The IAS School of Mathematics

Allyn Jackson

Depending on how one counts, the number of major mathematics institutes worldwide falls between ten and twenty. In a very real sense, the forerunner of them all is the School of Mathematics at the Institute for Advanced Study (IAS) in Princeton, New Jersey. That the school is still known informally among mathematicians as *the* institute is an indication of its preeminent status. Founded in the 1930s as the first of four schools at the IAS, the School of Mathematics is internationally known for having a powerhouse permanent faculty and for giving many postdocs their first opportunities for independent research. Over the years the school has grown and evolved as mathematics has changed and as the institutional structures supporting the field have grown more diverse and complex. Nevertheless, the School of Mathematics remains, as one recent visitor put it, "an island of sanity where scholarship is rewarded on its own terms."

Birth of the IAS

The IAS was founded in 1930 with funds donated by Louis Bamberger and his sister, Caroline Bamberger Fuld. The siblings had made $25 million by selling Bamberger's, a large department store chain, to the R. H. Macy Company just six weeks before the 1929 stock market crash that set off the Great Depression. They wanted to donate $15 million to a good philanthropic cause and initially thought of starting a medical school. They solicited advice from Abraham Flexner, a prominent authority on higher education in the United States. At this time Flexner was just finishing a book about universities in which he set forth a vision of a new kind of institution that would be devoted to advanced research. He convinced the Bambergers that their money would best be put to use in realizing this vision.

Also around this time Flexner had been in touch with the mathematician Oswald Veblen, who was at Princeton University, and Veblen eventually became one of his close advisers and one of the first professors appointed to the new institute. Flexner decided to start the institute with mathematics partly because the field's fundamental character fit with his notion of an institute where pure intellectual achievement was the goal. But he was also a practical man: one reason for starting with mathematics was that it was cheap. As Beatrice Stern put it in her history of the IAS [S], mathematics "required only a few rooms, books, blackboards, chalk, paper, and pencils." Flexner also found he could count on a degree of unanimity of opinion about who were the best mathematicians to hire for his new venture. Mathematics made sense, too, because of its connections to economics and physics, two other areas that Flexner had in mind for the IAS.

The institute's prestige was virtually assured from the start, for one of its first appointments was that of Albert Einstein. Like many other American institutions, the IAS benefited from the flight of intellectuals from Europe during the rise of Nazism. The institute officially began in 1933, and by the following year the faculty had grown to six: Einstein,

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Veblen, James Alexander, Marston Morse, John von Neumann, and Hermann Weyl; Kurt Gödel also came in 1933 but was not made a professor until twenty years later. At first the IAS occupied offices in Fine Hall, home of the Princeton University mathematics department. In 1939 the IAS moved to the newly built Fuld Hall, which is now the institute's main building, located in a bucolic setting of lawns and trees about one mile from the Princeton campus. Today, in addition to the School of Mathematics, the IAS has three other schools: the School of Natural Sciences, the School of Historical Studies, and the School of Social Science.

In an article about the history of the School of Mathematics [B], Armand Borel, now a professor emeritus there, comments that the institute was based on a "somewhat romantic vision" of a handful of elite scholars surrounded by a few carefully chosen associates who together would churn out one great idea after another. Borel writes: "Einstein, Weyl, and Veblen soon decided they were not quite up to that lofty ideal and that a justification for the Institute would not be just their own work but, even to a much greater extent, to exert an impact on mathematics…chiefly through a vigorous visitors program." Thus, from the very beginning the School of Mathematics established itself as a center where visiting mathematicians could get away from everyday distractions and concentrate on research. Initially there were suggestions that the IAS should award degrees, and Flexner obtained the necessary accreditation in 1934. Though the accreditation remains valid today, the institute has never granted any degrees. The emphasis has always been on education and training from the postdoctoral level upward.

Much of the early history of the institute can be found in the book *Who Got Einstein's Office?* [R], by the science writer Ed Regis. The question posed in the book's title is one that, according to IAS public affairs officer Georgia Whidden, is often asked today; people seem to expect that the office Einstein used would have been made into a sort of shrine, and Whidden says some grow testy when told it was not. The office was passed on to astronomer Bengt Strömgren and then to mathematician Arne Beurling; now it is the office of Robert Langlands. Entertaining and down-to-earth, Regis's book outlines the institute's history and describes some of the research that has gone on there. The book also delights in taking an irreverent look at what Regis describes as "infighting and backstabbing" going on behind the scenes. A mention of the book elicits a groan from Borel, who says that the book suffers from historical inaccuracies and makes it seem as if no serious intellectual activity goes on at the IAS.

