# DEPARTMENT OF MATHEMATICS

SELF-STUDY

## Contents



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# 1. Introduction

Mathematics is a vast and vibrant enterprise with theory at its core. Its history goes back to the ancient civilizations of Egypt, Babylon, India and China. For over two thousand years, thanks to the foundations laid by ancient Greece, the subject has been characterized by rigor and infallible reasoning through theorem-proof. This characteristic and its utility in problem-solving have placed mathematics at the core of science and engineering. Theory and applications, concentrating on questions that arise internally and externally, give the subject a dual nature. Mathematicians develop mathematical structures and ideas, and aim to understand relationships between different parts of the mathematical fabric. This quest is guided by a desire for absolute truth, and a notion of beauty that is very real to the trained mathematician. It relies on insight researchers develop through experience, and is often motivated by fundamental examples. Theory developed in this way has consistently found applications in the real world, sometimes decades later. Mathematicians are also motivated by questions that arise in practical applications. Theory motivated by applications will often identify critical properties, or make predictions, which can then guide the experimentalist. String theory is a vivid recent example of the rich interaction that can result. Begun as a branch of theoretical particle physics, it has evolved into an area of interdisciplinary research at the interface of mathematics and physics. A growing number of mathematicians, attracted by the inherent mathematical content and interest of string theory, have devoted themselves to working with physicists on the subject, and many physicists have been working on problems that are fundamentally mathematical.

Mathematics has been a partner of the physical sciences since the development of the calculus in the seventeenth century. Theoretical computer science was initiated by mathematicians around the middle of the twentieth century, and mathematicians led the way in the construction of the first computers. The close relationship with computer science continues today. Advances in computing have spurred a technological revolution in which mathematics plays a critical role. The influence of mathematics extends to other areas of science, and to the social sciences. Mathematics is fast becoming a partner with biology and medicine. This relationship, which has already had a large impact on areas such as medical imaging and genomics, will deepen as biology and medicine flourish in coming years. Probability theory has found application in many areas of science and engineering, and indeed in many aspects of our daily life.

The centrality of mathematics to our lives and its importance for scientific and technological leadership are widely acknowledged. For instance, consider the Mathematical Sciences Initiative of the National Science Foundation (NSF) which aims to double NSF investment in mathematics during the five-year period starting in 2001. Rita Colwell, Director of the NSF and a biologist, explained in a speech on November 10, 2000: "Roger Bacon observed that mathematics is the door and the key to the sciences. For us, seven centuries later, his words ring with even deeper truth. A more recent observation about mathematics comes from O. E. Wilson, the biologist. He writes: 'Mathematics seems to point arrowlike toward the ultimate goal of objective truth.' Given the accelerating cross-pollination of bioscience and mathematics, I think it is not a coincidence that Wilson is a biologist. Indeed, mathematics is the ultimate cross-cutting discipline. It is the springboard for advances across the board. Mathematics is both a powerful tool for insight, and it's a common language for science. I refer to it as the 'Esperanto' of science. Fundamental mathematics engenders concepts and structures that often turn out to be just the right framework for applications in what seem to be unrelated areas . . . Newton's invention of the calculus inaugurated a new role of mathematics, enabling mechanics to flourish and the physical sciences to thrive. And today we are watching mathematics empower new and exciting areas — biology, neuroscience, information technology, and nanotechnology. If we take a quick trip across the disciplines, we find mathematics is a full partner everywhere we alight."

**The Department Today.** The Department of Mathematics at the University of Washington has 58 full time faculty members, over 80 graduate students, and a total of about 400 undergraduate majors in the Mathematics and the joint ACMS (Applied and Computational Mathematical Sciences) degree programs. The department is responsible for about 15,000 student enrollments each academic year, and an additional enrollment of about 1500 during Summer Quarter. (Student enrollment equaled 15,275 during the 2002-03 academic year, resulting in 64,534 student credit hours. There was additional enrollment of 1,479 in Summer Quarter of 2003, for an additional 5,570 student credit hours.) As the mathematics department of the flagship university of the State of Washington and the leading mathematics department in the Pacific Northwest, the department carries a wide range of responsibilities. We are committed to excellence in research in mathematics and its applications, in undergraduate education, in graduate education, and in mathematical outreach. We will summarize in this section the department's recent activities and successes in these areas, and follow it with a summary of our challenges and opportunities.

The department's mission in the area of undergraduate education spans the teaching of precalculus and calculus courses, teaching of intermediate-level mathematics courses required of science and engineering students, and education of undergraduate majors in the mathematical sciences. Starting with the conception and opening of the Mathematics Study Center (MSC) in 1991, the department has overhauled its freshman courses and instruction. Our precalculus course, Math 120, was revised in the mid-1990s. Class size was reduced from over 400 to 160, and curricular change focusing on problem solving was implemented, coupled with a text by David Collingwood. There is now a stronger correlation between success in Math 120 and success in calculus. Departmental calculus reform was initiated in 1998 by an internal report. Two major changes took place the following year. Business precalculus/calculus, Math 111/12, saw class size reduction from over 600 to 160, and curricular changes in the direction of inquiry-based learning via texts developed originally by Steve Monk. A new calculus sequence, Math 144/5/6, was developed in consultation with life science departments. Both the mathematical content and examples used in the sequence are tailored to the needs and interests of students intending to major in life sciences.

The department then formulated a plan for reforming the traditional calculus sequence, Math 124/5/6. We are currently in the third year of a three-year Tools for Transformation grant for implementing the proposed reforms. The changes to Math 124/5 include reduction of lecture class size from 160 to 81, reduction of quiz section size from 40 to 27, extension of one of the two quiz section meetings to 80 minutes, adoption of a new text, the development of additional worksheets and homework problems, improved TA training for implementation of worksheets, and greater communication among instructors through weekly meetings. In addition to Math 124/5, curricular changes were made in Math 126 and its successor Math 324. We are in the process of making minor curricular revisions in other intermediate-level courses. We have put in place course coordinators for all freshman courses and intermediate-level service courses in order to ensure communication among instructors and uniformity of student experience across sections.

The revisions we have made in our undergraduate program have resulted in a higher degree of student satisfaction, an increase in student ratings of our courses, as well as increased demand for our undergraduate courses at all levels and an increase in the number of majors.

The department offers both BA and BS degrees. The BA degree program has several options, including the Teacher Preparation Option and the recently introduced Philosophy Option. The

Teacher Preparation Option, the most popular BA option, is served by three custom designed course sequences: algebra for teachers, geometry for teachers, and a special topics course in teaching. The Mathematics BS degree was revised during 1998-99. Two major changes were the introduction of a course in mathematical reasoning, Math 310, and the introduction of a senior-level sequence in topology and geometry, Math 441/2/3, to complement our 400-level offerings in analysis and algebra. These changes followed the creation of the Applied and Computational Mathematical Sciences (ACMS) BS degree program in collaboration with the Departments of Applied Mathematics, Computer Science and Engineering, and Statistics. This joint program has been very successful, with enrollment approaching the cap of 200 in recent years. The ACMS and Mathematics BS programs comprise various options (or tracks). ACMS absorbed the most popular Mathematics option, the Mathematical Sciences Option, at its inception in 1997. As a result, the number of Mathematics majors declined while the number of ACMS majors grew. This was followed, as our changes to the Mathematics program took effect, by an increase in the number of Mathematics majors that continues at a dramatic pace. At the end Spring Quarter of 2003, prior to graduation, there were 205 active majors in Mathematics and 191 in ACMS. Of these, 65 graduated in June with a degree in Mathematics and 57 graduated with a degree in ACMS. At the beginning of January 2004 the number of active majors in Mathematics and ACMS stood at 230 and 155, respectively. We expect each of these numbers to increase by about 40-60 between now and the end of the academic year. Thus, we have developed ACMS as a joint undergraduate program of the four departments, while returning the Mathematics program to the size before the creation of ACMS. We are currently reviewing senior-level courses in complex analysis, applied analysis and dynamical systems for streamlining that is likely to benefit both our undergraduate majors and Master's students.

The department has a successful honors program. Honors students are offered two accelerated year-long sequences, Math 134/5/6 and Math 334/5/6, in calculus and advanced calculus, and go on to major in all areas of science and engineering. An honors version of Math 124/5/6 has been in operation for five years to cater to the mathematically inclined students who are not in the accelerated track. Math 334/5/6 is regularly taught by Jim Morrow, and a number of the students go on to participate in the summer Research Experiences for Undergraduates program, and to do reading courses with Morrow. Some of these students have been in the news recently, due to their winning three Mathematical Contest in Modeling awards in two years.

Our PhD program has over 70 students. The first year of the program is devoted to *core courses* designed to build the broad and firm mathematical foundation needed to do research in mathematics. There are five core courses, in algebra, real analysis, complex analysis, manifolds and linear analysis, and students are expected to pass preliminary exams in at least three. The department offers an average of at least ten additional graduate courses per quarter. About five are intermediate-level graduate courses devoted to more specialized but mostly standard material, for example in algebraic geometry or partial differential equations. At least five courses each quarter are special topics courses designed to introduce students to research. In the second year, and sometimes for part of the third year, students take intermediate-level courses, special topics courses and individualized reading courses as they choose a research area and advisor, and make the transition into research. The third stage, mostly devoted to research, typically starts at some point of the third year or early in the fourth year, and takes two to three years.

Recruitment and retention of excellent graduate students is critical not only to our graduate program but also to undergraduate instruction and research; the department has always placed emphasis on graduate student recruitment and retention. When the number of applications to our graduate program and graduate student morale hit low points during the 1997-98 academic year, partly as a result of the economic boom, the department resolved to redouble its efforts in graduate student recruitment and student welfare. Moving students through critical transitions into graduate school, through the first year and prelims, and into research has long been a challenge for mathematics departments. Our department made progress in the early 1990s by adding two core subjects to the traditional three, and by allowing the substitution of excellent performance in the corresponding course for one of the three preliminary exam passes. As students indicated the need for more help with the first-year workload and the transition to research, faculty and graduate students worked together on implementing a variety of ideas: Assignment of preliminary advisors to students upon entry into the program, reinforced through the requirement of a Quarterly Plan, a *Handbook for Instructors and Advisors of First-Year Graduate Students*, individual meetings between the Graduate Program Coordinator and every first, second and third year student, Academic Excellence Awards given to students with outstanding performances in core courses and prelims, the Current Problems Seminar designed to introduce students to faculty research interests, and various events to encourage early interaction between faculty and graduate students. Student morale quickly improved.

We revised our Master's program in response to applications from students who, after several years in teaching or software, wish to attend graduate school in mathematics. The program gives students the opportunity to get back into mathematics by replacing one or two core graduate courses by the corresponding senior-level courses. Beginning in 1998, we have admitted about five Master's students per year, about two of whom transfer to the PhD program with little loss of time due to having started in the Master's track.

Faculty interest in the graduate program, which has always been high, was encouraged further by a small increase in the teaching credit given for graduate (and senior-level) courses, as well as by the introduction of teaching credit for successful PhD advising.

We made a number of changes to bolster recruitment. The biggest hurdle was presented by low TA salaries. Currently, the eleven-month salary of a starting TA at the University of Washington is $14,135, compared to salaries of $18,000 or higher at many peer institutions. Starting in 1998, we sought additional funding. We developed a support plan that offers to the majority of the top applicants an eleven-month salary of at least $18,000 for the first year and $17,000 for each of the following four years, subject to making satisfactory progress toward the PhD. We started to invite many of the top US applicants to visit the department, allowing the department and current graduate students to make our case. The results have been striking. Both the size of the applicant pool and the quality of applications went up. More significantly, there has been a dramatic change in our ability to recruit from the top of the applicant pool.

We are happy to report that the graduate program is now thriving, with an excellent group of students, good morale among students, and a very high level of faculty interest in the program.

The support plan is enabled by a patchwork of stipends and fellowships culled from the Graduate School, the ARCS Foundation, Microsoft Research, the VIGRE grant (which will be described below), other NSF grants, and departmental resources. We are grateful for this support, much of which became available during the past five years in response to our efforts to revitalize our graduate program. We remark, however, that little of this funding is permanent, and that much of it is made available to us on a year-to-year basis.

The department continues to maintain its status as a leading research department. The natural peer group for the department is AMS Group I (Public) of the top 25 mathematics departments at public universities[1] The 1995 National Research Council (NRC) rankings place the department in the middle of this peer group, 13th out of 25. The department has maintained its prestige despite a significant lag in salaries by offering competitive salaries to new faculty. Our strategy has been to attract the best junior faculty, and to retain them despite the presence of higher salaries at other leading research departments. The strategy has worked well, thanks to the stimulating and supportive mathematical environment of the department and the attractiveness of the Puget Sound region.

