Mathematicians Recognize Major Discoveries

At 9:00 a.m., on Sunday, 3 August, the International Congress of Mathematicians convened at Berkeley's open-air Greek theater. First on the agenda was the announcement of this year's Field's Medal and Nevanlinna Prize winners. These awards, the most prestigious in mathematics, are made every 4 years and, according to tradition, are given to young researchers—meaning those under age 40.

The Field's Medal winners this year are 35-year-old Michael Freedman of the University of Southern California, 29-year-old Simon Donaldson of Oxford University, and 32-year-old Gerd Faltings of Princeton University. The Nevalinna Medal, which was initiated at the last international congress to recognize information science researchers, went to 37-year-old Leslie Valiant of Harvard University.

Donaldson and Freedman won their awards for work in topology. Both got surprising results that apply to the structure of four-dimensional spaces (*Science*, 30 July, 1982, p 432). In August of 1981, Freedman announced that he had solved the four-dimensional Poincaré conjecture, an old and famous problem. It took Freedman 8 years of concentrated work, and when he finished, topologists unanimously expressed surprise and delight with the result. Topologist Robion Kirky of the University of California at Berkeley commented to *Science*, "I think it is one of the loveliest pieces of math I have ever seen. It has an element of originality. If Freedman hadn't done it, I don't think anyone would have done it for a long time."

In the process of proving the Poincaré conjecture, Freedman got a more general result, showing, among other things, that a particular space, called E8, exists. This turned out to be crucial to Donaldson's work.

Donaldson does not consider himself to be a topologist and says he arrived at his topological results "by a very lucky accident." He was "trying to understand partial differential equations" that are of interest to physicists because they arise in gauge theory. "By accident, I found an application to the topology of four-dimensional space," Donaldson says.

His result, which involves the space E8, indicates that there must be more than one manifestation of ordinary four-dimensional space. Michael Atyiyah of Oxford, who was Donaldson's thesis adviser, remarked to *Science* that with Freedman and Donaldson's work, "instead of four-dimensional geometry getting to a stage of being completely understood, really it's just the other way around. We're just beginning to understand it. Four-dimensional geometry is much more interesting and complicated than we had any right to think."

The third Field's Medalist, Gerd Faltings, was honored for his solution to the Mordell conjecture—an outstanding number theory problem that confounded mathematicians for more than 60 years (*Science*, 22 July, 1983, p 349). The Mordell conjecture, says Barry Mazur of Harvard University, bears on "the riddle of algebra," involving the nature of solutions to polynomial equations. The conjecture says that all curves associated with topological surfaces that have two or more holes have only a finite number of rational solutions. When Faltings announced his result, Spencer Bloch of the University of Chicago commented to *Science*, "It is no exaggeration to say that, at least in number theory, this is the theorem of the century."

Valiant, who won the Navanlinna Prize, declined to speculate on why he was awarded the prize, but Volker Strassen of the University of Zurich, who was asked by the conference organizers to speak about Valiant's work, says that Valiant most likely was recognized for three major contributions to computer science. Ironically, Valiant does not use a computer in his research. Like most mathematicians, he works with only a pencil and paper.

Around 1975, Strassen says, Valiant found important algorithms for certain computer problems. In order to have a computer translate from a language such as Fortran or Pascal into machine language, it must recognize and parse sentences in these languages. But this process can be extremely time-consuming. Before Valiant's results, it took an amount of time that was proportional to n^3 for a sentence of length n. Valiant found a way to accomplish the same task an amount of time proportional to $n^{2.5}$.

After that, says Strassen, Valiant proved a more negative sort of result. He was working on search problems—problems whose solutions can require an exhaustive and frequently completely infeasible search of all possibilities. For example, the traveling salesman problem is a search problem of such huge dimensions that there is no good way to find the optimum solution. This problem, which arises in various guises in many practical situations in the world of commerce, such as in collecting coins from vending machines, asks for the shortest route that a salesman can take if he must visit n cities, going to each one only once.

What Valiant did was to turn the search problems around somewhat. He asked how many possible solutions there are for search problems and found, says Strasen, that it can be at least as hard to count the solutions to search problems as to find the solutions. There are practical consequences of this work. For example, the problem of making a fail-proof electronic network is equivalent to a counting problem and, says Strassen, "it is hard."

The counting problem work "is important because it frees our resources," according to Strassen. By knowing how to classify problems into hard and easier cases, computer scientists can avoid wasting time on problems whose solutions are beyond anyone's current capabilities.

After working on the counting problem in the early 1980's, Valiant went on to work on the theory of building a general-purpose parallel computer. It is, says Strassen, "a very difficult problem." Computer scientists have used idealized conceptual models of parallel computers in much of their research. Valiant is focusing on the question of whether investigators can actually build a parallel computer that has the properties of the theoretical ones.

Asked to comment on the intellectual processes that enabled them to do their innovative research, the award winners unanimously remarked on their luck. "Really sharp and noteworthy accomplishments require luck as well as hard work," says Freedman. "I'd be surprised if I prove another theorem that attracts as much attention." ■ GINA KOLATA