The history by Beatrice Stern also had a less-than-enthusiastic reception by some of the institute

Photograph by Allyn Jackson.

Fuld Hall, the main building on the IAS campus.

faculty. J. Robert Oppenheimer, who served as IAS director from 1946 to 1966, commissioned Stern to write it. In *Who Got Einstein's Office?* Regis says he had a hard time obtaining a copy of Stern's history—no one at the IAS would show it to him—and winds up concluding that the institute was trying to suppress the document. Today a copy of Stern's history sits innocuously on a shelf in the Historical Studies Library. Ponderously written and meticulously researched, the book does not appear to contain any scandalous revelations. According to one IAS official, the history was never published because its scholarship was not up to institute standards and because it was somewhat gossipy. Some on the faculty were offended by Stern's portrayal of Oswald Veblen as scheming and power hungry.

Old Traditions, New Directions

Just as in Flexner's time, today IAS professors have no teaching duties, few administrative chores, and plenty of time to think. But having so much freedom year-round is not to everyone's taste. "The pressure of only doing research might be counterproductive," says Andrew Wiles of Princeton University. He has a special arrangement at the moment whereby he spends one term teaching at Princeton and one term doing research at the institute. In explaining why he likes this arrangement, he recalls a saying: with an undergraduate one can answer almost any question, with a graduate student one can answer some of the questions, but with a postdoc one can rarely answer any question at all. Right now Wiles is spending his time learning some analytic number theory, which he believes is especially important for the Langlands Program. His Princeton colleague and fellow number theorist Peter Sarnak has a similar arrangement and spends one term each year at the IAS.

Photograph by Allyn Jackson.

A bust of André Weil in the common room of the IAS mathematics building.

The research areas of Wiles and Sarnak are very much in keeping with the tradition in number theory that has been a mainstay of the School of Mathematics for many years, nourished by such permanent faculty as Carl Ludwig Siegel, Atle Selberg, André Weil, Enrico Bombieri, and Robert Langlands. Other areas historically associated with the IAS are algebraic geometry, representation theory, and Lie group theory. When he was on the IAS faculty from 1963 until his untimely death twenty years later, Harish-Chandra faithfully lectured two hours every week on his own work. His prodigious output is one reason the School of Mathematics came to be known around this time as the Institute for the Study of Semisimple Lie Groups. Jokes aside, breadth of coverage has always been a concern of the School of Mathematics faculty. Its small size—which has varied from six to eight permanent professors over the years—means that the school cannot cover the whole field. Efforts are made to avoid too much duplication in the professors' research and to respond to developments in mathematics by making permanent appointments in new areas. Such considerations led to the appointment of Michael Atiyah in 1969, John Milnor in 1970, and Shing-Tung Yau in 1980 (all three have since moved on to new positions). The school gained strength in analysis and applied mathematics through the 1985 appointments of Luis Caffarelli and Thomas Spencer and the 1994 appointment of Jean Bourgain; Caffarelli has now left, but Bourgain and Spencer are still at the institute. And in 2000 the school branched out into theoretical computer science with the appointment of Avi Wigderson, 1994 winner of the Nevanlinna Prize.

But the breadth of the permanent faculty does not tell the whole story; each year the school has about sixty long-term visitors, called "members", who range across all of mathematics. Indeed, some of the great achievements associated with the IAS were carried out by members: for example, Raoul Bott discovered crucial ideas leading up to his periodicity theorem while he was at the IAS, and Friedrich Hirzebruch completed his proof of the Riemann-Roch theorem there. Most mathematics institutes are organized around programs focused on particular areas, and the majority of visitors are clustered in those areas. At the IAS it is just the reverse: the majority of the members are not associated with the so-called "special programs". One, two, or sometimes three special programs are held each year, but they account for at most one-third of the members and do not dominate the school's activities. Consequently, over an academic year at the IAS, a great variety of different mathematical areas are represented. As Borel points out, the school offers many opportunities for chance encounters with new ideas. "Very often [such an encounter] creates a considerable change in the outlook and career of that person," he notes. "That is to me one of the main virtues of the institute, and it remains as it ever was."

