory result for a logicist theory of mathematics, and Ramsey increasingly departed from that view after the publication of *FM*. The paper *ML* appeared one year later, and in it he still defended a generally logicist outlook against the alternative approaches of Hilbert, Weyl, and Brouwer. In *ML* Ramsey remained dissatisfied with the status of the axiom of infinity, yet he was still convinced that it is needed. There is evidence, however, that his views soon began to change. Braithwaite reports that in 1929 Ramsey "was converted to a finitist view which rejects the existence of any actual infinite aggregate" (Ramsey 1931, xii), and among the notes written in the last years of his life there is clear evidence of his strong interest in finitism (Ramsey 1991a, notes 53 and 54). There is also this statement, written in 1929 at the end of an unpolished set of notes on theories:

> It is obvious that mathematics does not require the existence of an infinite number of things. We say at once that imaginary things will do. . . . But there are no imaginary things, they are just words, and mathematicians and physicists who use the infinite are just manipulating symbols with some analogy to propositions. (Ramsey 1991a, note 58)

There is no further indication how he thought to dispense with an axiom of infinity.

Ramsey's Theorem

All of Ramsey's work in logic and the foundations of mathematics predated the dramatic developments of the 1930s. Who can say how his views would have continued to evolve if he had lived? Before moving on to other topics, it is worth mentioning Ramsey's most lasting contribution to mathematics itself, Ramsey's theorem. In the paper "On a Problem in Formal Logic," Ramsey took up Hilbert and Ackermann's Decision Problem and proved a special case, the decidability of validity for $\exists\forall$-form sentences with identity. In 1936 Alonzo Church showed that the problem for full predicate logic is unsolvable. As a preliminary to the main topic of his paper, however, Ramsey established a remarkable result in combinatorics that has proved seminal to a great deal of subsequent mathematical research. Details can be easily found in mathematical sources on *Ramsey theory* or *Ramsey numbers.*

Probability and Partial Belief

Ramsey's greatest influence on the philosophy of science today is through his work on probability and degrees of belief. His writings on laws and theories introduced other important ideas that are now well remembered and widely used (see below), but Ramsey lacked the opportunity to develop them as fully as the ideas in the remarkable paper "Truth and Probability" (TP). The paper was not widely appreciated prior to Savage's (1954) work, but Ramsey and Bruno de Finetti are now recognized as the two key figures in the origin and early development of contemporary accounts of subjective, or Bayesian, probability. *TP* is a rich paper and cannot be covered fully here (see also Zabell 1991, Jeffrey [1965] 1983, Skyrms 1990, Sahlin 1990, and Galavotti 1991). The paper has five sections—Braithwaite (Ramsey 1931, introduction) says that at one time Ramsey planned to add a sixth, on probability in science, and to publish the paper separately. He later developed plans to include it in a book, or books, on logic, truth, and probability. Drafts of other portions of that project, chapters devoted mainly to truth and judgment, have been published (Ramsey 1991b), and other works contain notes on probability, degrees of belief, and chance (Ramsey 1931 and 1991a).

Ramsey opens *TP* by allowing that there may be two distinct interpretations of probability, one appropriate to logic, the other to statistics and physical science, and he made clear that his subject was the former. The framework he had in mind began by conceiving of logic as the science of rational thought, subdivided into what he called the 'logic of consistency' and the 'logic of truth.' The former contains formal deductive logic and mathematics. Most of *TP* is devoted to developing the idea that the logic of consistency also contains a theory of probability, and to explaining that the sort of probability it must contain is *subjective.* In the final section, Ramsey turned to the logic of truth with the observation that "we want our beliefs to be consistent not merely with each other but also with the facts." Conformity to the logic of consistency gives no guarantee of that, so there is room for a broader human logic, "which tells men how they should think" or what it would be reasonable to believe (Ramsey 1990, 87). Ramsey's remarks on the logic of truth will be discussed in a later section.