The department has also made it a priority to form research groups of typically three or more faculty members. It has helped faculty recruitment, and retention, that we often make new junior appointments into existing research groups, providing the faculty member with a natural group of colleagues to interact with from the moment of arrival. This strategy has not been seen to be an impediment to developing a diverse research faculty, since the department is large enough to represent many of the presently active research areas. In addition, we have been willing to venture into new areas. In the 1980s, following recommendations of the 1981 decennial review, research groups in numerical analysis and partial differential equations were initiated. More recent examples are the appointments of Sándor Kovács in algebraic geometry and Chuck Doran in string theory.

During the last fifteen years, string theory has developed into an exciting research area at the interface of mathematics and physics. Physicists have been drawn to problems that are fundamentally mathematical. Conversely, mathematicians have been motivated by mathematical questions that arise in string theory. Sensing a unique opportunity, the Departments of Mathematics and Physics have been forming an interdisciplinary research group in string theory. Three appointments were made in Physics during the past three years. Doran is the first of two appointments Mathematics plans to make in the area. The department has about a dozen faculty members whose work is related to or uses algebraic geometry, and has long been eager to hire an algebraic geometer. Sándor Kovács was appointed in 2000, and has created a lot of excitement for the area, particularly among graduate students. Due to the role algebraic geometry has come to play in string theory, its growing interaction with number theory, and other factors, the department is interested in additional hires in this area.

The department's current research appointment priority areas are string theory, probability, and number theory / algebraic geometry.

For the purposes of this review, we have divided research interests of faculty into 13 areas. The department's work in each area is discussed in some detail in section 5. The division is somewhat arbitrary, but it gives a reasonable approximation of the range of research that takes place in the department.

Department faculty have been recognized in numerous ways for their research. We highlight some of the notable honors received since our 1991 self-study: Sloan fellowships awarded to Ethan Devinatz, Hart Smith, Tatiana Toro, James Zhang, Sándor Kovács and Yu Yuan, AMS Centennial Fellowships awarded to Steve Mitchell, Chris Burdzy, and Sándor Kovács, the Guggenheim

[1]The American Mathematical Society separates departments of mathematical sciences into groups based on the highest degree granted and the score on the 1995 NRC ranking of departments. Group I is composed of 48 U.S. mathematics departments of scores between 3.00 and 5.00. Group I (Public) and Group I (Private) are Group I departments at public institutions and private institutions, respectively. Group II is composed of 58 U.S. mathematics departments with scores between 2.00 and 2.99; Group III consists of the remaining doctoral granting, mathematics departments. Other groups include departments (or programs) in statistics, biostatistics, biometrics, applied mathematics, operations research, and management science, as well as U.S. departments granting a master's or baccalaureate degree as the highest degree. (See `http://www.ams.org/employment/groups_des.html` for more information.)

Fellowship received by Gunther Uhlmann in 2001, invited lectures at the quadrennial International Congress of Mathematicians delivered by Hart Smith and Gunther Uhlmann in 1998, the Allendoerfer Prize awarded to Victor Klee in 1999 by the Mathematical Association of America (MAA), the 1997 Lanchester Prize and the 1999 John von Neumann Theory Prize awarded to Terry Rockafellar by the Institute for Operations Research and Management (INFORMS), the election of Victor Klee as Fellow of the American Academy of Arts and Sciences in 1997, and the election of Chris Burdzy as Fellow of the Institute of Mathematical Statistics in 1999.

The VIGRE program, the Pacific Institute for the Mathematical Sciences, and the Theory Group at Microsoft Research, all of which came into being during the last five years or so, have given the department a big boost. The three UW mathematical science departments were among the first group that received funding from the VIGRE (Vertical Integration Grants in Research and Education) program of the NSF in 1999. The VIGRE grant provides support for postdoctoral fellows, graduate fellows, undergraduate projects, and student travel. It aims to vertically integrate faculty, postdocs and students, and also horizontally across the three departments. We are currently in the final year of the five-year funding period.

The Pacific Institute for the Mathematical Sciences (PIMS) is a distributed institute based at the University of British Columbia. It has gone in seven years from an idea to a major national and a growing international force. PIMS has operations at UBC, University of Victoria, Simon Fraser University and four other Western Canadian universities. Members of our department have long had ties with colleagues at these institutions. UW joined PIMS in 2000 and, since then, we have participated in PIMS Collaborative Research Groups, broadened the Pacific Northwest seminars, and participated in PIMS workshops, as well as in workshops at Banff International Research Station (BIRS). BIRS opened in 2003 and will host 40 weekly workshops in the mathematical sciences each year. The Departments of Applied Mathematics, Mathematics and Statistics submitted a proposal to the NSF in the summer of 2003 for a new five-year VIGRE grant to consolidate and expand the work done under our current VIGRE grant, and to take full advantage of the opportunities presented by PIMS.

The Theory Group at Microsoft Research has presented our faculty and graduate students with the opportunity to work with not only the permanent members and postdoctoral fellows in the group but also with the numerous researchers brought here under their vigorous visitor program.

The department collaborates with many other units and organizations, both on and off campus. In particular, the department is engaged in outreach projects such as the GK-12 project, Extending the Community of Mathematics Learners, Northwest Mathematics Interaction, Mathday, and the Community College Educator's Sabbatical Program. Section 6 describes our interdisciplinary research and outreach activities in greater detail.

The department has eight staff in 7.125 staff positions. (Three staff members are part-time.) Four members of staff are assigned to the department's student services office. Led by our Director of Student Services Brooke Miller, this office provides support for our degree programs and handles advising of Mathematics and ACMS undergraduates. The main department office provides all other support for the activities of the department. It is led by our Administrator Mary Sheetz. Both offices function well under their very able leadership.

The Mathematical Sciences Computing Center (MSCC) provides computing support to the department, as well as the departments of Applied Mathematics and Statistics. MSCC has six professional staff members occupying 5.6 positions, and a 0.2 fiscal specialist position. It is led by its Director, Michael O'Connell, and reports to the three departments.

**Challenges and Opportunities.** Communication with other researchers, conference participation, and collaboration with colleagues at other institutions are essential components of mathematics research. Postdoctoral appointments bring "new blood" to the department to collaborate with faculty and graduate students over a period of two or three years. VIGRE, PIMS and Microsoft Research present new opportunities in these directions, as do our development efforts.

A high-quality Mathematics Research Library and computing support are critical for the department to carry out its research and educational missions. We work with University Libraries to ensure the purchase and maintenance of the necessary mathematics journals and books, and convenient access to them, as well as to electronic media. It is also our goal to ensure that high-quality computing equipment and software, as well as support by responsive computing staff, are available to enable the work of all department faculty, graduate students, and staff.

During the 2002-03 academic year, the average salary of a faculty member in our department was about 30% behind our peer departments.[2] A unit adjustment of 8.2% was awarded to the department effective August 1, 2003, in addition to the 2% raise provided to all departments. This is a substantial increase, and a very encouraging acknowledgment of the work the department has been doing in research and education. Departmental salaries remain 19.5% behind our peers, however. We realize that this is a university-wide problem, though more severe in the case of our department than most other units. We hope that, whether or not the legislature includes salary increases in future budgets, the University will continue to make substantial progress on salaries through resource re-allocations and other means. The following table compares 2003-04 averages by rank. (These computations do not include Ron Irving, who is currently Divisional Dean of Natural Sciences.)

| Rank | Number in rank | UW Mathematics 2003-04 average | Group I (Public) 2003-04 average | Lag |
|---|---|---|---|---|
| Assistant Prof | 3 | 56,712 | 58,688 | 3.5 % |
| Associate Prof | 12 | 60,759 | 66,992 | 10.3 % |
| Professor | 35 | 82,106 | 100,815 | 22.8 % |
| All | 50 | 75,459 | 90,170 | 19.5 % |

Despite salary problems, department morale in general has been high. We owe this partly to the collegial and democratic ways of the department. There are established procedures for departmental governance. The department's usual work is carried out by, or in consultation with, appropriate committees. The department has developed a teaching credit system, which we will describe in section 3, for equitable distribution of teaching duties. We have also established a system for allocation of compression components of merit raises. We have a tradition of working collectively on major issues that impact the department, which has enabled us to successfully tackle difficult problems. A significant contributor to morale has been the pride and satisfaction the department has derived from the reforms and successes of recent years. We are delighted by having been able to bring to the department new faculty of the highest caliber, and also by the dramatic improvements

[2]The University relies on the comparison established by the Washington Higher Education Coordinating (HEC) Board, which targets the 75th percentile of the salaries of that comparison group. See http://www.washington.edu/reports/account/appendixi.html for details of the HEC Board comparison. Salary data for this group is not readily available. However, the University gathered this data in 2002-03 to determine unit adjustments and computed a lag of 29.9% for our department. Using AMS data on average Group I (Public) salaries for 2002-03 we compute a lag of 27.0%.

in our graduate program and graduate student recruitment. Our undergraduate degree programs are expanding, following significant revision. Calculus reform has been a central activity that has resulted in greater student satisfaction and success. We now have the opportunity to solidify our successes, and to continue to innovate. As we will explain below, some of our achievements and their consequences are being sustained by temporary resources.

The support plan we have implemented is essential to the success of our graduate program. As we indicated, little of the funding that enables it is permanent, and much of it is made available to us on a year-to-year basis. We would like to increase the endowment income available for this purpose, thereby lessening the burden on other departmental budgets. This is one of the principal goals of our development efforts, which have gained momentum in the last two years.

The department's successes in undergraduate education have led to an increase in the number of majors, and a surge in demand for our courses. For example, when Math 310 was introduced the plan was to teach two sections during the academic year. We have increased the number to six sections, and could probably fill several more sections. Senior-level courses are also full, and we have added or plan to add sections of fundamental 400-level courses like Math 424/5. We have been using (and re-allocating) departmental resources in dealing with problems that affect our majors, not only due to the value we attach to our degree programs, but also because the number of students involved is small enough for us to make an impact. We are pleased that the College has provided resources this year to meet additional demand in our 300-level service courses. The numbers involved in our freshman courses are much larger, however, and here there has been a significant increase due to the success of our calculus reform.

Consider demand for Math 125. Since the implementation of reform in 2001-02, we have had to deny registration to significant numbers of students, and have frequently scrambled at the last minute to find instructors and TAs for extra sections. The situation was most striking during registration for Winter Quarter of 2004. We offered seven sections, for the usual total of 560 spaces for the quarter, and found that 340 students were being denied registration. (With financial help from the Office of Undergraduate Education, we were able to make last minute arrangements that allowed 160 additional students to take the course.) We did not teach any extra sections of Math 124 in Autumn of 2003. Where did the students come from?

We teach a total of around 1700 students in Math 124 each year. Success rate of students has increased from 81% to 87% with our reforms, so over 100 additional students are qualified to take Math 125. Further, student satisfaction has gone up, so that a larger percentage of the 1566 students qualified to take Math 125 desire to do so. Thus, a large portion of the extra demand we see is *permanent new demand* resulting from the revision of our courses. A similar argument applies to Math 126, and any increase in enrollments in Math 125 would further add to Math 126 demand. Calculus is required by virtually every science and engineering department. Every student enabled to continue in the sequence is a potential science, engineering or mathematics major. This is an opportunity created by our reforms, and we ought to take advantage of it by increasing the number of sections we offer. However, having just increased departmental teaching by about 10% as part of the department's contribution to calculus reform, we cannot add to our teaching without adding to faculty.

The Mathematics Study Center is a critical and successful component of our instruction at the freshman level. Although the original plan was to include 300-level service courses among those supported by the MSC, we now find that the MSC operates at close to full capacity, and cannot accommodate any 300-level courses without a significant increase in space. In fact, space in the MSC

is so tight that support for business precalculus/calculus, Math 111/12, is offered in an adjacent room and has to be limited to four hours in the afternoon. It would be very helpful to integrate this room with the rest of the MSC and offer Math 111/12 students support that is comparable to that offered for other freshman courses. (For a detailed explanation, see section 6 of the calculus report at the web address
`http://www.math.washington.edu/~m124/Reports/report_summer03_finalversion.html` )

The strongest students among our majors are highly involved in the department due to a variety of activities, some of which we have already mentioned. We would like to integrate a larger segment of our growing population of majors into the department. As a step in this direction, the increase in the number of undergraduate research projects has brought a wider group of undergraduates into regular contact with faculty outside courses. There have been events organized for undergraduates by individual faculty members, such as the screening in the Faculty Club of the PBS program on Andrew Wiles and his proof of Fermat's Last Theorem. The department plans to organize at least two undergraduate events at the Faculty Club this year. The most effective way of integrating majors would be to provide them with an undergraduate lounge, or other space that is largely for their use. Current constraints on space do not allow this, however.

