

Introduction. The Place of Logic Among the Sciences.

Logic is the science of correct argument.

A good example of an argument is a prosecuting attorney's summation to a jury. The prosecutor will suppose that the jury, at the end of the trial, having heard the testimony and seen the evidence, is convinced of certain propositions. The prosecutor will suppose that the jury already accepts that the gun identified by the ballistics expert as the murder weapon was registered in the defendant's name, that Mrs. McIvers, the cleaning lady, overheard the defendant quarreling with the deceased an hour before the shooting, and so on. These propositions that the prosecutor supposes that the jury already accepts are the premisses of the prosecutor's argument. The prosecutor's job is to convince the jury that these premisses give them compelling reason to accept the conclusion that the defendant is guilty of murder. The purpose of the argument is to lead the jury from the premisses to the conclusion, to persuade them that, having accepted the premisses, they ought to accept the conclusion as well.

A correct argument is one in which anyone who accepts the premisses ought to accept the conclusion. A correct argument is not the same as a persuasive argument. An argument can be persuasive without being correct (an appeal to the racial prejudices of the jury, for instance) or it can be correct without being persuasive (maybe the jurors were dozing off). A correct argument is an argument that ought to persuade, whether or not it actually succeeds in persuading.

To see whether an argument is correct, you look at the connection between the premisses and the conclusion. In judging whether an argument is correct, you don't look to see whether there are good reasons for accepting the premisses. You look at whether, once a person has accepted the premisses, for whatever reasons, good or bad, she ought also to accept the conclusion. If the argument is the only reason to accept the conclusion, and if the person does not have good reason to accept the premisses, she will not have good reason to accept the conclusion. But that's not the argument's fault; it's the premisses' fault.

There are two purposes for which we use arguments: to persuade others and to persuade ourselves. An example of the former is a prosecutor trying to persuade a jury. An example of the latter is a proof in geometry, in which you use an argument to prove a theorem, based on things you already know. If you are sure the argument is correct, then you can be at least as confident of the conclusion as you are of the premisses. Logic doesn't give you the premisses, but, once you have the premisses, it enables you to expand your knowledge by drawing new conclusions. The techniques of proof logic gives you are the same, whether the person you want to convince is your neighbor or yourself.

Logic, like the rest of western science, began in ancient Egypt, with the annual flooding of the Nile River. Every spring the Nile, richly loaded with silt from the melting snows of central Africa, flooded its banks. When the waters subsided, the land beneath was extremely fertile, and hence extremely valuable. But the floods washed away all conventional boundary markers, such as fences and posts. So how could the owners of the

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valuable land on the flood plain keep track of their property lines? To solve this problem, the Egyptians invented geometry. Using geometry, they could determine the property lines by triangulation, using objects that weren't disturbed by the floods – pyramids and whatnot – as reference points.

Egyptian geometry was a haphazard affair. Formulas were discovered experimentally and written down. Most, but not all, the formulas were accurate. A few of them gave more-or-less accurate answers for the particular examples on which they had been tried out, but weren't generally valid. The Greeks took over the Egyptian geometry and reorganized it, and the Greek geometry was a marvel of careful and systematic organization.

Ancient Greek geometry, whose classic exposition in Euclid's *Elements*, started out from certain basic principles, called *axioms* or *postulates*, which were regarded as obvious, self-evident, and in no need of demonstration. From these axioms, one derived *theorems*. These theorems were then used, together with the original axioms, in deriving still further theorems. In this way, starting with the axioms and building up, very sophisticated geometric laws that weren't at all obvious were obtained from basic axioms that were entirely obvious. The axioms expressed a great deal of information in a compact form, so that, for virtually any geometrical problem you started with, you could solve it, eventually, by deriving the answer from the axioms.

Aristotle made two important observations. First of all, sciences other than geometry could be organized in geometric fashion, starting out from basic axioms and building up. Second, the basic argumentative principles that you use in deriving the theorems from the axioms are the same in all the sciences. Aristotle hit upon the idea of singling out the principles of argument common to all the sciences for study in their own right. Thus the science of logic was born.

The patterns of argument Aristotle singled out for study were particularly simple patterns called syllogisms. Examples are:

All trout are fish.
All fish swim.
Therefore, all trout swim.

All Capricorns are lazy.
No woodcutters are lazy.
Therefore, no Capricorns are woodcutters.

Aristotle's logic was quite crude by today's standards. Certainly the reasoning one encounters in Greek geometry is much more sophisticated than the mere chaining together

of syllogisms. Still, we must not undervalue Aristotle's contribution. He created a science of logic where before there was nothing.

For the ancient Greeks, geometry was the paradigm of the sciences; Euclid's *Elements* was what a scientific theory ought to look like. Over the centuries, the geometric model has pretty much been abandoned. The problem has been that axioms that have seemed self-evident have often turned out to be false. Thus it seemed obvious to Aristotle that a moving body will come to rest unless something is pushing it. In fact, as Galileo discovered, moving bodies only come to rest because something stops them; without interference, a moving body will keep moving with a constant velocity.

Again, it seemed obvious to Aristotle that heavy bodies – bodies made up mostly of earth and water – naturally fall downward toward the center of the universe, while light bodies – bodies made of air and fire – naturally rise away from the center of the universe. It turns out that heavy bodies near the earth naturally fall toward the center of the earth, but the center of the earth isn't the center of the universe; and heavy bodies near Mars fall toward the center of Mars. Light bodies near the earth naturally fall toward the center of the earth, the same as heavy bodies. When we see light bodies rising, it's not because rising is their natural tendency but because heavier bodies have shoved them aside.