Ramsey sets the stage for his own account with a review of the two rival interpretations of probability that were familiar to his readers. (Zabell 1991 is particularly good on the background and context of Ramsey's theory.) One is the frequency account, and the other is J. M. Keynes' logical interpretation of probability. Ramsey made no attempt to refute a frequency interpretation of probability—it is clearly mathematically viable and appears to be useful to science. It turns out not to be a suitable basis for a logic (of consistency) for partial belief, however, and he set aside frequencies until he later took up the logic of truth. Keynes' interpretation, on the other hand, was clearly meant to be a part of logic, and Ramsey gave serious attention to its shortcomings. Keynes advocated the view that a probability is an objective logical relation holding between one proposition and another. He held that such logical relations are unanalyzable, yet they are at least sometimes perceivable, and they serve as guides to rational belief. The degree of belief it is rational to have in an unknown proposition p is given by the probability relation that holds between the proposition describing what one knows and p. Keynes' degrees of probability were not generally quantitative, but in some cases, by appeal to the principle of indifference, they could be compared and calculated. Especially since the failure of Carnap's sophisticated later attempts at a similar approach, accounts like this are today no longer widely held. Suggestions for their resurrection still emerge from time to time in areas of philosophy where this history is not well known, and Ramsey's criticisms of Keynes remain relevant. They begin with the straightforward observation that

> there really do not seem to be any such things as the probability relations [Keynes] describes. He supposes that, at any rate in certain cases, they can be perceived; but speaking for myself I feel confident that this is not true. . . . [M]oreover I shrewdly suspect that others do not perceive them either, because they are able to come to so very little agreement as to which of them relates any two given propositions. (Ramsey 1990, 57)

Ramsey developed this criticism thoroughly in the second section of *TP*. Later, after the presentation of his own view, three further criticisms of Keynes' theory were given in the fourth section of *TP*. Keynes' account (a) failed to make clear why the logical relations should obey the axioms of probability, (b) attempted to lay down a priori logical constraints such as the principle of indifference to generate what are surely empirical probability values in science, and (c) did not recognize or explain "a probable belief founded not on argument but on [uncertain] direct inspection," since the logical relation indicates the probability of a proposition based only on what is *known* (Ramsey 1990, 86). Ramsey thought it clear that his own theory had none of these flaws.

Degrees of Belief

The third section of *TP* is its longest and most significant. It introduced, as well as anything written since, a conception of *degrees of belief* that is now widely used. Ramsey offered two lines of justification for taking *rational* degrees of belief to be probabilities. One was based on a betting model of action, and led to the Dutch Book Argument. The second provided a groundbreaking generalization of the betting model. Ramsey stated an axiomatic theory of rational preference and derived from it an expected utility theory that put the agent's degrees of belief in the role of probabilities (it is considered in the next section).

What *are* degrees of belief, and why think that they can be quantified? Ramsey developed an account that applies to dispositional beliefs as much as to occurrent beliefs. He considered and rejected the suggestion that the degree of a belief corresponds to the strength of an introspective feeling one might have about it, proposing instead that it must be a causal property of the belief, "which we can express vaguely as the extent to which we are prepared to act on it. This is a generalization of the well-known view, that the differentia of belief lies in its causal efficacy" (Ramsey 1990, 65). Ramsey did not deny, of course, that beliefs are sometimes accompanied by feelings of various intensities—say, of various degrees of conviction. The apparent advantage of such feelings is that they can be known through introspection, which supports the view that one knows how strongly one believes things. But Ramsey doubted that one always knows how strong belief is, and suggested another way of judging a belief's strength that need not rely on internal observation of some belief-feeling: One imagines how one would act in various hypothetical circumstances. Even if there were some quantitative scale on which feelings could be measured, unlikely as that is, he argued, they contribute little to the role of belief as a basis for action.

In its focus on their action-guiding role, Ramsey's account of partial beliefs fits well with his wider perspective on belief, which was strongly influenced by his study of Peirce. That will be neglected here, except to note that in other writings (Ramsey 1927; 1991b, esp. Ch. 3), he offers a broadly functionalist account of a belief's content, or, in his terms, its *propositional reference.* Several discussions of Ramsey's treatment of belief appear in Mellor (1980). Ramsey clearly thought it a good working hypothesis that internal patterns of relevant causal properties or dispositions are present and susceptible of measurement, though he was under no illusion that such measurement is easy. He repeatedly drew analogies between the difficulties of measuring these causal properties and the complications that arise in physical measurements of, for example, length or electric current.