The special programs at the School of Mathematics are usually organized by a senior mathematician from outside the IAS. Bombieri remembers one program in the 1970s on the classification of finite simple groups, organized by the late Daniel Gorenstein. "He would come to my office and teach me finite groups," Bombieri recalls. Under Gorenstein's tutelage, Bombieri began to get interested in the classification of finite simple groups. "Somehow it was the atmosphere here at the institute," Bombieri says. "Everybody was very excited about finite groups." It was while Robert L. Griess Jr. was a member at the IAS that he proved the existence of the celebrated monster group. Sometimes a program organizer is appointed as a Distinguished Visiting Professor (DVP), meaning that he or she has the same salary and benefits as the permanent IAS faculty. During the 2001–2002 academic year Yakov Eliashberg was named DVP and organized a program in symplectic geometry, the activities for which encompassed about fifteen members and two conferences. Sometimes faculty from Princeton University organize programs, such as the one to be held during 2002–2003, organized by Weinan E, which will focus on stochastic partial differential equations and models of turbulence.

That the school is running a program in such an applied area is indicative of an evolution that has been going on at the IAS for the past fifteen or twenty years. "It used to be that if you understood what a differential is, you were out—that was already too applied," one observer joked. Since the hiring of Spencer, who has broad interests ranging from statistical mechanics to turbulence to materials science, the School of Mathematics has begun to expand into more applied areas. "We have a reasonably high profile [in applied mathematics], so people who would never have applied here before,...now they know this is a place that is interested in the area," Spencer notes. With a grant from the Sloan Foundation, which was specifically aimed at helping the institute explore areas of applied mathematics, the school organized several programs in theoretical computer science and combinatorics between 1993 and 1999. At the end of

this time the school hired Wigderson, whose appointment represented an expansion of the faculty size from seven to eight. "We believe that [discrete mathematics and theoretical computer science] is an area which is extraordinarily interesting and will be so for the next thirty years at least," Bombieri says. "It took six years of continuous programs and presence in combinatorics and computer science before we said, 'Okay, now we are convinced that it's really good and we want that.' And that's when we hired Avi."

Biology has never had a permanent presence at the IAS. Borel has been a faculty member during the tenure of five different directors, and he says all of them considered adding biology, including Oppenheimer. "I remember a faculty meeting where Oppenheimer said that the first third of this century was for physics, the second third was for mathematics, and the third third will be for biology," Borel recalls. But nothing more than inviting a few biologists as members was done. A much more ambitious move came in 1998, when, at the initiative of director Phillip Griffiths and Natural Sciences faculty member Frank Wilczek, the IAS launched the Program in Theoretical Biology (PTB). Griffiths explains that the plan is for the institute to try out several areas of biology for periods of five years. In this way, he says, "the institute is seeking to develop a sense of the way we can best contribute to biology on an ongoing basis."

The PTB began with the area of mathematical biology and with the five-year appointment of Martin Nowak, who came to the IAS in 1998. A leading theoretical biologist and protégé of Robert May, Nowak uses mathematical modeling to investigate a wide range of problems, such as language evolution, the development of tumors, and the spread of viruses, especially HIV, in the human body. At the moment Nowak's group has eight people, some of them postdocs and some midcareer or senior researchers. During 2001–2002 he has run a seminar together with Spencer and Joel Lebowitz, a member visiting from Rutgers University. The aim of the seminar is to bring in speakers who can communicate well with mathematicians about mathematical aspects of biology. Nowak also collaborates with medical researchers at nearby institutions.

Naming bioinformatics, protein folding, theoretical neurobiology, and theoretical ecology as some of the areas the institute could pursue, Nowak contends that there should be no hesitation in starting a permanent IAS School of Biology. "It's obvious that this is the thing to do," he remarks. Others at the institute seem less sure. The main question is whether, with its small size and without laboratories, the IAS can make a contribution to biology at the highest level. "Biologists correctly criticize a lot of mathematical work as being irrelevant," Spencer says. "But on the other hand, they've realized they do need more mathematical tools. So you have to pick the problems, you have to pick the areas pretty carefully." Faculty member Pierre Deligne sums up how some in the School of Mathematics feel about adding biology at the IAS: "If we can do it well, then it's worth doing. But if we cannot do it really well, we can do without."