As we have summarized in this section, and will detail in the following sections, the department is in a strong position. We have made significant progress on a number of fronts. We have benefited from our collaborations with other academic and administrative units. We are eager to continue our collaborations, build on our successes, and to make full use of the opportunities we see as we continue to aim for excellence.

## 2. Degree Programs

The Department offers academic degrees at the doctoral, master's, and bachelor's levels. Over the past decade, but particularly within the past five years, we have implemented substantial improvements in all three programs. In addition, in 1997 our department joined with the departments of Applied Mathematics, Computer Science and Engineering, and Statistics to form an interdepartmental Bachelor of Science degree program in Applied and Computational Mathematical Sciences (ACMS). In 1999, the three UW mathematical science departments were among the first group to be awarded a VIGRE grant by the NSF. The VIGRE grant has had an impact on the degree programs of our department, and has helped to integrate faculty and students at all levels.

We begin with some comparative data and remarks about our programs. We then discuss our doctoral, master's and bachelor's degree programs. We conclude the section with a discussion of the VIGRE program.

**Program Size Comparison with Peers.** The group of mathematics departments most similar to ours is the group of 25 leading mathematics departments at public universities (*Group I Public*). The 1995 NRC rankings place our department in the middle of this group, 13th out of 25. The following table, based on data in the American Mathematical Society (AMS) publication *Assistantships and Graduate Fellowships in the Mathematical Sciences, 2003*, gives a comparison between our department and our peer group.

| | Faculty | Tenured Faculty | Graduate students | New grad students | PhDs awarded (2000-2003) | Master's (2002-03) | Bachelor's (2002-03) |
|---|---|---|---|---|---|---|---|
| Mean of peers | 53 | 47 | 119 | 29 | 24 | 16 | 86 |
| Median of peers | 54 | 49 | 117 | 27 | 23 | 13 | 67 |
| UW | 51 | 48 | 83 | 20 | 17 | 26 | 121 |

The figure 121 for Bachelor's degrees includes the 64 Bachelor's degrees in Mathematics and 57 Bachelor's degrees in ACMS awarded between July, 2002 and June, 2003.

A number of comments are in order.

(1) Our current enrollment of 73 doctoral and 10 Master's students is relatively small. We have chosen to provide financial support to all of our PhD students and most of our Master's students. The level of support available thus determines the size of the program, and recent TA cuts have caused a small reduction in size to 83. We calculate that the minimal number necessary to maintain a vital graduate program is 80. In an ideal world, we would increase our graduate enrollment to around 100 students.

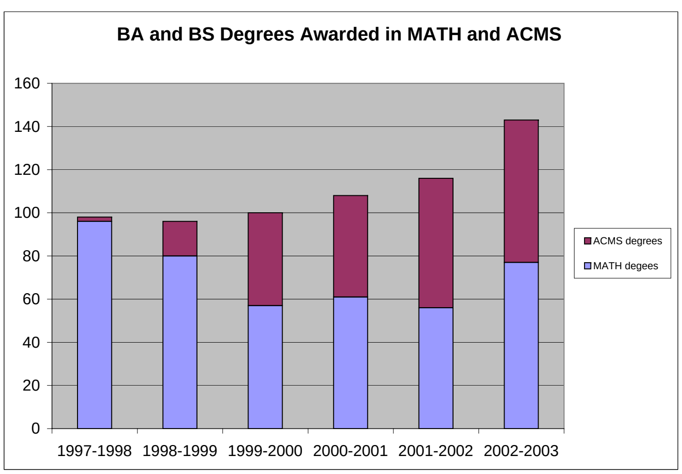
(2) Between 2000 and 2003, seventeen PhD students completed our program, an annual average of about 6. The completion rate is obtained by normalizing by the size of our program: $(17/3)/83 \approx 0.068$. The average completion rate for our peer group is $(23/3)/117 \approx 0.066$. Department faculty also serve as advisers of PhD students in other departments, particularly in Applied Mathematics. The following table presents a more complete picture of the enrollment in our graduate program since 1990. Here, the second row gives the number of PhDs awarded during each year, and the third row gives the number of graduate students.

| 90-91 | 91-92 | 92-93 | 93-94 | 94-95 | 95-96 | 96-97 | 97-98 | 98-99 | 99-00 | 00-01 | 01-02 | 02-03 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 8 | 5 | 11 | 3 | 5 | 6 | 9 | 9 | 9 | 3 | 5 | 8 | 4 |
| 95 | 110 | 109 | 95 | 87 | 86 | 79 | 78 | 74 | 71 | 84 | 89 | 83 |

These figures reflect both national trends and local factors. Nationally, enrollment in mathematics departments peaked in 1992, fell during the mid-90's partly due to the attraction of high-tech industries, and has seen a modest increase in recent years. The peak during 91-92 and 92-93 reflects the three-year GAANN (Graduate Assistance in Areas of National Need) grant we received from the US Department of Education, providing fellowship support for 18 graduate students. The loss of this support together with the dot-com boom, which had a particularly strong impact on the Puget Sound region, resulted in a gradual decrease. The increases in 00-01 and 01-02 are due to fellowships supported by the VIGRE grant, as well as additional TA positions for calculus reform and enrollment increases.

Although the size of our graduate program will see at best a modest increase during the next several years, we expect that the number of students completing our doctoral program will increase. This, as we will explain in Section 4, is a consequence of a dramatic improvement in our ability to recruit excellent students, as well as increased attention to mentoring our students.

(3) The numbers of both Master's degrees and Bachelor's degrees is significantly higher than the median of our peers. As we explain more fully below, this is due to substantial changes that we have made to these two degree programs. As the figure below illustrates, the number of undergraduate degrees awarded[3] has increased substantially in recent years. The decrease in the number of Mathematics degrees between 1997 and 2000 occurred as we phased out the Mathematical Sciences option of the Mathematics degree in favor of the ACMS degree. After this transition, the number of Mathematics degrees has recovered, and the number of declared majors continues to increase. At the beginning of January 2004, there were 230 active majors in Mathematics, and 153 in ACMS. (Each number will go up by 40-60 as the academic year progresses.)




[3]Number of Bachelor's degrees awarded between September and August of each academic year, which differs from the period July, 2002– June, 2003 used in the table.

**Doctoral Program.** Having a sizable doctoral program with excellent graduate students is critical for the Department. It enables us to offer the variety of seminars and advanced graduate courses that are needed to remain abreast of current research in mathematics, it helps to attract and retain top research mathematicians as faculty, and it is essential for meeting the teaching obligations of the Department. Graduate students most often serve as TAs in quiz sections of lower-level undergraduate courses, but they perform other duties as well. For example, some advanced graduates teach intermediate-level undergraduate courses or assist instructors of core graduate courses. Experience gained in a variety of duties is an important part of their professional development.

The contributions of Mathematics graduate students and faculty to teaching are critical to the mission of the University of Washington. Virtually every student at the University takes at least one mathematics course, and science and engineering students typically take several. Graduate students help the Department meet its teaching obligations. The Department also offers graduate courses, such as courses in optimization, numerical analysis, inverse problems, probability and combinatorics, that are of interest to other departments. An increasing number of graduate students and faculty have been working with undergraduates on research projects. (Last year 21 students in Applied Mathematics, Mathematics, and Statistics participated in projects sponsored by our VIGRE program.)

Our graduate program is also a source of mathematicians for the region. Graduates of our program are employed at many of the region's high-technology industries, four-year colleges, and community colleges. Graduate students and faculty have formed and participate in a number of successful outreach activities, such as *Math Day*, the *Northwest Mathematics Interaction (NWMI)*, and the *Summer Institute for Mathematics (SIMUW)*, that benefit both the University and the region. Links to these and other outreach activities can be found at the Department's website.

*Overview of Doctoral Program.* Doctoral students progress through our program in three stages. The ideal student will master the material in several "core" mathematics courses during the first year, passing the preliminary exams before the start of the second year. During the second year, the student will take topics courses, one or two reading courses, and attend seminars, and by the third year the student will have chosen an advisor. What happens next depends on the particular area within mathematics. In some areas, the student may be able to read research papers and begin working on a dissertation topic; while in other areas, such as number theory or algebraic geometry, an additional year of preparation may be necessary before even the strongest student can read research papers. It typically takes between two and three years to write a PhD dissertation. Students, therefore, can complete our program in five years. In rare instances, students with advanced preparation on entry to our program have completed our program in four years, but in practice, our students complete our program in an average of about 5.5 years, and some students who write excellent dissertations require seven years.

*First year.* The goal of the first year of our program is to ensure that students build the broad and firm mathematical foundation needed to do research in mathematics. The program is built around a set of five *core* courses, each of which has a heavy homework component. Students are expected to complete three core courses during their first year.

We have established an advising and mentoring program for all of our graduate students. Every entering student is assigned a preliminary advisor. To prepare faculty for mentoring beginning graduate students, faculty and graduate students have written a *Handbook for Instructors and Advisors of First-Year Graduate Students.* The handbook is given to all preliminary advisors and instructors of all courses taken by first year graduate students. Prior to the start of each quarter, the preliminary advisor meets with each advisee to plan the student's academic program. The student then submits a form, signed by the advisor, that details the student's academic schedule for the quarter. After completing preliminary exams, the student selects a doctoral advisor, who replaces the preliminary advisor. Master's students who do not transfer to the PhD program are encouraged to choose a Master's advisor at the end of the first year.

Three of the core courses are standard graduate courses in algebra (Math 504/5/6), real analysis (Math 524/5/6), and complex analysis (Math 534/5/6). In 1992 we added *Topology and Geometry of Manifolds* (Math 544/5/6) to the core. It includes a quarter-long introduction to topology, the fundamental group, covering spaces, and the classification of manifolds, followed by two quarters of differential geometry. It uses books written by Jack Lee. The fifth core course, *Linear Analysis* (Math 554/5/6), was introduced in 1994. It was developed primarily by faculty in the areas of partial differential equations, differential geometry, optimization, and numerical analysis. It focuses on advanced linear algebra, applied functional analysis, distribution theory, and related topics and applications.

*Preliminary Examinations.* Our system of qualifying examinations for the PhD, which we call "prelims", parallels our core courses. Prelims are designed so that an ambitious student can complete them by the beginning of the second year of study. By completing prelims early in their graduate career, students have more time during their second and third years to explore areas of specialization and make a smooth transition from course work to research.

Prelims are given in September of each year. Each prelim is based on one of the five core courses, and we offer an additional summer preparatory course for each prelim. Students are required to pass three prelims; a grade of 3.8 or above in all three quarters of a core course can be used in lieu of one exam pass.

Although it is not uncommon for students to pass all three prelims after one year, students making normal progress are expected to pass at least two by the end of the first year and to have completed all three exams by the end of their second year. About a third of our students complete prelims by the end of their first year. The last three entering PhD classes (of academic years 2001-02, 2002-03 and 2003-04) have been very strong, largely due to the support plan we have instituted. The table below, showing the percent of entering PhD classes that completed prelims, is one indication of this.

| Entry Year: | 1996-97 | 1997-98 | 1998-99 | 1999-00 | 2000-01 | 2001-02 | 2002-03 |
|---|---|---|---|---|---|---|---|
| Completed by end of 1st year: | 19% | 29% | 33% | 40% | 24% | 30% | 50% |
| Completed by end of 2nd year: | 38% | 36% | 61% | 47% | 42% | 55% | — |

Passing prelims remains the main focus of the majority of our entering students, sometimes discouraging students from focusing on research as early as they should. Facilitating the transition from course work to research has been a point of focus for a number of years. While we have made significant progress in this direction, it is still an important item on this year's agenda of the Graduate Program Committee.

*Second year.* The transition from coursework to research is particularly difficult for graduate students in mathematics for, unlike students in the sciences, beginning graduate students in mathematics usually spend their first year mastering standard material. We have designed our program to facilitate the transition.

A total of about 15 graduate courses are taught each quarter. In addition to the five core courses, we offer approximately five year-long courses each year in areas such as algebraic topology, geometric structures, numerical analysis, optimization, partial differential equations and probability theory. Some of these, for example algebraic geometry and geometric structures, are offered every second year. We also teach courses under *Special Topics in Mathematics* (Math 581/2/3) targeting second and third year students who have not yet started research. Each year faculty submit proposals for topics courses of one to three quarters in length. From these, the Graduate Program Committee chooses a slate of approximately five courses to be taught each quarter, selected partly on the basis of student interest.

