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The Recent History of Logic: A Perspective

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ABSTRACT
This short note reviews briefly the history of logic in the last 100 years or so, discussing the rise of "classical" logic, and then of non-classical logic. The role of logic in contemporary departments of mathematics, computer science, and philosophy is then discussed. A few final words address the question of where logic might be going.
Keywords: Classical logic, non-classical logic, philosophical logic

EDS *How do you see the changes in logic since you were a young logician?*

GP I learned logic initially between about 1969 and 1971. I think the best way to understand what has happened since then is to see matters in a slightly broader perspective.

Let us turn the clock back to the middle of the 19th Century. Medieval Europe delivered one of the most sophisticated and original periods in the history of Western logic. Sadly, most of the advances were forgotten due to the anti-scholasticism of Renaissance humanism. What remained by the middle of the 19th Century was what might be called 'traditional logic': Aristotle's *Organon*, plus some knowledge concerning "immediate inferences" such as *modus ponens*.

This changed when mathematicians got their hands on the subject, and started to apply mathematical techniques to the subject for the first time, thus launching the modern period. Of these mathematicians, two played a centrally important role: Frege and Russell.

The 19th Century may fairly be thought of the period of rigor in mathematics. Mathematicians had been operating with a variety of kinds of numbers (irrational numbers, complex numbers, infinitesimals, etc) though the understanding of these was somewhat unclear. 19th Century mathematicians such as Cauchy and Weierstrass succeeded in putting matters on a much sounder footing. By the time Frege and Russell appeared on the scene, it was only the nature of natural numbers and the various set-theoretic constructions that had been applied to these which were unclear. The two inaugurated the philosophy of logicism. As we might put it now, set theory was to be given a foundational role, as part of logic, and the natural numbers (and so all the other kinds of numbers) were to be defined as sets of a certain kinds. Traditional logic was just not up to the job of securing all the inferences required for the process, and so the pair had to develop an account of inference that was. This was the logic of Frege's *Grundgesetze* and Russel and Whitehead's *Principia*, a logic that was cleaned up later by mathematicians such as Hilbert and Tarski, to give us what is nowadays called—somewhat misleadingly—'classical logic'.

The logicist program crashed spectacularly. But classical logic was a permanent achievement, and it was so much superior to its predecessor that it soon became the received logic. It had been designed to account for the mathematical reasoning of its period, but it became assumed—without any real argument ever being given—that is was an account of how to reason about *anything*. Work in logic and philosophy proceeded largely on this assumption till about the 1960s and 1970s.

Logicians then started to question this assumption. There were a number of topics of reasoning where classical logic just didn't seem to work properly—or at least, it could be made to work only by torturing it into a procrustean bed—reasoning with conditionals or vague predicates are obvious (but by no means the only) examples of this. Thus we saw the inauguration of the development and investigation of so called non-classical logics. My education in logic occurred at about this time.

Of course, such logics were well known before this. Indeed, many of them were invented soon after classical logic itself: intuitionist logic, many-valued logic, and modal logic, are all creatures of the 1910s and 1920s. But these often seemed to rest on somewhat shaky philosophical foundations, such as the intuitionist critique of classical mathematics, and confusions around the material conditional and entailment. So such logics could be written off as of no import. They were deviant, as Quine famously tagged them (forgetting that is was classical logic that was deviant a few generations before). By the period in question, philosophers and logicians had seen enough of the attempts of torturing classical logic to treat non-classical logics with much more respect.

So since then we have seen an explosion in the development of non-classical logics, their properties and underlying philosophical foundations. (I guess a lot of my own work has been in this area.)

Of course, matters are more complicated than this. For a start, it must be remembered that logic is studied in departments of mathematics, computer science, and philosophy (and sometimes linguistics, but I have little knowledge of developments in these, so I can say little here). Even by the period in question, we were seeing disciplinary fragmentation.