The institute has moved to continue its exploration of biology: in early June 2002 it announced that the next area of emphasis would be biophysics and that Arnold Levine of Rockefeller University has been appointed to a five-year term. Levine is "perhaps the leading cancer biologist of his generation," Griffiths notes. "He sees the future of biology as being tightly dependent on linking it to physics,

School of Mathematics Faculty

Below are the names of past and present professors in the IAS School of Mathematics, followed by the year of the appointment and the year of resignation or retirement.

* James W. Alexander, 1933–1947
Michael F. Atiyah, 1969–1972
* Arne Beurling, 1954–1973; Emeritus, 1973–1986
Enrico Bombieri, 1977–present
Armand Borel, 1957–1993; Emeritus, 1993–present
Jean Bourgain, 1994–present
Luis A. Caffarelli, 1986–1996
Pierre Deligne, 1984–present
* Albert Einstein, 1933–1946; Emeritus, 1946–1955
* Kurt Gödel, 1953–1976; Emeritus, 1976–1978
* Harish-Chandra, 1963–1983
Lars Hörmander, 1964–1968
Robert P. Langlands, 1972–present
Tsung Dao Lee, 1960–1962
Robert D. MacPherson, 1994–present
John W. Milnor, 1970–1990
* Deane Montgomery, 1951–1980; Emeritus, 1980–1992
* Marston Morse, 1935–1962; Emeritus, 1962–1977
* J. Robert Oppenheimer, 1947–1966
Abraham Pais, 1950–1963
Tullio Eugene Regge, 1965–1966
Atle Selberg, 1951–1987; Emeritus, 1987–present
Carl Ludwig Siegel, 1945–1951
Thomas Spencer, 1986–present
Bengt Strömgren, 1957–1966
* Oswald Veblen, 1932–1950; Emeritus, 1950–1960
Vladimir Voevodsky, 2002–present
* John von Neumann, 1933–1957
* André Weil, 1958–1976; Emeritus, 1976–1998
* Hermann Weyl, 1933–1951; Emeritus, 1951–1955
* Hassler Whitney, 1952–1977; Emeritus, 1977–1989
Avi Wigderson, 1999–present
Chen Ning Yang, 1955–1966
Shing-Tung Yau, 1980–1984

* Deceased

Photograph by Allyn Jackson.

Clifford H. Taubes of Harvard University presenting the 2002 Hermann Weyl Lectures in the seminar room of the IAS mathematics building.

computer science, mathematics, etc., and establishing those linkages was the hallmark of his tenure as president of Rockefeller University." Levine will start his appointment at the institute in 2002 or early 2003.

Another way in which the institute has changed is that it now has some programs that address education and equity issues. Since 1991 the IAS has sponsored the Park City Mathematics Institute (PCMI), an annual three-week program held at a conference center in Park City, Utah. The PCMI brings together mathematicians, postdocs, graduate students, undergraduates, and mathematics school teachers. While there are activities tailored for the different groups—this year the research part will focus on automorphic forms, and the education part will focus on mathematics knowledge for teachers—a main goal is to get the groups to interact. The IAS Mentoring Program for Women in Mathematics was originally designed to prepare women for participation in the PCMI. But the two-week program developed a life of its own and is now an independent program jointly sponsored by the School of Mathematics and the mathematics department at Princeton University. The School of Natural Sciences is starting a similar program this year, which will target members of minority groups as well as women.

Appointing New Professors

When it comes time to fill a vacant professorship, the School of Mathematics has a big job on its hands. The number one requirement is stellar mathematical achievements, but there are other considerations as well. "You want to avoid too much overlap between the interests of the faculty," Bombieri explains, "but at the same time, you don't want the faculty areas to be so far apart that they become overly isolated." Personality characteristics such as whether the candidate interacts well with other people or tends mostly to work alone can also come into play. Another factor is the current age distribution in the faculty. Deligne remarks that the school has had a tendency to appoint older, established people rather than taking risks on younger mathematicians. "We have been a little bolder recently," he notes. "I think hiring Voevodsky was very good." Vladimir Voevodsky, appointed in February 2002, is thirty-six years old. The school will not make any more permanent appointments until the retirement of Bombieri and Langlands.