The *Current Topics in Mathematics Seminar* (Math 580), which graduate students initiated in 2000 and now run, is especially appropriate for first and second year students. In Math 580, faculty members give expository lectures about their specialty and research, providing students, especially those in the first two years of graduate work, a broad overview of research taking place in the department. Usually, a faculty member gives an informal overview of his or her area, together with an idea of the faculty member's research contributions. A few seminars are devoted to practical topics, such as the use of mathematical software or "how to choose a PhD advisor".

We strongly encourage each second year student to take at least one special topics course each quarter, to attend the Current Topics Seminar, and to take one or two reading courses.

*Third year and beyond.* The majority of our students start to do research in the third year or the beginning of the fourth year, after a period of specialized reading and study. We hope that PhD students will have chosen a PhD advisor by Autumn Quarter of their third year, and we require that students have a PhD advisor by the end of Winter Quarter of the third year.

From the beginning of the third year we encourage each student to attend, in addition to the departmental colloquium, at least one of the weekly research seminars. Weekly seminars are available in many of the research areas represented in the department:

- Algebra Seminar
- Combinatorics and Geometry Seminar
- Complex Analysis Seminar
- Current Problems Seminar
- Differential Geometry/PDE Seminar
- Topology Seminar
- Algebraic Geometry Seminar
- Inverse Problems Seminar
- Optimization Seminar
- Probability Seminar
- Rainwater Seminar (Dynamics and Analysis)
- Joint Math-Physics String Theory Seminar

In addition, students sometimes attend seminars and colloquia sponsored by the Departments of Applied Mathematics and Statistics.

Post-prelim students are also encouraged to attend conferences. The Department participates in a number of regional conferences and workshops that meet annually or biannually, for example, the Northwest Probability Seminar, the Pacific Northwest Algebraic Geometry Seminar, the Pacific Northwest Geometry Seminar, and the Pacific Northwest Numerical Analysis Seminar. Graduate student travel support is available from grants and departmental budgets.

Our department is the only U.S. mathematics department with formal ties to the Pacific Institute for the Mathematical Sciences, which gives our graduate students and faculty ample opportunity to participate in PIMS-sponsored activities, including workshops at the Banff International Research Station and industrial workshops sponsored by MITACS (Mathematics of Information Technology and Complex Systems).

As graduate students progress in our program, they become integrated into the mathematical community through seminars, conferences, and a range of other activities, such as brown-bag lunches on educational topics, dinners that bring together graduate students and faculty in groups of ten, lunches with colloquium speakers, and Women In Math luncheons.

*Recent graduates.* Almost all of our students completing the PhD have found either academic positions or jobs in industry. Exit surveys recently performed by the University (see appendix) indicate a good level of satisfaction with the programs among graduates of both our Master's and PhD programs.

**Master's Program.** Although the Department has offered a Master's degree for decades, we did not actively recruit students into our Master's programs prior to the mid 1990's, and the majority of Master's degrees were obtained by students who were originally recruited into our doctoral program. More recently, however, after studying the composition of our applicant pool, we strengthened our Master's program, and we now actively recruit students to our Master's program.

Every year, the Department receives applications from promising students who took a job (typically in teaching or in the software industry) immediately after receiving a degree in mathematics and who, after several years, want to obtain a graduate degree. A few want to get a Master's degree and plan to return to teaching or to a job in industry. The majority, however, are interested in our PhD program, although they are often not sure if they are ready to enter our PhD program: they might not have studied some of the material that we expect our doctoral students to have mastered, or more likely, they have taken the required courses but have not used the material for some time. If admitted to the PhD program, their chances of success would be low, since the first year of our PhD program is a challenge even for the most well-prepared students.

We revised our Master's program to meet the needs of these students. For students whose ultimate goal is a PhD, we alleviate the pressure of the first year by allowing them to take a combination of senior-level courses and core graduate courses. If all goes well, they apply for transfer into our doctoral program in spring quarter of either their first or their second year, and work towards a PhD with little loss of time.

We offer Master of Arts and Master of Science degrees, both of which generally require two years to complete. The Master of Science degree program includes a number of options. Of these, the MS non-thesis program has the most demanding course requirements and most closely matches the early stages of the PhD program. Most students who enroll in the department begin their studies with the PhD or MS non-thesis program in mind. The more specialized MS options in numerical analysis or optimization provide more focused training, and are designed for students seeking employment in industry.

**Future plans.** This year we continued our tradition of dinners that bring faculty and graduate students together in groups of ten to discuss our graduate program in an informal setting. These dinners have been helpful to graduate students. They have also been a source of ideas that help to improve our program; for instance, the idea of a Current Problems Seminar first arose at such a dinner. We will continue to organize one or two dinners each quarter.

We are conducting reviews of our "core" upper level undergraduate courses in algebra, complex variables, real analysis, topology and geometry, and linear analysis. These are foundational courses for our Master's program, as well as for our majors.

We currently offer only one quarter of complex variables (Math 427). One quarter is not sufficient to cover all of the material one would wish to include, so instructors often leave out important material. We have formed an *ad hoc* committee to investigate possibly expanding Math 427 so that it dovetails with our dynamics course (Math 435/6) via complex dynamics. This would also entail revisions to Math 428/9, our advanced undergraduate course on Fourier series and boundary value problems.

The sequence in real analysis (Math 424/5/6) is particularly important, as it is also required of beginning graduate students in the Statistics and the Biostatistics programs. Another *ad hoc* committee will meet during Winter Quarter of 2004 to review the course content. The committee will pay particular attention to the treatment of measure and integration in Math 426 to ensure that it meets the needs of students in the Departments of Mathematics, Statistics, and Biostatistics.

Some faculty and students think that there is too much emphasis on analysis in the prelims. Students going into algebra or areas that requires a lot of specialized study before research, such as number theory and algebraic geometry, or students who enter with advanced training in mathematics and want to specialize quickly, are not able to do so for at least a year. We plan to look for ways of adding flexibility to our prelim system that would address this problem, while continuing to make sure that each student has a broad mathematical education.

Prelims loom large in the minds of many of our first and second year students, often detracting from their educational experience during the crucial first and second year of graduate school. We will continue systematic advising and mentoring of first through third year students to help them make the transition to research.

**Undergraduate Program.** The department offers both Bachelor of Arts and Bachelor of Science degrees. These two degrees attract different groups of students. Over the past ten years we have made revisions in both tracks and we have implemented an interdisciplinary undergraduate degree program, the Applied and Computational Mathematical Sciences (ACMS) degree. As highlighted in our introductory remarks, while the introduction of the ACMS program initially led to a decrease in the number of Mathematics majors, those losses have been regained and we are currently in a period of increasing numbers of Mathematics majors. The end result is a healthy undergraduate degree program with numerous course offerings and a dedicated seminar series (the ACMS seminar) aimed at undergraduates.

*Bachelor of arts degree program.* This degree program provides a solid foundation and broad perspective in mathematics for students planning a variety of careers or graduate study in various fields. Currently, there are three options available to students: Teacher Preparation Option, Standard Option and Philosophy Option. The Standard Option is seldom used and lacks focus. With this in mind, the department recently added the Philosophy Option, combining a broad mix of mathematics and philosophy courses. We hope that this track will attract a number of students heading toward advanced degree programs in law, business or medicine. It is too soon to tell if this will be a success, but it could be the model for other BA options combining mathematics with a study of art or music, for example. This tack is our current effort toward providing focus to the seldom used BA Standard Option.

The Teacher Preparation Option, which is designed for students anticipating careers as secondary mathematics teachers, is the most popular BA degree option. It culminates in a pair of two-quarter sequences, one emphasizing modern algebra (Math 411/12) and the other emphasizing geometry (Math 444/5 and Math 487). Majors in this option also often take a two-quarter sequence (Math 354/5) where students visit Seattle middle school classrooms and write papers reflecting on their experiences; writing is a central component of this course. Our program is distinguished by the fact that it offers three courses that were designed specifically for future mathematics teachers: most teacher preparation programs offer only one such course. These courses engage students in a way that is particularly useful for future teachers. For instance, in Math 411/12, the emphasis is on group work using a text written by one of our own faculty members. In the case of Math 444/5, facility in the use of "Geometers Sketchpad", which is widely used in the secondary mathematics curriculum, is one key skill students develop. Finally, the department additionally offers Math 497, a topics in teaching course, which serves both in-service teachers and graduate students in the school of education.

*Bachelor of science degree program.* This program prepares students for careers or graduate programs requiring a substantial mathematical base. This degree is especially useful for students going on to a variety of professional careers in law or business, where the development of critical thinking and reasoning skills is essential. The BS program has been revised since our last ten year review to incorporate greater flexibility and breadth. Students are now required to take Math 310, a foundational course in mathematical reasoning. A senior-level sequence in topology and geometry, Math 441/2/3, has been introduced. The Mathematics BS degree track is revitalized, and enjoying a substantial increase in student interest and enrollment. We should emphasize that this increase occurred during a period when the department experienced no significant increase in resources. As we described in the Future Plans section, we are reviewing some of our senior-level courses; resulting changes will better serve mathematics undergraduates, as well as Master's students.

The last ten year period has also seen the introduction of a successful interdisciplinary degree program, the Applied and Computation Mathematical Sciences (ACMS) program. This is a joint effort with the departments of Applied Mathematics, Computer Science and Engineering, and Statistics. The overall aim of the degree program is to provide a solid foundation in both theoretical and computational mathematical science with significant exposure to applications. A core set of courses in the basic tools is followed by options (tracks) emphasizing particular types of applications. The result is a program that gives students a firm foundation in applied and computational mathematics, together with a rigorous mathematical underpinning. We will discuss ACMS in greater detail below.

It is common for majors in experimental sciences to spend a year or two working within a research lab, obtaining bench experience and exposure to the excitement of research. In mathematics, an analogous experience is not possible. Mathematics is created by a single researcher, or by a small group of researchers who make similar and roughly equal contributions. This makes it difficult to directly involve undergraduates in research. However, the department has successfully created a number of research projects for undergraduates, with the understanding that such "research" is to be taken to mean learning a new set of mathematical ideas or perhaps working through a number of sophisticated examples of a more abstract theory. During the 2002-03 academic year, thirteen students were engaged in such projects with nine faculty members. The continuation and growth of these will be a central component of our VIGRE program if our proposal for another five years of support is successful. We highlight here one undergraduate project where the end product was "new". The project developed software to optimize the scheduling of tutors in the Math Study Center; the resulting software has proved to be a tremendous time saver for the Math Study Center.

The increase in the numbers of Mathematics and ACMS majors has placed considerable enrollment pressure on Math 310 (introduction to mathematical reasoning), Math 381 (mathematical modeling) and many senior-level capstone courses, particularly Math 424/5/6 (real analysis). Meeting this increased demand in a time of limited resources has been a challenge for the department.

*Honors program.* The department has participated in the UW honors program for decades. A small group of students take our first and second year honors calculus sequences; Math 134/5/6 and Math 334/5/6. These courses operate at a much higher level than the usual sequences, serving the very best prepared and motivated students. Jim Morrow has been a driving force behind the success of these sequences and mentors a number of the students to compete in the international mathematical modeling competition each spring. Three of our teams were rated Outstanding Winners, the highest category, during the last two years. Each of the three teams was selected for an additional prize, bringing each of the three possible prizes, the INFORMS prize, the MAA prize and the SIAM prize, to the department. Morrow also selects a few honors students to participate in the REU program he runs every summer. As another testament to the achievements of these students, we mention that last year's recipients of the President's Medal and the Dean's Medal, the top accolades available to UW seniors in science, obtained their mathematical training in our honors track. Interestingly, many of the outstanding students in the honors calculus sequences are not mathematics majors.

Math 134/5/6 and 334/5/6 operate at an accelerated pace. We have additionally started to offer an "honors" version of Math 124/5/6, the standard first year calculus sequence. The honors version covers the Math 124/5/6 at greater depth by delving into reasoning and proofs. In this way, we are now able to cater to a broader audience of highly motivated and interested students. Finally, we offer students the opportunity to graduate with "honors" or "distinction in mathematics" by writing a senior thesis.

*ACMS degree program.* The BS degree in Applied and Computational Mathematical Sciences (ACMS) was introduced Autumn Quarter of 1997. It was jointly developed and is administered by the departments of Applied Mathematics, Mathematics, Statistics, and Computer Science and Engineering. The ACMS program has been an integral part of our VIGRE program, and we have used VIGRE funds, as well as matching funds provided by the university, to expand and improve the program.