A person's degree of belief in p is a causal property contributing to the belief's influence over that person's choices and actions. A familiar "old-established" technique for measuring it, which Ramsey regarded as "fundamentally sound," is to offer that person bets on p and see what bets, at what odds, that person is willing to accept. The person's willingness to give high odds on p indicates a high degree of belief in p; an insistence on receiving high odds indicates that the person's degree of belief is low. More precisely, if the least favorable bet that the person is willing to make on the truth of p is one where the person pays \$$a$ if p is false and wins \$$b$ if p is true, the person's degree of belief in p is the betting quotient $a/(a + b)$. A conditional degree of belief in *p given q* is similarly measured by the odds of the least favorable conditional bet—a bet on p that is in effect only if q is true. (A degree of belief in *p given q*, Ramsey said, is not always the same as the degree to which one would believe p if one believed q for certain.) Ramsey noted that there are many complications that undermine the generality and precision of the method: the diminishing marginal utility of money or of whatever goods are the payoffs, the possibility that one has particular eagerness or reluctance to make bets, the possible disturbance of one's opinion by the act of making the offer, and so on. Ramsey compared these to similar difficulties in carrying out physical measurements—it can be difficult to isolate one out of a number of forces at work, and measurement may require a physical intervention that alters the system being measured. The use of the betting model to characterize strength of belief predates Ramsey—it was used by Borel (1924) and de Finetti (1937), for example.

The betting model has since been the subject of much discussion and criticism, yet it remains the best way of getting across the idea on which contemporary Bayesian theory is founded. Explicit wagering is a specialized form of activity, and most persons engage in it only occasionally. But the model has the two advantages of familiarity and flexibility, since one can readily imagine betting on a wide variety of propositions. So in a theoretical effort to understand the action-guiding role of degrees of belief, betting makes a good, though hardly perfect, stand-in for actions of all sorts. Many actions can be regarded as expressions of implicit wagers, "Whenever we go to the station we are betting that a train will really run, and if we had not a sufficient degree of belief in this we should decline the bet and stay at home" (Ramsey 1990, 79). Ramsey's own remarks about the usefulness and limits of the idealized model are more sensible than a great deal of what has come after. According to the model, a given person at a given time has *a single* (definite) degree of belief in the proposition *p*. This involves assumptions of both *precision*—degrees of belief have precise numerical values—and *stake-insensitivity*. The latter holds that the action-guiding strength of a belief is unaffected by the size of the stakes involved in the actions so guided (or, at least, unaffected over some significant range of stakes). The degree of belief one has, for example, in "It will storm this afternoon" is unaffected by whether the stakes involve the inconvenience of carrying an umbrella, or more seriously, the risk of death in a small sailboat. There is no doubt that the magnitudes of the stakes affect how one makes choices, but Ramsey's theory and its descendents locate the effects not in changes to the strengths of one's beliefs, but in the interplay between beliefs and desires that yields choice (this point is further discussed in Armendt 1993).

The Logic of Consistency for Degrees of Belief

The fundamental claim is that *rational* degrees of belief satisfy the principles of probability. The argument Ramsey actually presented for it is based on his axiomatic theory of rational preference. But he also stated, for the first time, what has since become known as the Dutch Book Argument. That argument concludes that when degrees of belief violate the axioms of probability, they are flawed, because under their guidance the believer who holds them would be willing to accept a combination, or book, of bets that together yield a sure loss to him, whatever turns out to be true and however the bets pay off—a Dutch Book. Ramsey (1990) did not fill in the argument, but he clearly could have: "If anyone's mental condition violated these laws ... he could have a book made against him by a cunning bettor and would then stand to lose in any event" (78). He also stated the conclusion of the Converse Dutch Book Argument:

> Having any definite degree of belief implies a certain measure of consistency, namely willingness to bet on a given proposition at the same odds for any stake. ... Having degrees of belief obeying the laws of probability implies a further measure of consistency, namely such a consistency between the odds acceptable on different propositions as shall prevent a book being made against you. (Ramsey 1998, 78–79)

Both the argument and its converse also appear in de Finetti (1937). In the voluminous later literature on the Dutch Book Argument, Skyrms best addresses the heart of the topic (see e.g., his essay "Higher Order Degrees of Belief" in Mellor 1980; Skyrms 1990, Ch. 5). The key element of Skyrms' interpretation, in keeping with what seems to be Ramsey's own, is that the Dutch Book is a dramatic device. The believer's susceptibility to a Dutch Book illustrates the presence of a flaw in his beliefs; it does not in itself constitute the flaw. Armendt (1993) follows Skyrms' interpretation and further discusses the relationship between the betting model and axiomatic preference theories.

Ramsey used the betting model to present the intuitive idea of degree of belief, but his general account of subjective probability as a norm for degrees of belief really comes from his preference theory, only an overview of which can be given here (for further details, see Jeffrey [1965] 1983 or Sahlin 1990). Ramsey replaced betting with the more general device of a *gamble*. A gamble yields one outcome or another, say α or β, depending on whether a proposition *p* is true. The outcomes α, β were taken to be states of the world very fully specified with respect to things that the believer or agent cares about. In a nutshell, the account was this: The agent has a systematic set of preferences among various outcomes, as well as among a large set of imaginable gambles on them. His preferences are subject to certain principles, which Ramsey stated as axioms of the system and its preference relation. Some axioms are richness assumptions—the system includes preferences among fine-grained arrays of gambles on every proposition in which the agent has a degree of belief. To the extents that this richness is an acceptable idealization and the other axioms (e.g., transitivity and connectedness) are plausible components of a model of rationality, systems that satisfy the axioms can be regarded as systems of rational preference. Ramsey showed that for any such system, two appropriately unique, and so nonarbitrary, measures can be derived. One is a real-valued measurement of the values of the outcomes and gambles (a utility function, though he did not call it that), and the other is a numerical measurement of the propositions that is provably a probability function. The two measures together obey a principle of expected utility, and Ramsey interpreted the probability function as the measure of the agent's degrees of belief. Ramsey's account provides a foundation for both the theory of subjective utility and the theory of subjective probability, though the latter is what he emphasized in *TP*. The theory is a forerunner of many later axiomatic treatments of belief, utility, and decision developed by philosophers, economists, statisticians, and others. The later literature is immense and impossible to survey here. Savage's (1954) theory was extremely influential, and it contributed to the later recognition of Ramsey's work; particularly well known among philosophers is Jeffrey's ([1965] 1983) theory.

The Logic of Truth

Ramsey took the result just described to establish the legitimacy of a logic of consistency for partial beliefs. When the account is regarded as a decision or utility theory, its direct inclusion of degrees of belief clearly makes it an *epistemic* account. When viewed either as a doxastic theory or a utility theory, it is also *subjective*, in that the constraints applying to degrees of belief and preferences are internal to the system, not imposed by what is true or objectively desirable in the world. In later subjective probability theory, and especially in the *radical probabilism* of de Finetti, Jeffrey, and others, subjectivism is fundamental to the account—the apparent objectivity of some probabilities is held to be explicable by the dynamic behavior of interacting systems of subjective (conditional) probabilities. Ramsey himself expresses such a view in the later note "Chance" (Ramsey 1990). The remaining part of *TP*, however, does not contain an explicit commitment to radical probabilism. Here Ramsey sought a fuller account of good epistemic practice, one that goes beyond the logic of consistency by ascertaining the standards and sources of successful belief. On the other hand, in this most exploratory part of the paper, Ramsey asserted little or nothing with which a radical probabilist need disagree.

What is the connection between probability in the sense of (rational) degrees of belief, and probability in the sense of frequencies, or "class-ratios"? While still considering the logic of consistency, Ramsey (1990) allowed that "experienced frequencies often lead to corresponding partial beliefs, and partial beliefs lead to the expectation of corresponding frequencies" (83), but he denied that a general connection along such lines can be made out. What can be said to connect the interpretations is that, "supposing goods to be additive, belief of degree *m/n* is the sort of belief which leads to the action which would be best if repeated *n* times in *m* of which the proposition is true" (84). This is the sense in which the calculus of frequencies was linked to a calculus of consistent partial beliefs. (In the later note, "Reasonable Degree of Belief" [Ramsey 1990], he explores difficulties and refinements associated with this idea.) C. S. Peirce's pragmatism greatly influenced Ramsey's approach to the question of what, beyond consistency, makes degrees of belief reasonable. The *habits* by which one arrives at and maintain beliefs should be at the focus of attention. This led Ramsey (1990) to regard inductive inference as a central topic in the logic of truth, which is not to say that the logic of consistency is silent concerning induction:

> [I]f *p* is the fact observed, my degree of belief in *q* after the observation should be equal to my degree of belief in *q* given *p* before. . . . When my degrees of belief change in this way we can say that they have been changed consistently by my observation. (88)

Beyond conditionalization, though, what inferential habits produce reasonable beliefs, and what standards guide judgments about them? A richer account of induction than Ramsey's, based on the idea of exchangeable sequences of events, was soon given by de Finetti (1937). As to goals and standards, *always fully believe the truth* comes to mind, but it is not very helpful for human belief or for the habits followed in the many predicaments where certainty would be misplaced. A better standard, Ramsey proposed, is that a habit should yield partial beliefs whose strengths correspond to the frequencies with which relevantly similar beliefs are true. He illustrated the point with an example concerning the wholesomeness of toadstools; one might also think of weather forecasts. A habit that yields a degree of belief in p equal to x is reasonable when the frequency with which such beliefs are true is x. (For a discussion of how this proposal may be linked to deeper decision-theoretic standards of success, see Adams 1988).