As might be expected in a place where high-achieving, strong-minded people are brought together, there are disagreements from time to time about who should join the elite group of IAS professors. In the late 1980s there was a contentious battle over a proposal by the School of Social Science to appoint Bruno Latour, a French sociologist of science whose works have been lambasted by some scientists. The entire IAS faculty is invited to comment on all appointments, and professors in the School of Social Science enthusiastically backed Latour's appointment, while those in the Schools of Mathematics and of Natural Sciences adamantly opposed it. Before a final decision was made about whether to make an offer to Latour, he withdrew his candidacy, in order, he told *Lingua Franca* magazine [Be], to avoid embarrassing his backers at the institute.

Controversy has also surrounded Piet Hut, an astrophysicist who was appointed to the faculty of the School of Natural Sciences in 1985. The initial proposal to appoint Hut met with skepticism among some of the IAS faculty, but his supporters at the institute won out. Dissatisfaction grew as Hut began to write nontraditional papers relating Western science and Eastern philosophy. A 1993 visiting committee evaluating the School of Natural Sciences singled Hut out as a weak point. In an attempt to settle the matter quietly, Griffiths drew up a letter of agreement, which Hut signed, stipulating that Hut would leave the institute by the year 2001. When the time came for him to leave, Hut declared the agreement invalid and said he would remain on the faculty. The institute filed a motion in court to determine whether the agreement he signed was legally binding. News of the motion provoked outrage within the academic community, where the motion was mistakenly seen as a lawsuit and as an attempt to revoke Hut's tenure and restrict his academic freedom. The institute quickly backed out of the legal proceedings, because, Griffiths says, "In the big picture this is a relatively small matter, and we didn't want it to be a distraction for the members and faculty." Hut remains at the IAS, and next year he will become a professor without a school affiliation.

The Hut and Latour appointments were proposed at a time when the procedure for evaluating such proposals was handled completely internally by the IAS. Today the evaluation is made by a

six-person committee consisting of three IAS professors from outside the school where the appointment would be made and three experts from outside the IAS. Since the new procedure was put in place, no public battles have erupted. It is a fact that in mathematics, more so than in other fields, there is greater consensus about who is at the top of the field, and disagreements like the ones over Hut and Latour have never plagued the School of Mathematics. When a mathematician is proposed for a permanent appointment, "the other schools care a lot, and they look carefully at the files," says mathematics faculty member Robert MacPherson, but there has never been widespread disagreement. "There were none that were turned down, and none that were later seen as a mistake by the faculty at large."

The Atmosphere: Serious, Intense

Every afternoon at three o'clock IAS members and faculty gather for tea in the common room of Fuld Hall, the 1939 Georgian-style brick building that is the focal point of the institute campus. The common room has an Old World feel, with oriental rugs and leather sofas. Some remember the good old days, when the serving staff was a bit less brusque and the beverages were served in china rather than paper cups. But the purpose of teatime remains the same: to provide an opportunity for relaxation and informal chit-chat. Because so many mathematicians from so many places pass through the institute during a year, going to tea is a good way to catch up on the latest news and gossip.

The atmosphere at the institute is intense and serious, but not frenetic. In the School of Mathematics there are seminars and lectures every day, but the schedule is not so overloaded as to distract members from their own work (though members participating in a special program tend to be busier than others). Some members might have a specific project they are focusing on, while others come to the IAS to expand their horizons, explains Mark de Cataldo, a member visiting from the State University of New York at Stony Brook. He has been doing the latter, reading papers that he would not ordinarily find the time to read. "The IAS gives you time to think about new things," he remarks. Members can literally do whatever they want, including doing nothing. "But if you come here for a whole year and you get nothing done, you'll feel bad," de Cataldo says. "So there is an internal pressure. It's a pretty large pressure."

Generally the working conditions are excellent. Each member gets his or her own computer-equipped office (though sometimes short-term visitors must share). The computing facilities work fairly well but can be a little chaotic: for example, a "print" command may send one's document to a printer in another building. The school's ample and helpful

Photograph courtesy of Public Affairs Office, IAS.