ACMS students take a set of common core courses to provide them with a solid foundation, from which they can pursue one of eight "tracks" or pathways of specialization. The program core includes the standard courses in calculus, linear algebra, differential equations, and computer programming, as well as courses in numerical methods, discrete modeling, continuous modeling, and probability and statistics.

Recently, two new pathways were introduced (Mathematical Economics and Social and Behavioral Sciences), one eliminated (Alternative Focus), and existing pathways reformulated in light of experience. For example, some pathway requirements have been revised to provide greater flexibility and a richer set of electives. It is now easier to use the ACMS degree as a double major or double degree. An Honors Program in ACMS requiring a 3.5 GPA and a senior thesis has been introduced. The most popular pathway continues to be Discrete Mathematics and Algorithms, with its orientation toward computer science.

With these changes in place, the program currently consists of eight pathways:

- Biological and Life Sciences
- Discrete Mathematics and Algorithms
- Engineering and Physical Sciences
- Mathematical Economics
- Operations Research
- Scientific Computing and Numerical Algorithms
- Social and Behavioral Sciences
- Statistics

A key feature of the program is the Friday afternoon ACMS Seminar, which may be taken for credit. This seminar offers undergraduates, as well as VIGRE fellows and other graduate students, a wide view of the mathematical sciences and has proved to be an excellent method for horizontal integration of disciplines. VIGRE postdoctoral fellows and VIGRE graduate fellows have given talks in this seminar, undergraduates supported by VIGRE have described their research projects, and outside visitors have shown students how mathematics impacts the real world. Some impression of the broad sweep of topics covered in the ACMS seminar can be gleaned from the ACMS web site. During Autumn 2003, for example, the ACMS seminar series highlighted the increasingly important role mathematics is playing in modern biological research.

**VIGRE.** In 1999 the departments of Applied Mathematics, Mathematics, and Statistics were awarded one of the first large-scale grants under the National Science Foundation's VIGRE program. The primary goal of VIGRE is "increasing the number of well-prepared U.S. citizens and permanent residents who pursue careers in the mathematical sciences." Our award was for approximately $2.5M over five years, and provided funds for graduate student fellows, postdoctoral fellows, undergraduate research projects, and a variety of special events. The department's graduate program, undergraduate programs and research have all benefited from the VIGRE grant.

A key feature of the UW VIGRE program is *horizontal integration* across the three departments, in addition to vertical integration of academic levels. Students, postdocs, and faculty have a far better opportunity under VIGRE to learn about other academic cultures and how they operate.

Each year VIGRE supports about six graduate student fellows in each of the three participating departments. These fellows have two academic quarters plus two summer months of VIGRE support. In the remaining academic quarter they are involved as TA's, a requirement of the VIGRE grant. As a way of horizontally integrating these students, we have formed three cross-departmental committees of VIGRE fellows: Planning, Undergraduate Involvement, and Web Site. These groups not only build community and provide a focus for activities, but they also give valuable professional training for later academic life. VIGRE fellows planned two professional workshops last year, one on finding an academic job (attended by 55 graduate students from the three departments), and the other on industrial jobs in the mathematical sciences (attended by about 40 students).

VIGRE supports a wide variety of undergraduate research projects with faculty and graduate students. Last year, for example, a team of three undergraduates worked with James Zhang and an NSF Postdoc on a project involving computations in noncommutative curves. In another project, two undergraduates supported by VIGRE worked with Rekha Thomas and two graduate students to develop a program to schedule tutors in the MSC, and now this program is used to do in seconds what used to take hours. Another use of these funds was to provide assistants for the department's summer REU program. These are alumni of the program, who work with the current participants virtually 24 hours a day to establish a stimulating atmosphere for mathematical exploration.

VIGRE postdocs have been successful in establishing their careers. In Mathematics, the first VIGRE postdoc was Lisa Korf, who now has a tenure-track position in the department. The second was Tim Chartier, who left after two years for a tenure-track job at Davidson College. The third is currently Isabella Novik, who is well-integrated into our discrete geometry and combinatorics group.

Our current VIGRE grant expires in August of 2004. This past September the three departments applied for another five years of VIGRE funding. We have just learned that our proposal was ranked in the top group of "highly recommended" by the evaluation panel, and that we will be having a site visit by the NSF during Winter Quarter. Our proposal is backed by over $1.75M in matching commitments by the University of Washington.

# 3. Teaching

The department offers a full complement of courses at the undergraduate and graduate levels. Through a large coordinated effort, department faculty aim to offer a learning experience that is both challenging and satisfying to our students. Our commitment to teaching excellence has been acknowledged by UW Distinguished Teaching Awards presented to Dave Collingwood in 1999, Ron Irving in 2001, and to Jim Morrow in 2003. The departmental commitment is also reflected by student ratings of our courses, increased demand for the courses, and an increase in the number of majors in the Mathematics and ACMS degree programs. Our undergraduate students have been successful in the Mathematical Contest in Modeling, and have gone on to top graduate schools, most of them receiving support in the form of teaching assistantships and some receiving prestigious fellowships such as the NSF Graduate Fellowships. At the graduate level, one measure of teaching excellence is the quality of our graduates and the positions they have been offered, a list of which may be found in appendix E. Members of our faculty have written a number of successful books; for example, texts written for two of our five core courses have become nationwide standards.

Our undergraduate offerings range from three versions of calculus to senior-level capstone courses in analysis, algebra, topology and geometry. Our three calculus sequences are aimed at students interested in science and engineering, business, and the life sciences. Graduate level offerings range from five first-year core courses to specialized topics courses that vary from year to year to reflect the latest research developments as well as student and faculty interests. In total, we teach approximately 65,000 student credit hours each academic year, and about another 5000 student credit hours in the summer. We meet this obligation through 51 tenure-track research faculty, three postdoctoral instructors, a small number of stable lecturer positions, year to year visitors and/or part-time employees paid through the recapture budget, and approximately 80 graduate students, many of whom serve as teaching assistants. As noted previously, the department has thriving undergraduate and graduate degree programs, with 230 Mathematics majors, 155 ACMS majors, 10 Master's students, and 73 PhD students as of January 2004. Thus our teaching mission is large in scale, and also requires teaching styles appropriate to mathematical levels ranging from precalculus to individualized PhD advising.

A typical Mathematics faculty member is qualified to, and often wishes to, teach a wide range of courses at both the undergraduate and graduate level. Unlike other disciplines, the majority of our undergraduate courses can be taught by any member of our faculty. For instance, it is not unusual for a tenured full professor to teach two sections of freshman level calculus one quarter, then teach at the graduate level for two quarters. In this way, a typical faculty member is invested in teaching at several levels of the curriculum. The teaching credit system of the department results in a teaching load averaging between 4 and 5 courses per year. More specifically, the system assigns a "teaching credit" to each course, as well as to a small number of other educational tasks, and aims for a uniform overall total load for each faculty member. Course weights depend on class size, likely preparation time, and demand. Larger freshman calculus courses carry the highest weight of 0.8, whereas small sophomore level service courses such as introductory linear algebra carry the lowest weight of 0.6. Advanced undergraduate courses and graduate courses are worth 0.75 each. The current average annual load is 3.3. The point system was introduced over 15 years ago, and has evolved over the years. Its key advantages are equitable distribution of teaching effort, and flexibility. It allows a finer measure of teaching effort than course count. Each faculty member can carry forward a small debit or credit from one year to the next, which can be a big plus from both instructional and research perspectives. For example, a faculty member anticipating a research visitor may negotiate a slightly lower teaching load for a term or even a year, making up the debit after the research visitor leaves (or perhaps the faculty member would have anticipated the visit and already achieved a small teaching credit surplus to cash in during the visit). As another example, teaching demands on the department are heaviest during Autumn Quarter and lightest during Spring Quarter, and the system allows the department to reduce some teaching loads during a given Spring with the understanding that debits incurred will be repaid the following Autumn.

Collegiality is an overarching value in much of what occurs within the department and this extends to teaching assignments. Faculty are solicited for their teaching preferences at both the graduate and undergraduate level. The Chair and the Undergraduate and Graduate Program Coordinators, in consultation with the Undergraduate and Graduate Program Committees, coordinate teaching assignments, taking into account student demand and faculty preferences. This system has served the department well. The size of the department and diverse interests of the faculty enable us to ensure that each year nearly everyone is able to teach a schedule he or she is happy with.

**Undergraduate Service Teaching.** Since the last ten-year review, the department has undergone a major overhaul in the way it teaches its freshman courses. This story has several parts, but the catalyst for all subsequent change occurred in 1991 with the opening of our Math Study Center (MSC). This facility, dedicated to assisting students in our precalculus and calculus courses, has been a huge success. Students can gather at the MSC to work on problems with their peers, with help from three sources: undergraduate tutors employed on an hourly basis, graduate teaching assistants who are either assigned to the center or who hold office hours for their courses in the center, the director and faculty holding office hours in the center. These three levels of assistance, together with the interaction that takes place among students, have made the MSC a learning center that meets the needs of our precalculus and calculus students. In fact, the MSC has become a model for other units on campus. Having the MSC in place set the stage for a multi-year reform effort at the freshman level.

Our precalculus course, Math 120 serves approximately 1200 students a year, many of whom progress into our calculus tracks. In the early 1990s, the department was presented with data from the Office of Educational Assessment highlighting a disturbing fact: success in precalculus had little correlation with future success in calculus. Viewing this as unacceptable, the department moved to improve the success and satisfaction of students in Math 120. This involved a significant reduction in class size, from classes of over 400 students to classes of 160 students. In addition, wholesale curricular change was put in place, resulting in a text focusing on multi-step problem solving. This text has been successfully used since 1995. Dave Collingwood was behind much of this revision, and won a UW Distinguished Teaching Award for it in 1999. We now find a stronger correlation between success in Math 120 and success in calculus.

With precalculus under better control, an internal 1998 report on calculus marked another turning point. This report led to revision efforts on several fronts, including some changes implemented the following year with departmental resources. Two major changes involved courses outside the traditional science and engineering calculus track (Math 124/5/6): the reduction of class size in business precalculus/calculus (Math 111/112), and the introduction of a life sciences calculus sequence (Math 144/5/6). However, with some 1600 students taking Math 124 each year, our largest freshman calculus audience is concentrated in the science and engineering track. The department was challenged by the Dean of Arts and Sciences to offer a "bold plan" for reforming and improving Math 124/5/6. Acknowledging the importance of this challenge, the department proposed and implemented dramatic change in the way in which Math 124 and Math 125 are taught. The key components of our reform include:

- Use of a single textbook for Math 124/5; the same text is also used for the subsequent two quarters of calculus (Math 126 and Math 324).
- Smaller lecture class size of 81 students, a reduction from the prior level of 160 students.
- Smaller quiz section size of 27 students, a reduction from the prior level of 40 students.
- One of the two quiz section meetings was extended to 80 minutes, so that each student now has a weekly meeting of 80 minutes, and one of 50 minutes, instead of two 50-minute meetings. The 80-minute meeting allows time for students to work through discovery-based worksheets that are integrated into the course. It also allows extra time for midterm exams.
- Improved TA training for implementation of worksheets.
- Greater communication and collegiality among instructors of different sections of each course, resulting in uniformity in the experiences of students across sections, achieved through the introduction of course coordinators and weekly meetings of instructors.

One could describe our successful calculus reform as a "continuous improvement model": a model of reform was proposed, implemented, underwent extensive assessment for both student and instructor satisfaction, was fine-tuned, and continues to be fine-tuned to ensure that the courses are kept fresh and all instructors have a sense of ownership. We believe that the courses resulting from this seven-year effort engage students, faculty and teaching assistants in a satisfying learning/teaching experience. A detailed report on our calculus reform project may be found at the following web address: http://www.math.washington.edu/~m124/Reports/report_summer03_finalversion.html

While the reform efforts emphasized Math 124/5, curricular changes were also made in Math 126 and Math 324 (the third and fourth quarters of calculus). It should be noted that Math 126 is still being taught under the "pre-reform" format: lecture classes of 160 students, TA sections of 40 students. Surveys of Math 126 students, carried out as part of our assessment of the changes, show overwhelming preference for smaller lecture and TA section sizes.

Experiences gained in the course of our reforms of freshman courses have led to cultural change in the way we handle other undergraduate service courses. We found that instructor collegiality and satisfaction improves dramatically when there is active communication and a sense of shared course ownership among course instructors. In turn, student satisfaction improves when they realize they along with their peers are obtaining a fairly uniform experience in their courses. (We do want to emphasize that strict uniformity is not something we strive for. We believe strongly that individual instructors need leeway in how to teach their courses, but a uniform skeletal structure does seem to work well.) We now have course coordinators, whose job is to appropriately orchestrate this communication, in all of our core service courses: Math 111/112 (business precalculus/calculus), Math 120 (precalculus), Math 124 (calculus I), Math 125 (calculus II), Math 126 (calculus III), Math 324 (calculus IV), Math 307 (ordinary differential equations), Math 308 (linear algebra) and Math 309 (Fourier series).