The final blow came when it was discovered that even the axioms of Euclid's *Elements* aren't all true. Einstein showed that two points don't necessarily determine a line.

On the modern conception, you should accept an axiom, not because it seems self-evident to you, but because it is confirmed by observation and experiment. The good scientific theory is the one that successfully predicts and explains the outcomes of observations. Once you get the basic axioms, science proceeds pretty much the way Aristotle said it did. Starting with the axioms, you use logic to derive more and more sophisticated and specialized theorems and to obtain solutions to particular problems. The difference between the modern conception and Aristotle's conception is that (apart from pure mathematics), modern science starts from observation.

In principle, there should be two parts to logic. There should be *inductive logic*, which tells you how to get general laws out of particular observations, and *deductive logic*, which tell you how to go from general laws to specialized laws and particular predictions. In practice, we hardly understand anything about how to get from observations to general laws. Although people have had some interesting things to say about inductive reasoning, there isn't, as of today, anything that really deserves to be called a science of inductive logic. So deductive logic is what we'll study here.

The Renaissance brought two great changes in the way we do science. The first was the experimental method: observation and experiment became paramount. The second was the much greater use of mathematical methods. The Greeks had used mathematical

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methods in geometry and in geometry-based sciences like astronomy and optics. Galileo started using mathematical methods in mechanics, and nowadays mathematics is used everywhere.

The first successful use of mathematical methods in logic came in the last half of the nineteenth century. In fact, from the time of Aristotle until the last half of the nineteenth century, logic stagnated. A lot of people worked on logic and had some interesting ideas, but the ideas were never pursued very far, so that in 1850 logic was in basically the state in which Aristotle had left it.

In 1854 George Boole wrote a book called *The Laws of Thought* in which he applied the methods of algebra to the study of logic. (Leibniz had attempted the same thing a century and a half earlier, but without making a lot of progress.) Boole's book was the first of many works to apply, with increasing sophistication, the methods of modern mathematics to the study of logic. The result was to revolutionize the way we do logic, in much the way Copernicus, Galileo, and Newton revolutionized the way people did physics. Aristotle's theory of the syllogism is now entirely obsolete.

I said this before, but I want to emphasize it. In spite of the fact that the details of Aristotle's logical theory no longer have value for us, the fundamental value of his contributions must never be forgotten: He created a science of logic where before there was nothing.

Aristotle conceived of the sciences as arrayed in a hierarchy. The higher sciences were general and fundamental, whereas the lower sciences were specialized and derivative. Thus physics, which studies the properties of all bodies, lay above biology, which restricts its attention to living bodies. The laws of physics apply to all bodies, living or not, whereas the laws of biology are applicable to only a special kind of body.

At the top of the hierarchy there is a first science. Each of the other sciences studies some special kind of being, but the first science is the fully general science of being. Everything is within its scope. The first science has two parts: *Ontology* addresses questions like "What is the ultimate stuff the universe is made of?" and "Does the universe have a beginning and an end?" The other part is logic, which is included in the first science because the methods of reasoning it studies are employed throughout the sciences.

What Aristotle called the first science was more-or-less what people nowadays call philosophy, but no one nowadays regards philosophy as the first science. Nowadays, I suppose you'd say that mathematics plays the role Aristotle envisaged for the first science.

Philosophy's role has become dramatically narrower. In Aristotle's time, questions about the ultimate constituents of matter were philosophical questions; "natural philosophy" was the subdivision of philosophy that focused on them. Today, such

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questions are the province of theoretical physics. Hitherto philosophical questions about the nature of space and time are now questions for cosmology, a branch of astronomy. More recently, the study of mind was the business of philosophy until the last century or so, when it broke off to become a separate science of psychology. Linguistics and microeconomics have made the break from philosophy even more recently. Logic appears to be making the transition from a part of philosophy to a part of mathematics even as we speak. In a typical contemporary university, about half the logic courses are taught in the philosophy department and the rest in the math department.

No longer the first science, philosophy today is the primordial ooze from which the sciences emerge. Before we understand a subject well enough to formulate even the most basic laws, before we lack the needed vocabulary even to ask the right questions, the subject is a topic of philosophical inquiry. Once we have secured the vocabulary and a basic framework of laws, the discipline can take a place among the sciences. That, at least, is my understanding of the place of philosophy among the sciences. J.L. Austin had a similar view; let me quote him:

In the history of human inquiry, philosophy has the place of the initial central sun, seminal and tumultuous: from time to time, it throws off some portion of itself to take station as a science, a planet, cool and well regulated, progressing steadily towards a distant final state. This happened long ago at the birth of mathematics, and again at the birth of physics: only in the last century we have witnessed the same process once again, slow and at time almost imperceptible, in the birth of the science of mathematical logic, through the joint labours of philosophers and mathematicians. Is it not possible that the next century may see the birth, through the joint efforts of philosophers, grammarians, and numerous other students of language, of a true and comprehensive science of language? Then we shall have rid ourselves of one more part of philosophy (there will still be plenty left) in the only way we ever can get rid of philosophy, by kicking it upstairs. (P. 232 of "Ifs and Cans," *Philosophical Papers*, 2nd ed. (Oxford University Press, 1970), pp. 205-32.)