Simonyi Hall.

secretarial staff runs a tight ship. Some members were surprised to find the lecture hall patrolled by one of the staff, who forbade anyone from taking drinks inside. One member who broke the rule received a reprimand by letter. A short-term visitor who had just arrived and was filling out the necessary forms was treated to a lecture from a staffer about the necessity of following the institute's rules, though he was unaware he had broken any.

The mathematics and physics library, located on the second floor of Fuld Hall, is well stocked for IAS needs. When it comes to mathematics books, the collection is quite good; lack of space, rather than lack of funds, is the main limitation. As for mathematics journals, the holdings are less extensive: the library subscribes to a core set of about 140 journals. Just about anything that is not in the IAS library can be obtained within a day or two from the Princeton University library. And if one needs a single paper not available at the institute, there is an electronic system whereby a request can be sent to Princeton to scan the article and send it as a PDF file. Librarian Momota Ganguli, a cheery and helpful presence at the IAS for the past twenty years, is happy to make such requests and says that they are usually filled within a couple of hours. In another sign that the good old days are gone, the library is no longer open to all around the clock; members are issued passkeys to enter after hours. The passkey system, which is also used for other buildings on the campus, was installed a few years ago after a security guard found a couple of men rolling up rugs and carrying them out of the common room.

For many years the offices of the School of Mathematics were spread across the IAS campus. Some were in Fuld Hall and some were in Building C, the squat brick structure a few steps away. Others were in the ECP Building, which was purposely built for von Neumann's Electronic Computer Project. After von Neumann died, the computer was moved to the Smithsonian Institution, and the ECP Building was converted into offices. A 5-minute walk from Fuld Hall, the ECP Building is much less convenient for

Photograph courtesy of Public Affairs Office, IAS.

Aerial view of the IAS campus.

accessing the library and going to tea. Some liked having offices in the ECP because it was quiet and had central air-conditioning; others felt like second-class citizens. Today the ECP houses a child-care center and a fitness room, and the School of Mathematics has a new building, Simonyi Hall, finished in 1993. The building is named after Charles Simonyi, distinguished engineer at Microsoft and an IAS trustee, who made a major donation to the School of Mathematics.

Comfortable and elegant, Simonyi Hall bears little resemblance to other purpose-built mathematics institute buildings, such as the Mathematical Sciences Research Institute in Berkeley or the Isaac Newton Institute in Cambridge, where the buildings encourage interactions by their very design. Simonyi Hall, by contrast, is more like an office building, with long corridors and no central area for mingling. Even the design and placement of the common room do not invite one to wander in and hang around. Because the library and the afternoon teas were to remain in Fuld Hall, creating spaces for informal contacts at Simonyi was not a priority. In addition, Simonyi Hall was not designed to hold the entire School of Mathematics; about thirty, or around half, of the mathematics offices remain in Fuld Hall.

The institute's several buildings stand in a parklike setting of lawns and trees. Flocks of geese collect around an artificial pond that forms part of the institute's heating and cooling system. There is comfortable on-campus visitor housing and laundry facilities, as well as the much-beloved IAS dining hall. All of this is situated on 800 acres of woods, which are under a permanent preservation agreement and will never be developed. The somewhat sleepy town of Princeton is about half an hour by foot; New York City is an hour by train. Whether the setting strikes one as idyllic or boring may depend on one's mood. As one younger member put it, "If you want to work, it's great. But if you don't feel like working, it's a prison." But probably the prevailing view was expressed by a senior member, who said, "For a mathematician coming here on sabbatical, it's like a country club."

Where the Gods Reside

John Nash comes quietly down the stairs and makes his way over to a stack of lunch trays, his sneakers padding softly across the floor. Edward Witten, tall and stately, carries his tray to the table where the physicists have lunch. Next one might see Andrew Wiles, then more Fields Medalists: Enrico Bombieri, Jean Bourgain, Pierre Deligne. This is the daily scene in the IAS dining hall, one of the main centers of social activity at the institute. The excellence of the food and the reasonable prices mean that a large fraction of the faculty and members eat lunch in the dining hall every day.

At the table where the mathematicians customarily sit, the conversation is casual and lively—and not always about mathematics. Despite the informality, it can be daunting to be plunged into the company of so many mathematical giants. Recalling his own time as an IAS postdoc in the late 1960s, Herb Clemens of the University of Utah says, "Your first goal when you arrive is to avoid embarrassing yourself" in front of all these "gods who are floating around." A legend from the 1950s, promulgated by the late Irving Segal and still in circulation today, maintains that the School of Mathematics professors keep in the basement a list of the top ten mathematicians in the world—and the list is updated *daily*.