Implementation of course coordinators in these courses was also encouraged by a survey our Math Services Committee undertook during the 2002-03 academic year. Charged with communication with client departments, the committee set about surveying other units' level of satisfaction with our service courses offerings. Although we found no groundswell of support for massive change, a certain amount of fine-tuning is apparently in order. For the most part, this is a natural response to the changes made at the freshman level. Implementation of course coordinators will be followed by some curricular changes in 300-level courses.

Another important lesson learned from our calculus reform experience is the valuable role outside assessment can play in improving both instructor and student satisfaction. The department has forged a strong connection with the Center for Instructional Development and Research (CIDR), utilizing their expertise to obtain midterm feedback information through Small Group Interactive Diagnostic Surveys (SGIDs). These facilitated sessions between a CIDR consultant and the class, with the instructor absent, often improve the course experience during the quarter, and can lead to discussions to improve the course in the longer term. Additionally, we have had faculty members work closely with CIDR to improve their teaching, leading to notable success stories. The department has also been relying on its Teaching Quality Committee for evaluations of teaching, in particular for colleagues who may be nearing consideration for promotion. These internal teaching assessments offer extensive assessment of student satisfaction, often involving student interviews, as well as class visits and reviews of course materials.

**Undergraduate Majors Teaching.** As already noted, the department is currently enjoying an increase in the number of undergraduate majors. It is worth noting that this increase has occured at a time when we have actually "raised the bar" for students to progress toward a major in mathematics. As described earlier, in revamping the BS degree program during the 1998-1999 academic year, the department put into effect a new requirement for a degree in mathematics: a first course in mathematical reasoning, Math 310. This course, which is now a prerequisite for all of the more rigorous mathematics courses, has proved to be a success. Instructors of subsequent courses now requiring Math 310 have noticed improvement in the reasoning skills that are critical for upper division mathematics courses. In fact, Math 310 has become so popular that it has been oversubscribed due to undergraduate minors wishing to take the course. While we are happy with this outcome, we have recently made changes that give registration priority to majors for whom the course is essential. It would be wonderful if the department had the resources to teach the number of sections of Math 310 that would meet the full demand, since this is one way in which the department can make a lasting (and we think important) contribution to the education of many non-mathematics majors. It is worth noting that the department initially planned to teach two sections of Math 310 during the academic year, and a third one in the summer. We have increased the number with departmental resources to six sections during the academic year, with an additional two sections in the summer.

Another outcome of the revision of the BS degree has been the creation of the Math 441/442/443 sequence in topology and geometry. This sequence has filled a gap in our degree program. Students can now study each of the foundational areas of algebra, analysis and geometry during their junior/senior years.

Due to the increased number of Mathematics and ACMS majors, our capstone courses in real analysis and abstract algebra have been overflowing. We plan to return to the model of some ten years ago where multiple sections of each course are offered. This is indeed a happy turn of events since our last ten-year review. The sequences Math 427/8/9 (complex analysis) and Math 434/5 (dynamical systems) are undergoing review, as we already described, for possible consolidation into a single coherent sequence that will better meet the needs of mathematics majors and Master's students.

A teaching practice that has been very successful in the Honors sequences Math 134/5/6 and Math 334/5/6 is to use as teaching assistants undergraduates who have taken and excelled in these courses. These undergraduate TAs, paid as hourly tutors, bring to the course a tremendous energy and enthusiasm, as well as their knowledge.

The department recognizes that mathematics education starts with a student's first encounter in elementary school with the rules of arithmetic and builds new layers of knowledge and insight upon those previously gained. For this reason, the department takes very seriously its courses for future teachers at both elementary and secondary level. For example, Math 411/12, our course in modern algebra for teachers underwent extensive revision over a two-year period. Ron Irving received the Distinguished Teaching Award in 2001 for this revision effort. In another direction, a relatively new course in writing, Math 354/5, strives to improve exposition skills of teaching majors.

**Graduate Level Teaching.** Our educational mission at the graduate level is to prepare every graduate student for the most common career paths of research university professor, two-year or four-year college instructor, and mathematician employed by government or industry. This necessitates two fundamental teaching models. First, the department must teach a large number of graduate courses, ranging from foundational courses up through special topics courses that deal with the latest research. Secondly, one on one advising of PhD students in research is a central part of teaching at the graduate level, a fact that is acknowledged by the assignment of teaching credit to the advisor upon the completion of the student's thesis.

As already noted, the department teaches a slate of five foundational first year graduate courses. These courses are typically small in size, averaging 12 students, allowing the faculty member ample opportunity to interact closely with the students. Since our last ten year review, this list of foundational courses has been expanded from three to five. Intermediate-level graduate courses cover standard material in specific areas, for example, optimization or algebraic topology.

Each year, the department runs at least 15 special topics courses, many of which deal with the latest research developments. These courses vary from year to year and are carefully selected by the Graduate Program Committee, tapping into the diversity of interests represented by the permanent faculty, temporary faculty, visiting faculty and affiliate faculty based at Microsoft Research. For example, during 2003-04, we offer 19 quarters of special topics courses, as tabulated below.

| **Autumn 2003** |
|---|
| Linear Elliptic PDEs |
| Ergodic Theory |
| Probability on Trees and Graphs |
| Characteristic Classes and Cobordism |
| Foundations of Combinatorics: Enumeration |
| Advanced Algebraic Geometry |

| **Winter 2004** |
|---|
| Nonlinear Elliptic PDEs |
| Statistical Physics Expansion Methods |
| Characteristic Classes and Cobordism |
| Foundations of Combinatorics: Graph Theory |
| Scattering and Inverse Scattering |
| Advanced Algebraic Geometry |

| **Spring 2004** |
|---|
| Model categories |
| Optimization Under Uncertainty |
| Configurations of Points and Lines |
| Foundations of Combinatorics: Polytopes |
| Scattering and Inverse Scattering |
| Representations of Algebras |
| Advanced Algebraic Geometry |

Two of the nineteen courses are taught by postdoctoral faculty (acting assistant professors) and one by an affiliate faculty member at Microsoft. Similarly, in 2002-03 we offered 18 quarters of special topics courses, one of which was taught by a visiting professor and three by affiliate faculty members based at Microsoft Research. More detailed information about these courses, as well as on previous years' graduate courses, may be found at the following web address:

http://www.math.washington.edu/Grads/Courses/index.html

# 4. Graduate Students

The welfare of our graduate students is critical to maintaining a vital graduate program in mathematics. We have initiated a number of practices aimed at attracting top students to our program and helping them to succeed after they enter our program. We begin this section with a description of our current recruitment strategy and then give some data to document its effectiveness. We then discuss several practices that we have adopted for advising and mentoring our students.

**Recruitment.** Thanks to 18 fully supported fellows funded by a U.S. Department of Education GAANN grant awarded to the Department in 1989, enrollment in our graduate program increased to 110 full-time students in the 1991-92 academic year. This in turn resulted in an increase in the number of PhDs awarded from an annual average of 6 in the 1980's to 9 in the early 1990's. Our applicant pool in 1992 contained over 200 completed applications.

The GAANN grant expired in 1993. This, together with the dot-com boom of the mid 1990's and the relatively low salaries of Teaching Assistants at the UW, made it increasingly difficult to recruit top students to our graduate program. By 1998, the number of completed applications to our graduate program for the academic year 1998-1999 had declined to 109. The consequent decrease in quality of our entering classes, combined with the attraction of lucrative careers in the software industry, resulted in a decreased retention rate, and a deterioration of the morale. In response to these events, we took several steps.

We enhanced the department's website, paying particular attention to those parts pertaining to our graduate program. Prospective students can now get a good overview of our program by visiting our website.

We began inviting top applicants to visit the department. By supplementing travel money provided by the Graduate School with departmental funds, we are now able to support visits to campus for all top US applicants who desire to do so. Several faculty members, including the Graduate Program Coordinator and the Director of Admissions meet with each visitor. We match each visitor with a graduate student host; the resulting interaction with graduate students is critical to the success of the visit. Several students have mentioned to us that the deciding factor in their choice of our department over other highly rated ones had been the supportive atmosphere they experienced during their visit.

We have developed a multi-year support plan for top applicants. Top applicants typically receive multiple offers, often with significantly higher financial inducements than our TA salaries can provide. The eleven-month base TA salary at the UW of $14,135 is significantly lower than those of our peers (e.g. $18,000 at UI at Urbana, $17,000-$20,000 at UCLA, and $17,000 at U. Minnesota. In addition, many of our peer institutions offer financial incentives over and above the base TA salary.

Our multi-year support plan became fully operational during the 2001-2002 admissions season. We offer an *Academic Merit Award* (AMA) to the majority of the top 20% of our applicant pool. An AMA consists of an eleven-month salary of $18,000 for the first year and $17,000 for each of the following four years, subject to making satisfactory progress toward the PhD. To fund this plan we have to call upon all sources of funding available to us, for a patchwork of fellowships and stipends culled from the Graduate School, from outside sources such as Microsoft and the ARCS Foundation, the VIGRE grant and other NSF grants, and departmental endowments. Here is a more detailed list of some of the components.

- The Graduate School Fund for Excellence and Innovation (GSFEI) has contributed $30,000 in each of the last several years for use as recruitment stipends. This is critical for our support of entering students.
- Microsoft Research funds four-year *Microsoft Scholars* who receive an annual stipend of $5,000 in each of the four years. Two awards are given to entering students each year.
- In recent years, the ARCS (Achievement Rewards for Colleges Scientists) Foundation has given awards to two entering mathematics students each year. ARCS fellowships provide an annual stipend of $5,000 for three years. One of the awards made available to our department in 2002-03 was an *ARCS Founders' Fellowship*, which carries an annual stipend of $10,000 for three years.
- The VIGRE grant currently supports six VIGRE fellows in our department.
- The department has a number of endowments, established by faculty or former faculty, that support graduate education.

The support plan is the most critical component of our recruitment strategy; it would not be possible without the generous support from these sources.

The Department is an active participant in the Graduate Opportunities & Minority Achievement Program (GO-MAP) at University of Washington, and in recent years we have been able to award a GO-MAP fellowship to a woman in each entering class. The main focus of our diversity efforts is increasing the representation of talented women in our program. Currently, 28% of our graduate students are female. This is close to the national average of 30%.

Our recent recruitment efforts have been dramatically successful. As the table below illustrates, after 1998 the number of completed applications to our program has steadily increased and appears to have leveled off at around 160. More important than the size of our applicant pool is the number of top students in the pool and our ability to attract these top applicants to our program. We "grade" each file on the 4.0 scale. Applicants graded 3.0 or above are judged likely to succeed in our PhD program, while applicants graded 3.5 are the "cream of the crop" and are targeted for recruitment awards. The table below demonstrates that our increased recruitment efforts are paying off.

| Year | number of applicants | applicants to PhD program | rated above 3.5 | size of entering PhD class | entering from top group |
|---|---|---|---|---|---|
| 1999-2000 | 132 | 99 | 24 | 15 | 3 (20%) |
| 2000-2001 | 113 | 83 | 23 | 22 | 7 (58%) |
| 2001-2002 | 154 | 105 | 36 | 16 | 12 (75%) |
| 2002-2003 | 159 | 90 | 38 | 11 | 7 (63%) |
| 2003-2004 | 160 | 121 | 49 | 14 | 12 (86%) |

We remark that in the years preceding 1999-2000, we were able to recruit very few, if any, applicants from the top group. Another indication of the success of our recruitment efforts is the percent of the entering PhD class completing prelims by the beginning of the second year of study; this data was presented in section 2.

**Retention.** To help graduate students to succeed we have instituted a number of practices that guide them through various stages of our program.

In addition to the University's orientation program, the department holds it own orientation. The program begins with a half-day introduction to the department, consisting of presentations by the Graduate Program Coordinator (GPC), the Director of Student Services, and the Teaching Assistant Coordinator, followed by an intense four-day TA training program that must be attended by all entering math students receiving financial support. The TA training program is organized by our TA Coordinator and the lead TA, and is conducted with the help of the Center for Instructional Development and Research (CIDR). A handbook written to complement the TA training program is given to each new graduate student on the first day of our orientation. The program concludes with a picnic open to all graduate students, faculty, and staff.

During the first quarter of teaching, each new TA in our department is also assigned to an experienced graduate student (*TA mentor*). TA mentors meet regularly with new TAs, observe their teaching, and provide support as needed.

To acquaint TAs with the worksheets used in the first two quarters of our main calculus sequence (Math 124/125), we have established a worksheet training program. The program consists of weekly hour-long meetings during which the worksheet for the week is discussed in detail, areas that are likely to present problems for the students are identified, and a uniform message is agreed upon for delivery to the students regarding the goal of the worksheet. Every TA assigned to Math 124/125 for the first time is expected to attend these meetings.

The Department sponsors an annual Graduate Awards Ceremony to honor outstanding graduate students in mathematics who received awards and fellowships during the past year, as well as outstanding TAs. Students with outstanding performances in core courses and prelims are given *Academic Excellence Awards*. Two *Excellence in Teaching Awards* are given to outstanding TAs. In addition to a certificate, each award includes a $1,000 supplementary academic stipend.

Activities aimed at integrating graduate students into the mathematical community include the following.

- In addition to daily afternoon teas, we have instituted a series of informal dinners at a local restaurant. About twice quarterly, five faculty and five graduate students are invited to attend dinner at which topics of concern to graduate students and/or faculty are discussed. The dinners not only provide valuable information about the concerns of our students but also give our graduate students a better understanding of how the department functions.
- As part of our colloquium series, each colloquium speaker is invited to have lunch with a group of graduate students interested in her/his area of research.
- The VIGRE program sponsors a number of activities to enrich the professional training of our graduate students. In addition to the weekly VIGRE/ACMS seminar, VIGRE sponsors panels on professional issues such as finding an academic job or learning more about industrial jobs. VIGRE graduate students are planning a VIGRE Distinguished Lecture series. Last academic year VIGRE funded many travel grants for graduate students to attend conferences and workshops so crucial to the success of our students. More recently, VIGRE funded a pair of introductory lectures on string theory to share with students the excitement of this new field of emphasis here.

To provide additional guidance to students who have not yet chosen doctoral advisors, the GPC conducts individual annual meetings with every first, second, and third year graduate student. Meetings with second and third year students occur early in autumn quarter, while meetings with first year students are held early in spring quarter.

A Graduate Student Representative (GSR) is elected by graduate students each year. The Chair solicits input from the GSR regarding the committees on which graduate students would like to have representatives. Currently the GSR is a member of the Colloquium Committee and the Graduate Program Committee, while the lead TA serves on the TA Advisory Committee and the Undergraduate Program Committee. We are initiating the practice this year of inviting graduate students to meet with every tenure-track job candidate that is invited to give a talk, and to provide input to both the Department Chair and the Appointments Committee.

The feeling among faculty and graduate students is that we have a vibrant graduate program, with particularly strong groups of recruits in each of the last three years. We are pleased to also report that morale among graduate students is high. There is a sense of camaraderie and support, both academic and social, among graduate students. There is also constant interaction between faculty and graduate students, with conversations and informal advising taking place in the hallways and other common areas of the department. Both faculty and graduate students participate in recruitment of new students each spring, and help new students adjust to graduate school the following autumn.

Our discussion of the graduate program in section 2 describes the ways in which we work with students on transitions that are an integral part of graduate education: transition into graduate study, through the first year and prelims, followed by transition into individualized study, reading and, finally, research.

At the end of each quarter, instructors of the core graduate courses, as well as instructors of the courses taken by Master's students, are asked to provide a short written evaluation of the performance of each graduate student taking the class. In early January, the doctoral advisor of each PhD student submits a report summarizing the progress of the student. At the same time, research students are asked to fill out a form on their progress and plans. These reports, course grades, and teaching evaluations are all considered by the Graduate Program Committee during its annual renewal meeting in May. The Committee's decisions regarding the student's status and financial support for the following academic year are given in writing to each graduate student.

We believe that our recent recruitment and retention efforts have been successful. But maintaining it will require continual effort. In particular, our support plan relies on funds that we need to apply for or solicit each year. We will continue this annual effort, and also seek to increase the permanent funding available for the support plan.

# 5. Research and Scholarship

The Mathematics Department at the University of Washington continues to maintain its status as a research department of international reputation. Using the most recent NRC ratings, the department ranks 13th among the AMS Group I public universities - right in the middle of this group of top 25 institutions. The department has maintained its prestige despite a significant lag in salaries in large part by focusing on making excellent tenure-track appointments into existing research groups. By being a desirable destination for junior faculty, and by offering competitive salaries at the assistant professor level, the department has been able to attract promising young researchers. We then aim to retain faculty in the face of significant outside offers. While the department has lost professors to institutions such as Stanford and Northwestern, it has successfully countered offers from similarly prestigious institutions. The department's goal has been to maintain a stimulating and supportive research environment, to attract the best young faculty, and to retain them despite the presence of higher salaries at other leading research departments.

Financial resources required to successfully conduct mathematics research are not large compared to the sciences. This gives mathematics an advantage in continuing to be successful in research in a time of decreasing state support for education. It also makes it possible to have an impact with a relatively modest increase in support. Indeed a number of states, for example California and Texas, made such an investment in the 1980s and 1990s, resulting in a leap in activity and prominence of the mathematics departments of their public universities. The primary resource mathematics researchers require is ample uninterrupted time dedicated to research. Additionally, funds to visit other universities and invite visitors are important. While much of mathematical development occurs in an individual mind, collaboration is vital to the stimulation of research. An increasing number of research projects require the differing expertise of two, and occasionally more, specialists. Funds in support of travel and collaboration are especially important in a geographically isolated university like UW. We remark that, again in contrast to the laboratory sciences, most mathematics papers have one or two authors, and it is relatively rare to have more than three authors on a research paper. The input of the authors on a paper is generally about equal, and names are listed alphabetically to reflect this.

The special nature of mathematics research is also reflected in the federal funding picture. A typical mathematical research grant is a 3 to 5 year grant for an individual researcher from the National Science Foundation, which provides one or two months of summer salary each year, travel funds to attend conferences or to invite visitors, and may contain support for the investigator's graduate students. While such a grant is obviously very helpful, it is by no means necessary for successful research, and obtaining one has become a very competitive process in recent years.

The National Science Foundation also makes available other funding possibilities besides individual grants. The CAREER award is the NSF's most prestigious award for junior faculty members. This is a four to five year grant providing $200,000 to $500,000 of general support for early career development. The program covers many areas of science, engineering and mathematics, at different levels of funding. There are few CAREER awards in mathematics, compared with the sciences and engineering. In the most recent year, there were 20 such awards across all of the mathematical sciences, which includes applied mathematics and statistics, out of more than 400 total. Currently, Associate Professors Sara Billey and Sándor Kovács hold this award. Billey additionally received a PECASE (Presidential Early Career Award for Scientists and Engineers), which is the highest honor bestowed by the United States Government on scientists and engineers beginning their independent careers. Nominees for PECASE are selected from among new CAREER awardees.

Focused Research Group awards are a new initiative of the NSF which provide 3 year grants to fund collaborative research among mathematicians at different universities. In 2003, Steffen Rohde of the department received an FRG award, in conjunction with colleagues at Michigan, Purdue and Syracuse, for research in complex analysis. Members of the department have since applied for support for participation in several other FRG.

While the NSF continues to be the principal source of federal funding for mathematics, there has been some broadening of mathematics funding to other agencies. Since 1990, department members have additionally received grant support from the Office of Naval Research, the Department of Energy, and the National Institute of Health.

Currently, 34 of the 51 regular faculty in the department receive research support from one of the above federal agencies, and in some cases are supported by multiple grants. As we have remarked, federal grants in mathematics have become highly competitive, and are not required to pursue research. Internal sources, to be described below, provide travel and visitor support for department faculty. A majority of those not currently on a grant remain active in mathematical research, as evidenced by the fact that 44 of the 51 regular faculty have two or more publications appearing within the past five years.

In addition to grant support, department members have also had their research acknowledged by fellowships from the American Mathematical Society, the Alfred P. Sloan Foundation, the Guggenheim Memorial Foundation, and the Fulbright Program.

The AMS Centennial Fellowships and Sloan Foundation Fellowships acknowledge excellence in research, and are more prestigious than a research grant. The Sloan Foundation provides post-doctoral fellowships for tenure track faculty, which pay a stipend to partially cover salary for two years. The department has had a significant number of Sloan Fellows; in 2002 it was the only department in the nation to have two such fellowships awarded, to Yu Yuan and Sándor Kovács. Since 1990, Ethan Devinatz, Hart Smith, Tatiana Toro, James Zhang, Sándor Kovács and Yu Yuan have received this honor. The AMS Centennial Fellowship carries a stipend comparable to the Sloan Fellowship. Faculty members Steve Mitchell, Chris Burdzy, and Sándor Kovács have received this fellowship since our last self-study. The Guggenheim Fellowship is even more selective, and provides a stipend for the researcher to spend part of the year at a fellow department; Gunther Uhlmann received this award in 2001. Fulbright Awards allow researchers to lecture and conduct research abroad in a wide variety of fields. Boris Solomyak spent the 1998-1999 academic year at the Hebrew University in Jerusalem as a Fulbright Research Scholar.

Mathematics faculty have received numerous other national and international awards and distinctions, as can be seen in the individual vitae. We mention here a few examples. Two departmental members, Hart Smith and Gunther Uhlmann, gave invited lectures at the quadrennial International Congress of Mathematicians in 1998. Victor Klee received the Allendoerfer Prize in 1999 from the Mathematical Association of America for articles of expository excellence. Terry Rockafellar received the Lanchester Prize from the Institute for Operations Research and Management for his 1997 book with Roger Wets *Variational Analysis*, and the John von Neumann Theory Prize from that institute in 1999, for career research contributions in mathematical theory. Chris Burdzy received the Rollo Davidson Prize in 1992. Victor Klee was elected Fellow of the American Academy of Arts and Sciences in 1997, and Chris Burdzy as Fellow of the Institute of Mathematical Statistics in 1999.

The Office of Research at UW has supported new research programs in mathematics through the Royalty Research Fund, which distributes a portion of the license and royalty fees from UW-developed intellectual property through competitive grant awards. An average of two mathematics faculty have been supported this way each year.

An important source of visitor support is the income from the department's Milliman Endowment. About $4000 of the annual income of about $26,000 is used each year to invite a prominent mathematician to deliver a series of three Milliman lectures directed at a general mathematical audience. The Milliman lecturer visits the department for a week, and interacts with the faculty and graduate students. The remaining Milliman funds are used to support research visitors to the department for periods ranging from a few days to a month. The department is able to allocate a modest amount of money to fund travel by faculty to conferences and other universities. Using part of the money recaptured from faculty members who are on sabbatical leave with partial salary, we annually bring several visitors, for one quarter or longer, to teach and collaborate with departmental faculty.

A unique opportunity for the department has been the development of the Theory Group at Microsoft Research in Redmond. This group has eight permanent Researchers and Senior Researchers, and several postdoctoral fellows. They also bring numerous visitors, short and long term, to the area. The eight permanent members have been appointed as affiliate professors in our department. Senior Researchers who are affiliate professors include Fields Medalist Michael Freedman and Wolf Prize winner Lázsló Lóvasz. Department faculty in several research areas, in particular combinatorics, probability and complex analysis, work closely with the group and visitors. Researchers and Senior Researchers of the theory group have taught several graduate topics courses in these areas in the department. This winter, Christian Borgs is teaching a course on "Statistical Physics Expansion Methods in Combinatorics and Probability". In recent years, László Lovász, David Wilson, and Henry Cohn have taught special topics courses. Postdoctoral members of the theory group teach undergraduate courses as well as graduate topics courses in the department, and visitors to the group frequently collaborate with department members.

Intellectual contributions of the department extend well beyond mathematical research. The department is engaged in outreach activities at all levels; these will be described in section 6. A significant number of advanced mathematical texts have been authored by faculty members. Neal Koblitz is the author of several foundational texts in number theory and cryptography, which have been translated into numerous languages. Jerry Folland has written advanced undergraduate and graduate texts in analysis and partial differential equations. Jack Lee is author of three graduate texts on geometry. These books have become standards in their respective areas. Other textbooks and research monographs written by department members are too numerous to mention here. Some of these books are proudly displayed in a cabinet in the department's mail room.

We now turn to a more detailed description of the mathematical research carried out within the department. For the purpose of this review, we have divided the research interests of the faculty into 13 categories. This division is in some cases approximate, and several researchers fall into two or more areas. Each is an internationally recognized area of research and all are currently experiencing significant research activity. As with other scientific disciplines, areas of mathematics rise and fall in prominence. There can be breakthroughs, as happened about ten years ago in number theory, that are followed by periods of intense activity during which previously intractible problems are solved. After such a period of progress, an area can experience a slowdown until new connections emerge.

The area of partial differential equations has experienced considerable growth in the past twenty years, and, partially as a consequence of a recommendation of the review committee of 1982, the department has developed a widely recognized group of researchers in this field. Most recently, string theory has emerged as an active and highly promising area. As explained below, in response to developments in theoretical physics, and in conjunction with the physics department, the department has made a commitment to start an interdisciplinary research group in this area.

Typically, though, priority is given to hiring researchers who can interact closely with an active research group in the department. This assures more effective mentoring of young faculty, and makes it easier to identify and attract excellent junior researchers. We emphasize that this strategy has not been seen to be an impediment to developing a diverse research faculty, since the department is large enough that the fields represented in it do span the majority of presently active research areas.

The department has identified three areas for priority in research appointments: string theory, probability, and algebraic geometry / number theory.

We summarize below the recent activity of each of the thirteen areas represented in the department. More detailed information on individual faculty, such as recent publications and recognitions, are provided in the faculty vitae.

**Algebraic and Geometric Combinatorics.** The department has long been recognized for the strength of its research group in combinatorics. In the latter part of the 20th century, this reputation was based on the leadership of Branko Grünbaum and Victor Klee, who played an important role in establishing the field through their work on geometric combinatorics, and its connections to computer science and operations research. With the impending retirements of Grünbaum and Klee, in 1997 and 2000, the department placed a high priority on maintaining this reputation through selective hiring in algebraic and geometric combinatorics. The department has now assembled an active group of young researchers in this field, consisting of associate professors Eric Babson (appointed 1998), Rekha Thomas (2000) and Sara Billey (2002). In addition, the group includes acting assistant professor Isabella Novik and senior lecturer Katalin Vesztergombi. The combinatorics group is further bolstered by our affiliate faculty in the Microsoft theory group with interests in combinatorics, including Christian Borgs, Jennifer Chayes, Henry Cohn, László Lovász, and David Wilson.

Babson's research includes a wide variety of topics in the applications of algebra and topology to combinatorial geometry problems. Recent work includes polynomial time identification of graphs and oriented matroids, enumerative combinatorial topology, percolation, and torus actions on manifolds.

Billey's research interests lie in the intersection between combinatorics, algebraic geometry and Lie theory. The focus of her work is on Schubert varieties, Bruhat order, Weyl groups, root systems, and symmetric functions. Recent joint research includes a new approach to computing the Kostka numbers in symmetric function theory, and the study of a new family of varieties related to intersections of Schubert varieties indexed by higher dimensional analogs of permutation matrices.

Thomas works on problems that lie at the intersection of discrete optimization, computational algebra and geometry. Recent research has focused on the combinatorics of toric Hilbert schemes, and the complexity of Groebner bases. Thomas is involved in joint work with Babson and Novik on algebraic shifting, a transform on simplicial complexes which preserves combinatorial data. She has also been involved in developing software for problems in computational algebra.

The research interests of Isabella Novik lie in combinatorics of simplicial complexes, and in connections between combinatorics, commutative algebra, and algebraic topology. Her work includes problems related to bounds on the number of faces for complexes of a given dimension.

Vesztergombi works in the area of graph theory. Recent work includes publishing the undergraduate text used in our combinatorics course, and new techniques to construct graph representations with favorable properties.

**Number Theory.** The number theory group currently consists of two internationally recognized researchers, Neal Koblitz and Ralph Greenberg. Neal Koblitz recent work lies in the applications of number theory to cryptography. He is most well known as the co-inventor of Elliptic Curve Cryptography (ECC), which is currently one of the main mathematical tools used for data security applications. He is also author of two texts in mathematics on cryptography, including the graduate text in mathematics *A Course in Number Theory and Cryptography.* Both texts have been translated into Japanese, Russian, and Polish. Koblitz has been active in industrial consulting work in cryptography. In 1999, he was instrumental in discrediting an algorithm that purported to compromise both Elliptic Curve Cryptography and the Digital Signal Standard.

The earlier research of Koblitz lay in the theory of elliptic curves and modular forms. He is the author of numerous papers in this area, as well as author of two of the standard graduate texts in the field, *p-adic Numbers, p-adic Analysis, and Zeta Functions*, and *Introduction to Elliptic Curves and Modular Forms.*

Ralph Greenberg's research interests concern algebraic number theory and the interplay between algebraic geometry and number theory. Specifically, Greenberg is a specialist in the area of Iwasawa theory, which involves the study of algebraic objects, including the Selmer group and special values of L-functions.

Greenberg's research has a close connection to the famous Birch and Swinnerton-Dyer conjecture concerning elliptic curves, and also various generalizations of that conjecture. In addition, some of his research deals with the more analytic side of Iwasawa theory - the study of p-adic L-functions. In the early 1990s, Greenberg and Glenn Stevens found a novel approach to studying properties of the p-adic L-function associated to an elliptic curve, leading to a proof of a conjecture of Mazur, Tate, and Teitelbaum.

**Algebraic Geometry and Noncommutative Algebra.** For many years the department has been eager to hire in the area of algebraic geometry. This was finally achieved in 2000 with the hiring of Sándor Kovács to the faculty. Charles Doran, who was recently appointed Assistant Professor, will add to our representation in this fundamental area.

Kovács complements Professors James Zhang and Paul Smith in the related area of noncommutative algebra. The algebra group as a whole maintains an active seminar series. Zhang and Kovács have held Sloan Postdoctoral Research Fellowships, and Kovács was awarded a prestigious five year NSF CAREER Award Grant in 2001. The algebra group also includes Ron Irving, who is currently serving as Divisional Dean of Natural Sciences, and whose research interests center on ring theory.

The research interests of Sándor Kovács lie in moduli theory, singularities, and the study of varieties of general type in higher dimensions. A major development of modern algebraic geometry is Mori Theory, which extends the theory of minimal models of surfaces to higher dimensional varieties. Important aspects of Kovács's work are the use of the techniques of Mori theory to understanding families of varieties of general type, and the study of singularities that are central to this theory.

As the sole regular faculty member in the field of algebraic geometry, Kovács has been the unique source for students seeking to take a reading course or to do thesis research in this area. As a result, Kovács currently has six graduate students working with him, and has been running a Student Algebraic Geometry seminar for three years. Recently, Kovács has helped resurrect the "Western Algebraic Geometry Seminar" conference series, with participating schools of UBC, UW, UC Berkeley, Stanford, Utah, and UC Santa Barbara.

The research of acting assistant professor Vitaly Vologodsky also lies in algebraic geometry, in particular in birational geometry and birational maps between threefolds. Recent work also includes the topology of moduli spaces, and connections of algebraic geometry to physics.

James Zhang's primary research interests are in noncommutative projective geometry, which has experienced rapid development since its origin in the late 1980's in the work of Artin, Schelter, Tate and Van den Bergh on classification of quantum projective planes. Zhang and Artin set out the basic theory of noncommutative projective schemes, including its cohomology theory; Serre duality for noncommutative projective schemes was proved by Yekutieli and Zhang. Zhang has also written many papers on the structure and homological properties of noncommutative algebras, such as graded algebras with finite global dimension, Hopf algebras and rings satisfying polynomial identities. Yekutieli is spending his sabbatical year in our department during 2003–04.

The research of Paul Smith concerns the interactions between non-commutative algebra and algebraic geometry. Most recently, he has been studying resolutions of certain symplectic orbifolds that can be realized as moduli spaces of representations of certain non-commutative algebras.

**Representation Theory.** The department's group in representation theory study representations from an algebraic point of view, with a focus on the representation theory of Lie algebras associated to the classical groups. In addition to the faculty whose research interests fall primarily in this group, the combinatorialists Eric Babson, Sara Billey and Rekha Thomas often work on questions inspired by, or with applications to, representation theory.

Monty McGovern works on primitive ideals in, and quotients of, enveloping algebras, exploring the interplay between them and the combinatorics of crystallographic Coxeter groups, particularly Kazhdan-Lusztig theory.

Ron Irving is at present Divisional Dean of Natural Sciences. The focus of his mathematical work has been in the study of modules related to representation theory of complex semisimple lie algebras, in particular generalized Verma modules and modules arising in Kazhdan-Lusztig theory.

John Sullivan is currently studying the Schur algebras of representations of classical Lie algebras over fields of characteristic zero. Recent work exploits the theory of crystal bases to construct a basis for the Schur algebra of an irreducible module in terms of elements in the universal enveloping algebra.

David Collingwood's most recent work in representation theory focused on connections between the singularity theory of representations and the asymptotics of their matrix coefficients. His research has been redirected toward interdisciplinary problems in computational molecular biology, focusing on a collaboration involving the analysis and application of DNA microarray data to study and understand the process of cellular division.

**Complex Analysis.** In response to a hiring priority in complex analysis, the department appointed Steffen Rohde in 1998, whose research interests complement those of Don Marshall and Lee Stout. The appointment of Rohde has led to significant activity in both complex analysis and complex dynamics.

The research of Rohde spans the fields of complex dynamics, conformally invariant stochastic processes, and conformal and quasiconformal maps and their generalizations to metric spaces. The hiring of Rohde thus provides a bridge to probability and real analysis, through his interests in stochastic processes and analysis on metric spaces. He has run seminars with Toro on the structure of metric spaces, and with Chen on percolation theory.

In addition, Rohde has an ongoing collaboration with Oded Schramm of the Microsoft Theory Group. Oded Schramm's recent discovery of the stochastic Loewner evolution SLE, the Loewner equation driven by one-dimensional Brownian motion, has opened up a new area of investigation involving conformal mappings, probability theory and mathematical physics. Rohde and Schramm have written several joint papers on SLE. In the autumn of 2002, Rohde and Chen taught a research seminar on applications of SLE to rigorous problems in percolation theory.

The research interests of Don Marshall lie in complex analysis with an emphasis on function theory in one variable and applications to problems in functional analysis, numerical analysis and probability. Recently, Marshall and Rohde proved convergence of a numerical algorithm, discovered by Marshall in 1983, related to the classical Loewner equation.

Marshall has recently completed a book with John Garnett of UCLA, covering classical complex analysis through recent advances in geometric function theory. Other recent joint work includes an application of a classical extremal problem to the study of numerical polynomial hulls with Greenbaum, and Faber (Cytoprint, Inc.), and domains with large expected hitting time for reflected Brownian motion, with Burdzy and Chen.

The research interests of Edgar Lee Stout lie in the theory of functions of several complex variables. His most recently published work is a cycle of three papers, including a Memoir of the American Mathematical Society, carried out in collaboration with Jean-Pierre Rosay of Madison, that concerns a general theory of boundary values for functions defined on certain domains of either $R^N$ or real-analytic manifolds. Other work of Stout has involved the problem of solving the second Cousin problem with continuous dependence on parameters, and the theory of removable singularities for CR functions. Stout is currently at work on a monograph on the general subject of polynomial convexity.

**Partial Differential Equations.** In response to a recommendation of the 1981 Decennial Review, the department placed priority on building up a research group in partial differential equations. Since then, the PDE group has become a highly recognized unit of the department. Smith and Uhlmann were both Invited Lecturers at the 1998 International Congress of Mathematicians in Berlin, and Smith, Toro, Uhlmann, and Yuan have all held Sloan Research Fellowships. All members of this group could also fit under other standard classifications: Folland and Smith in classical analysis, Toro in geometric analysis, Uhlmann in inverse problems, and Yuan in variational analysis. Furthermore, there are strong links to the differential geometry group, including a common weekly seminar. In 1999, Uhlmann began the Pacific Northwest PDE seminar series, in cooperation with UBC, Vancouver.

The recent work of Smith has centered on the harmonic analysis of hyperbolic equations, with particular attention on properties of solutions to wave equations with wave speed metrics of limited differentiability. His pioneering work on wave packet techniques for proving Strichartz estimates played a key role in joint work with Tataru proving an optimal existence result for nonlinear wave equations similar to the Einstein field equations.

Toro's research has recently focused on free boundary regularity problems, with boundary data that lies below the continuous threshold. Joint work with Carlos Kenig introduced a novel blow-up technique to the field, helping settle a conjecture on one-phase free boundary problems, while initiating work on the more involved two-phase problem. Toro spent the academic year 2001-2002 as a visitor to the Harvard Mathematics Department and a member of the Radcliffe Institute for Advanced Study. She also maintains an ongoing collaboration with Guy David of Paris VI.

The research interests of Yu Yuan lie primarily in fully nonlinear equations and differential geometry. