A Very Brief History of Logic

Philosophy begins with wonder. What is the world made of? Where does it come from? Why are we here? The speculations of primitive peoples were often imaginative, but were unfounded, irrational. Philosophy as we think of it today did not arise until the Greek philosophers of the sixth century BCE sought some overriding theories about the world. Is there one stuff of which the world is made? One principle that is fundamental throughout?

We think of Socrates and Plato as the great figures in the birth of Western philosophy, and we study them still today. Their greatness lies in part in their efforts to bring things into intellectual order—to provide, or at least to seek, some coherent system that can explain why things are the way they are. But even before Socrates there had been deep thinkers—Thales, Parmenides, Heraclitus, Democritus and others who had proposed assorted accounts of the fundamental stuff of the world, or of the fundamental principle by which all is governed.

They were theorizing, not merely guessing—but there was no real science in these early speculations. Dogmatic suppositions, supernatural forces, the gods, ancient myths and legends had always to be called upon. As philosophy gradually matured there grew the drive to *know*, to discover principles that could be relied upon in giving explanations.

Thus logic begins. Judgments are sought that can be tested and confirmed. The *methods* with which we discover and confirm whatever we really know need to be identified and refined. We must *reason* about things, and we hunger to understand the principles of right reasoning.

That first climb from chaotic thought into some well-ordered system of reasoning was an enterprise of extraordinary difficulty. Its first master, Aristotle (see p. 3), having developed a system within which the principles of reasoning could be precisely formulated, was rightly held in awe by rational thinkers from his day to ours. He was the first great logician.

Aristotle approached reasoning as an activity in which we first identify *classes* of things. We then recognize the *relations* among these classes. Then we can manipulate the propositions in which these relations are specified. The fundamental elements of reasoning are, he thought, the groups themselves, the categories into which we can put things. He therefore distinguished types of *categorical* propositions (e.g., "All Xs are Ys"—a universal affirmative proposition; "Some Ys are not Xs"—a particular negative proposition; and so on) and with those understood we can reason immediately to conclusions about the relations among these propositions (e.g., "If some Xs are Ys, then it cannot be true that no Ys are Xs"). More importantly, by combining categorical propositions involving three terms (say, Xs, Ys, and Zs) in various ways, we can reason accurately by constructing *categorical syllogisms* (e.g., "If all Xs are Ys, and some Xs are Zs, it must be that some Zs are Ys"). Using such techniques, a great system of deductive logic can be built, as will be shown in Chapters 5, 6 and 7 of this book.

A century after Aristotle the work of the Stoic philosopher, Chrysippus (see p. 7), carried logical analysis to a higher level. The fundamental elements of reasoning were taken to be not the Aristotelian categories, but *propositions*, the units with which we can affirm or deny some states of affairs (e.g., "X is in Athens," or "X is in Sparta"). We can then discover the logical relations among propositions: "If X is in Athens then X is not in Sparta." We can then identify elementary arguments that depend upon these various relations: "If X is in Athens then X is not in Sparta. X is in Athens. Therefore X is not in Sparta." The form of this simple argument, called *modus ponens*, is common and useful; many other such elementary forms may be identified and applied in rational discourse, as we will see in later portions of this book.

With these advances it soon becomes clear that the validity of a deductive argument, the solidity with which a conclusion may be inferred if the premises are true, depends upon the *form* of the argument, its shape rather than its content—or as logicians say, its syntactic features rather than its semantic content. *Modus ponens*, and every such argument form, can have an unlimited number of realizations, or instances. The consequences of this formal nature of validity remained to be investigated. With the decline of the Roman Empire, the work of the Greek logicians had been preserved by Muslim scholars, most notably Al-Farabi (c. 872–c. 950), who wrote, in Baghdad, a commentary on the works of Aristotle, and came to be called "the Second Teacher," second only to Aristotle in breadth and depth of learning. He was followed by the great Muslim polymath, Ibn Sina, known by his Latinized name, Avicenna. Their scholarship eventually penetrated and refreshed Western thought. Syntactic forms came again to be of central interest in logic in the twelfth century, in France, with the work of the monk, Peter Abelard (1079–1142).