The perception of the IAS as an intimidating place is very much in the eye of the beholder and probably afflicts postdocs more than midcareer or senior mathematicians. Finding that some postdocs end up feeling a bit lost and isolated, the School of Mathematics has set up a system whereby each faculty member is assigned about five postdocs to look after. In the old days each member was expected to turn up in Hermann Weyl's office and spend ten minutes describing what he or she was working on. Taking a less pressurizing tack, the school now has established a tradition whereby each member presents such a description in a 15-minute talk that is open to the whole institute. The IAS also sponsors a host of social events, from wine tastings to dancing lessons to excursions in New York City and Philadelphia, all designed to help members get to know one another and become acclimated to the social environment.

That it takes postdocs some time to get settled is one reason some mathematics faculty members support the idea of more multiyear postdocs. Very few postdoctoral visitors are offered more than one year in the School of Mathematics, and a handful are renewed after a year. By contrast, in the

School of Natural Sciences three- and five-year appointments are the norm. But in mathematics for a postdoc not to teach for such a long period puts him or her at a big disadvantage when it comes time to look for a permanent position. A good compromise is reached with the three-year Veblen Research Instructorships, in which a year of research at the institute is sandwiched between two years of teaching at Princeton University. The School of Mathematics now has about five Veblen postdocs in residence each year.

The school annually receives over four hundred applications for about sixty member slots. Usually fifteen to twenty slots are set aside for invitations to participants in the year's special programs, and about half of the slots go to postdocs. Most members come for the full academic year, some for only a term. In coming years the school plans to shift slightly the balance of its memberships away from postdocs and toward midcareer mathematicians. "These are the people who are already reasonably established in their fields, and when they come here, they are not lost; they know what they want to do, and their time can be used efficiently," Spencer explains. "That's sort of the ideal candidate for us."

Decisions about whom to invite as members are made collectively by the School of Mathematics faculty. Each faculty member can appoint one person as an "assistant" without having to get the approval of the full faculty. Nowadays, though, this privilege is rarely exercised. Much more common is to invite collaborators for short-term visits, which might last from a week to a month; members can also extend such invitations after getting the faculty's approval. Decisions about the topics of special programs are also made collectively in the School of Mathematics. "We work as a team," says Bombieri. "We definitely don't say 'It's my turn to do this, I want this, I want that.' There are collective decisions every time." Generally the topics for special programs are decided three or four years in advance.

The standard package for postdocs in the School of Mathematics is $45,000 per year; some younger members who are past the postdoc stage also receive this package. For senior people the compensation picture varies. For example, if a person's presence is important for a special program, then the school will make efforts to see that the compensation is sufficient to attract that person. For a member coming on sabbatical with half-salary from the home institution, the school generally cannot make up the full pay, especially given the rapid growth in salaries for those at the top of the field. The situation for short-term visitors also varies: one person who asks out of the blue to come to the IAS for a month might receive only free housing, while another who is invited for a month to take part in a special program might be paid a stipend and receive travel costs as well. As MacPherson sums it up, "We have flexibility. What we don't have is lots of money." It is this flexibility that allows the IAS to attract a good number of top senior mathematicians every year. As a result, the institute has a quite different atmosphere from other institutes that are populated mostly by postdocs.

Much of this flexibility comes from the institute's $400 million endowment, which covers about $1.5 million paid to members each year; the endowment also pays the salaries of the permanent professors. In addition, there are a few separate endowments, earmarked specifically for School of Mathematics activities. The school has for years received grants from the National Science Foundation (NSF) to support visitors, and these grants carry more restrictions than does the endowment money. For example, there is pressure to use the NSF money predominantly to support U.S. citizens and to move in more applied directions. Right now the school has a $6 million, five-year grant from the NSF. When that grant runs out in 2003, the School of Mathematics will officially become an NSF-funded mathematics institute (see "New NSF Institutes Announced," page 945 in this issue). The school also has a grant from the computer science directorate of the NSF to support activities of Avi Wigderson's group. Altogether, the school runs on a budget of around $6 million per year. As a comparison, the NSF-funded mathematics institutes have budgets in the range of $3 million to $5 million per year.