Ramsey's further remarks in *TP* are a prolegomenon to the logic of truth, rather than a development of it. He asserts that scientific inductive reasoning will be indispensable to the project of identifying and assessing mental habits—judging when and how well they work. Induction is itself such a habit, and a useful one. To understand it better, and to determine how useful it is, one cannot avoid employing it. There is a circle here, but as Ramsey conceives the point of the project, nothing vicious about it.

The Value of Knowledge

TP is by far Ramsey's most substantial and polished effort in the area of partial belief, decision, and probability, but a number of other notes on related topics are among his papers. Two were mentioned above; another particularly interesting note is "Weight or the Value of Knowledge" (Ramsey 1991a, 285–287), in which Ramsey demonstrated a result that was independently rediscovered by Savage and by I. J. Good. Can a decision maker generally expect to be better off by acquiring more information before making a choice? Ramsey showed, in the context of his decision theory, that when free information is available, acquiring it will not lower, and may increase, the expected utility of the decision. Skyrms (1990, ch. 4) points out that the setting Ramsey uses in his treatment suggests that he may also have partly anticipated the generalized form of belief updating developed by Jeffrey ([1965] 1983) known as *probability kinematics*.

Scientific Theories, Laws, and Causality

During 1928–1929, Ramsey wrote several notes and papers on these topics that contain ideas of lasting influence. Since the papers are unfinished, and his views were in some respects clearly evolving and unsettled, the focus here will be on their general direction and on several ideas that were later taken up and developed more fully than Ramsey himself had opportunity to do. One theme that runs through the papers is an instrumentalist view of laws and theories.

The 1929 paper "Theories" investigated the formal structure of scientific theories. Ramsey's approach reflected his study of recent work by Nicod, Carnap, and Russell; he was interested in the content of theoretical assertions and in how such content is related to the observational assertions that the theory explains. Assume for the moment that the two sorts of assertions can be clearly distinguished. An idea attractive to logical positivists was that, in principle, anything expressed by theoretical assertions could also be expressed in a more roundabout way by observational assertions alone. One way to do this is to show that theoretical terms are explicitly definable from observational ones and that the definitions can be inverted. Ramsey presented a simple, toy example and explored what would be required to show this. He concluded that it might be done, but only in a way so complex and cumbersome that it would never be worth doing. That was not surprising, but a more significant problem is that the theory obtained by the method of explicit definition is too rigid. Further observations might suggest additions to the theory, but additions cannot be made without altering the definitions and thereby changing the meanings of its terms (this point was further developed by Braithwaite 1953, Ch. 3).

Ramsey offered another proposal. Assume a theory T that is axiomatized in first-order logic, with a distinct theoretical vocabulary whose terms appear in T and in a set C of correspondence rules (or as Ramsey says, a dictionary) relating theoretical and observational assertions. Conjoin all the axioms of T and all the rules of C, replace the occurrences of each distinct theoretical term with a second-order variable, and introduce for each distinct variable a second-order existential quantifier that binds its occurrences. The resulting sentence contains only observational terms, it is entailed by $(T \wedge C)$, and the particular observation sentences it entails are the same as those entailed by $(T \wedge C)$. This device is now known as the *Ramsey sentence* of the theory, and it has since been widely used in diverse treatments of the content, meaning, and truth of theories (see e.g., Hempel 1958, Carnap 1966, and Lewis 1970; there are many others). One notable area in which Ramsey sentences have been widely used is in the philosophy of mind. Functionalists in particular, following Lewis (1972), have often advocated employing Ramsey sentences to characterize mental states.

How much is accomplished or shown by any particular use of the Ramsey sentence technique clearly depends upon the application. Is the matter at hand one in which a relationship between two distinct linguistic, syntactic systems is really the main target of interest? Proponents of semantic or model-based approaches to understanding theories generally think that this is not the significant issue, and believe that more light can be shed on theories by thinking of set-theoretic or model-theoretic structures.