In England the great logical figure of those early modern years was William of Ockham (1287–1348). He identified some of the theorems more precisely formulated many years later by the mathematical logician, Augustus De Morgan; De Morgan's theorems we will encounter and apply in the second part of this book. Ockham sought to rid metaphysics, in which he was chiefly interested, of useless concepts. He urged that when a term or notion has been shown fruitless it should be simply cut out and discarded. This imperative principle, "Ockham's razor," remains a common guideline: In all rational thinking, entities must not be multiplied beyond necessity.

Deductive logic had largely begun with Aristotle's compiled treatises, *The Organon*. That logic allowed and encouraged the powerful manipulation of what is already known, and that is indeed extremely useful. However, the long-studied analysis of propositions and their relations did not provide the stuff of new knowledge, desperately needed and widely sought in the early modern centuries. What the intellectual world required, many thought, was a *new Organon*. That *Novum Organum* was published by Francis Bacon (1561–1626) in England in 1620. The Baconian method aimed to codify the procedures used by scientists when investigating all natural things. Called "the father of empiricism", Bacon, with other pioneers of the scientific revolution in astronomy and medicine, did not reject the work of classical logicians, but supplemented that work by formulating the methods that make possible the *acquisition* of empirical truths. Facts—what we learn about the world—constitute the premises upon which deductive arguments can be built. These were the first great steps in formulating the principles of *inductive logic*.

It was time to gather the threads of logical analysis, deductive and inductive, into one coherent fabric. The first textbook of logic (*Logic, or the Art of Thinking*), was published anonymously in 1662 by a group known as the Port-Royal logicians. The principal authors, Antoine Arnauld (famous for his published disputes with Descartes) and Pierre Nicole, were joined by Blaise Pascal (1623–1662), a great French mathematician who had invented, while a teenager, a functioning mechanical calculator. Pascal was also one of the originators of the theory of probability—a sphere of logic that we will enter in the final chapter of this book. Other textbooks followed, including *Logick, or the Right Use of Reason* (1725) by Isaac Watts; then *Logic* (1826) by Richard Whately. Then, in 1843, there was published in England one of the greatest of all logic textbooks: *A System of Logic*, by John Stuart Mill (1806–1873). In this work the techniques with which we uncover and confirm causal connections in the real world were for the first time set forth in accurate detail. Mill's methods, his still relevant contributions to the study of inductive logic, we discuss at length in Part III of this book.

In deductive logic much creative work remained to be done. Reasoning was known to be burdened by the ambiguities and imprecision of ordinary language. One of the greatest of early modern thinkers, Gottfried Wilhelm Leibniz (1646–1716), set himself the task of overcoming these deficiencies by developing a mathematically exact symbolic language, one in which concepts might be expressed with unambiguous clarity. Leibniz (also one of the independent inventors of the infinitesimal calculus) had envisioned a sort of logic machine—one with which operations of a logical nature might be performed efficiently and accurately, as can be done in the algebra that he knew well. That great logic machine he never produced, but his dream of it may be seen as the foreshadowing of the modern electronic computer.

A major advance toward Leibniz's goal was made by the English logician George Boole (see p. 189), who devised, in his *Investigation into the Laws of Thought* (1854), a general system for the accurate expression and thus manipulation of propositions. Propositions had played a central role in logic since the time of Aristotle and Chrysippus. But it was only with Boole's deep analysis of propositions—the *Boolean interpretation* discussed in great detail in Chapter 5 of this book—that a fully consistent system of the logic of propositions was at last possible.