The Peerless IAS

The influence of the IAS on the development of mathematics, especially in the United States, has been enormous. From its beginnings, the IAS was a magnet for the best mathematicians, giving them ideal working conditions and making a statement, heard clearly by other institutions, about the need to prize and cultivate mathematics research. "Already applications have been received for next year from men who have reached the position of associate professor in the most prominent institutions in the United States," wrote Abraham Flexner in the minutes of a trustee's meeting from 1934 [S, page 187]. "I confess that I myself did not expect that so promptly we should attract scholars who will probably ten years hence be leading figures in the mathematical world."

If the institute today does not have as decisive an influence in the mathematical world as it did in the past, this is probably due to changes in mathematics and the institutions supporting it than to any decline in quality at the School of Mathematics. For one thing, mathematics is simply a much larger field today, and it is far more difficult now than it was, say, forty years ago, for eight faculty members to

exert a large influence in the field. Nowadays there is not just *the* institute, but many institutes, as well as mathematics departments that offer low teaching loads and good conditions for research. "It used to be that if you were a pretty good graduate student and you had a good adviser, you would very likely come to the institute as a postdoc," remarks James Arthur of the University of Toronto, who has visited the institute many times and now sits on the IAS Board of Trustees. The growth in number of mathematicians means that the IAS has lost its position as the way station that everyone destined for a research career would eventually pass through. Nowadays top postdocs sometimes turn down the School of Mathematics in favor of Harvard, Chicago, Berkeley, and the like.

Nevertheless, there remains a sense in which the IAS School of Mathematics is peerless. For one thing, it has been home to some of the great mathematicians of the modern era. Arthur remarks that the "ghosts" of people like André Weil and Harish-Chandra still contribute to the atmosphere. "The traditions here really mean something," he says. "There is a sense in which what went on before inspires people." These traditions are sustained and supported by a well-financed, independent, self-contained operation in charge of its own destiny. Among the permanent faculty of the School of Mathematics one finds a sense of pride and ownership—these are people who take very seriously the development and nourishing of the mathematical life at the IAS. Their attentiveness to this task ensures that the institute will remain an exciting place for mathematics for years to come.

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About the Cover

A Remarkable Fundamental Region

This month's cover was suggested by David Ruelle's article on the zeta functions of dynamical maps. The phrase "a remarkable fundamental region" is from Roy Adler's survey article "Symbolic dynamics and Markov partitions" (*Bull. Amer. Math. Soc.* 1998). What one sees are several different aspects of what is sometimes called the Pythagoras tiling of the plane, generated here by a rather special right triangle. Pythagoras' theorem asserts that the assembly of the squares on the sides of the triangle amounts to a fundamental domain for the group of integer lattice translations.

The really remarkable feature of the diagram is that it has ties to at least three cultures across a span of 2,500 years. (1) The figure at upper left illustrates what might be reasonably considered as the first proof of Pythagoras' Theorem, to be found in the Hindu sulbasutras dating from about 600 B.C. (*The Crest of the Peacock*, G. G. Joseph). This diagram also appears in a manuscript of the Arabic mathematician and philosopher Thabit ibn Qurra, perhaps independently of the Hindu tradition (A. Sayili, 'Thabit ibn Qurra's generalization of the Pythagorean Theorem', *Isis* **51** (1960)). (2) The diagram at upper right exhibits the symmetric dissection proof discovered by the eccentric Englishman Henry Perigal in the early nineteenth century, and in comparison with the first figure it also illustrates the observation of Felix Bernstein that there exists a two-dimensional continuum of dissection proofs (*Dissections: Plane and Fancy*, Greg Frederickson). (3) The particular configuration at hand was chosen to give rise to a Markov partition of Arnold's "cat map", which is mentioned by Ruelle. The construction is explained in Adler's article, as is the construction of the partition into five pieces that actually gives rise to the map's symbolic dynamics, shown at lower right. How to use the partition to find the zeta function of the cat map is explained in the booklet *On Axiom A Diffeomorphisms* by Rufus Bowen. (4) The eigenslope of the cat map is the golden ratio. If you look carefully you will be able to find bits of the Fibonacci sequence in there.

The image of Riemann is from a pen sketch by the French *mathématicienne* Anne-Marie Aubert.

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