Ramsey explored two ways of thinking of causal laws. The brief 1928 note "Universals of Law and of Fact" (Ramsey 1990) explains the difference between universals of law and universals of fact (between lawlike and accidental generalizations) by appeal to an ideal future system of complete knowledge about the world. If one knew everything, Ramsey said, one would want to organize that knowledge in a deductive system in a way that strives for simplicity. The general axioms of the system would be the fundamental laws of nature, and the generalizations derivable from them without reference to facts of existence are derivative laws of nature. The choice of axioms "is bound to some extent to be arbitrary, but what is less likely to be arbitrary if any simplicity is to be preserved is a body [of such generalizations]" (Ramsey 1990, 143). This is as close as Ramsey came to a uniqueness claim, and he did not invoke a set of independently natural properties, or ways of carving up the world, that the ideal theory need capture. "As it is," he said, "we do not know everything; but what we do know we tend to organize as a deductive system and call its axioms laws, and we consider how that system would go if we knew a little more and call the further axioms or deductions there would then be, laws" (ibid). In this unpublished note, Ramsey did not cite him, but the account may well have developed from Ramsey's familiarity with John Stuart Mill's work. In any case, within a year Ramsey discarded the view. Its influence has endured, however, in the work of more recent philosophers, notably Lewis (1973) and Earman (1986) (see Laws of Nature).

The paper "General Propositions and Causality" contains Ramsey's second, revised treatment of causal laws. It was written in 1929, at a time when Ramsey had frequent conversations with Wittgenstein, who had just moved to Cambridge. The new view was that a law is not a summary of propositions about particular events; its causal force lies in our trust of it as a guide to inferences about particular events. Causal generalizations "are not judgments but rules for judging 'If I meet a ϕ, I shall regard it as a ψ.' This cannot be *negated* but it can be *disagreed* with by one who does not adopt it" (Ramsey 1990, 149). To assert a causal law is to assert a formula from which one can derive propositions about particular events. Its *causal* character lies in the temporal ordering of the events (ψ does not precede ϕ). The special importance attached to rules for judgments so ordered is traceable to how one thinks about one's actions; in deliberation one gives special importance to forward-looking rules, those that look to the future. Ramsey's views here have affinities to a number of subsequent treatments that strive for pragmatic, reductive accounts of causal necessity; a noteworthy example is Skyrms (1980).

This article concludes by mentioning a suggestion Ramsey (1990) made in a footnote to a discussion of conditionals in "General Propositions and Causality," at a point where he was distinguishing "hypotheticals" from material implications: "If two people are arguing 'If *p*, will *q*?' and are both in doubt as to *p*, they are adding *p* hypothetically to their stock of knowledge and arguing on that basis about *q*. ... We can say that they are fixing their degrees of belief in *q* given *p*" (155). The idea is that the acceptability of an indicative conditional corresponds to the acceptability of its consequent after the antecedent is hypothetically added to one's beliefs. Ramsey took the latter to be measured by the conditional probability of the consequent on the antecedent. The idea has been extensively developed by Adams (1975). In later philosophical literature on conditionals, Ramsey's suggestion, known as the *Ramsey test*, is widely embraced, at least up to a point. Precise characterizations of the idea vary, however, as do opinions about the scope of its adequacy. The large body of literature cannot be covered here (a recent survey of much of it is in Bennett 2003).

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See also **Decision Theory; Dutch Book Argument; Epistemology; Laws of Nature; Probability; Russell, Bertrand**

RATIONAL RECONSTRUCTION

Philosophers of science do many things. Nevertheless, the demand arises on occasion for them to give a general account of the relation of the work of philosophy of science to work in the sciences. To this demand, there are several responses (e.g., logical analysis of scientific and metascientific concepts, an explicit account of scientific method). One answer that has been employed in various places and times since the twentieth century is that philosophy of science engages in a rational reconstruction of science. This seems to raise as many questions as it answers. Does not the need for a "rational reconstruction" of science at the hands of philosophers seem to indicate that science as practiced is in some important sense not (wholly) rational? What is it about science that needs to be reconstructed in order to better exhibit its rational structure? What are the proper tools for reconstructing science?

This article seeks to provide a brief but balanced account of the point of rational reconstruction in the two projects that most importantly advanced that understanding of the proper business of philosophy of science: logical empiricism and Imre Lakatos's methodology of scientific research programs (see Logical Empiricism; Research Programs). Rational reconstruction is connected with many central issues of philosophical method within analytic philosophy of science. Arguments over rational reconstruction connect also to large debates about proper method in philosophy generally and, in particular, to the debates in the late