Other mathematicians and logicians made significant advances that brought greater precision and efficiency to the realm of deductive logic. One of these was Augustus De Morgan (1806–1871), alluded to above in connection with the work of William of Ockham. The theorems that still carry his name remain to this day critical logical tools in proving the validity of deductive arguments. Another English logician, John Venn (1834–1923), contributed brilliantly to the process of determining deductive validity by designing a system, as beautiful as it is simple, for the iconic exhibition of the relations of the terms in categorical propositions. Venn diagrams, consisting of interlocking circles, are now very widely used. They serve as an easily applied device with which the sense of propositions can be given visual force, and with which the validity or invalidity of categorical syllogisms can be established. We use Venn diagrams extensively in Part II of this book.

One of the greatest American philosophers, Charles Sanders Peirce (1839–1914), best known as the founder of the movement known as *pragmatism*, thought of himself primarily as a logician. Logic was for him a very broad study, involving the methods of all inquiry; formal deductive logic, to which he made some notable contributions, he took to be one of its branches. We think with signs, said Peirce, and logic is the formal theory of signs. He introduced some new concepts, such as inclusion and logical sum; he devised symbols for the expression of novel logical operations; he explored the logic of relations—and he anticipated work later done in expressing Boolean operations using the features of electrical switching circuits, a key step toward the actual development of the all-conquering logic machine that had been envisioned by Gottfried Leibniz.

A rigorous, formal system of propositional logic was produced by the German logician Gottlob Frege (1848–1925). That system, and his invention of the concept of *quantification*, establish him as one of the greatest of modern logicians. With quantification—as we explain in detail in Chapter 10 of this book—it is possible to deal accurately with a huge body of deductive argument that cannot otherwise be readily penetrated by the machinery of modern symbolic logic.

Bertrand Russell (1872–1970) and Alfred North Whitehead (1861–1947) sought to integrate all this modern work on deductive logic in one great and remarkable treatise: *Principia Mathematica*, published in segments from 1910 to 1913. Using (with some adjustments) the notation that had been devised by the Italian logician Giuseppe Peano (1858–1932), as well as the logical system earlier developed by Frege, Russell and Whitehead attempted to show that the whole of mathematics could be derived from a few basic logical axioms. Much of what appears in chapters 8, 9, and 10 of this book is derived from their work.

Deductive logic continued to develop. The completeness of axiomatic systems became a matter of great interest in the twentieth century. Kurt Gödel (1906–1978) was able to demonstrate that any formal axiomatic system, if it is consistent, must in fact be incomplete, and from Gödel's incompleteness theorems it follows that within any formal system there will be some formulas that must remain undecidable. Other aspects of deductive logic have been more recently investigated: the distinction between "fuzzy" and "crisp" logic has been explored; modal logic, in which the concepts of possibility and necessity are manipulated, has been highly developed.

But perhaps nothing that modern logicians have accomplished has had more profound impact than the development—by John von Neumann (1903–1957) and others—of the intellectual architecture of the circuits of digital computers. Not long thereafter, with the actual construction and gradual perfection of the electronic digital computer during the twentieth century, Leibniz's great vision was at last made real.

The account above sketches the history of logic in the West, mainly in Europe and North America. Elsewhere on the planet logic was also studied, of course—but we do not have accessible and accurate records of the discoveries made long ago in China and India. We know that in India much work had been done on the principles of logic. Augustus De Morgan was influenced by that work; the theorems that bear his name, explained in Chapter 9 of this book, were developed independently in India. George Boole was influenced by Indian thinkers as well. The rules of immediate inference, discussed in this book in chapter 5, appear also to have been articulated in India, but logic there emphasized effective philosophical argumentation, including both deductive and inductive elements, rather than formal systems. In China, at the time of the philosopher Mozi (470–391 BCE), the principles of analogical reasoning, discussed in chapter 11 of this book, were developed. But of that history we cannot be sure, because in the years 213–206 BCE the Qin dynasty, to erase all marks of preceding dynasties, burned many books and killed many scholars. Much work done in earlier periods was thus permanently lost.

From the time of Aristotle's *Organon* to the twenty-first century more people have studied logic from one book than from any other; that book, now in your hands, is *Introduction to Logic*, originally conceived and written by one of the most powerful and incisive thinkers of the twentieth century, the late Irving Copi (1917–2002).