For a start, in mathematics departments most of the investigations of logic were (and still are) on the applications of classical logic to certain kinds of mathematical structures (models, cardinals, complexity hierarchies, and so on). These investigations have become more and more specialised and, if I may say so, esoteric (though I do not use that word in a pejorative sense). I have not been able to understand the articles in the *Journal of Symbolic Logic* for many decades—and I suspect that those who can understand some of these cannot understand many of the others. This is not to suggest that non-classical logic has no mathematical interest. On the contrary, the mathematical structures that have appeared—and are still appearing—in the investigations of non-classical logic have just as much interest and sophistication as those in classical logic. It is just that logicians who work in the mathematics department have not caught on to these yet. (It must be said that most mathematicians have never regarded logic as a very important part of mathematics, so mathematical logicians have had to struggle to have what they do received into mainstream mathematics.)

So let us turn to computer science departments. The foundations of computation theory of course lie deep in mathematical logic. These, and so logic, have always, therefore, had a central place in studies of computer science. Now, computer science is largely driven by practical concerns. So the important questions concerning any sort of system that is developed are only: can it be made algorithmic? will the algorithm run in real time? and does it deliver the goods? Indeed, to these ends, in recent years we have seen a great deal of emphasis on the techniques of neural networks and machines that learn for themselves. The connection of such things with logic is at best tenuous.

It remains the case that non-classical logics are important to computer science. One of these is in the area of "knowledge representation". Here the techniques of modal logic have been deployed to great effect. However, for my money, the most important developments in logic largely from computer science departments concern non-monotonic logics: logics where the addition of further premises can render a valid inference invalid. Of course, discussions of inferences of this kind have a venerable history in logic. They were just called by a different name: inductive inferences—and it must be remembered that most inferences we make—at least outside mathematics and its applications, and maybe some philosophy—are of this kind. (Formal logic might have been quite different had it been developed by doctors and lawyers, and not mathematicians and philosophers!) Investigations largely in computer science departments have now given us a very sophisticated understanding of non-monotonic logics, their proof theories and semantics.

Let us now turn to philosophy departments—the area I know best. I think it fair to say that logic is not now seen as so central to philosophy as it once was—in the heydays of logical

empiricism—though it still remains central to areas of epistemology, the philosophy of language, and—increasingly—metaphysics. It is in philosophy departments where the bulk of the developments in non-classical logic have taken place over the last 50 years.

The variety of logics that have been developed and investigated in this period is enormous—and continues to expand. These include intuitionist and sub-intuitionist logics, many valued—including "fuzzy"—logics, modal logics (including tense and deontic logics), conditional logics, relevant logics, paraconsistent logics, logics with truth value "gaps" and "gluts", various substructural logics. (These categories are neither mutually exclusive nor exhaustive.) And here is not the place to go into matters. (Many of them, but by no means all, are discussed in my *Introduction to Non-Classical Logic*.)

Of course, these technical developments have gone hand in hand with discussions of the philosophical issues that prompted such logics. To name just a few of very many: do indicative and subjunctive conditionals behave differently? how should one understand the borderline of a vague predicate? could logical paradoxes be both true and false?

The developments have prompted new and "second order" philosophical questions. For example, is there any sense in which one of these logics could be the right logic, "the one true logic"? Or should we suppose that there is no such thing, "logical pluralism"? Whatever one says about this matter, it is certainly the case that different logics have been proposed for the same area of application. (Thus, the logics that have been proposed to handle vagueness include classical logic, intuitionist logic, fuzzy logic, supervaluational logics, paraconsistent logics.) It is clear that each, in effect, provides a theory of how to reason about that area. How should one choose the right (or at least best) theory? Indeed, those with a knowledge of the history of logic will see that logicians have been proposing theories of what follows from what and why for as long as there have been logicians; so this is hardly a new question. However, logic has never before seen a situation of the present kind, where there is such a plethora of logics, each with its own group of advocates. So the question has been thrust onto centre stage.

And where is logic now heading? Only a fool would make definite predictions. Developments are likely to be driven by new ideas which—by definition—we do not know. But for my part, I do not see the philosophical and technical investigations of non-classical logics drying up any time soon. It took logicians half a century to absorb the fact that the mathematical tools that were used to forge classical logic could be used, equally, to forge many different logics—and I think there is much more to be done in this direction. Possibly, philosophical consensus in some areas involved will be achieved; possibly not. But if the last 50 years is anything to go by, novel technical developments will generate all kinds of new philosophical questions and ideas.

At any rate, I don't expect young philosophical logicians to be out of work for the foreseeable future!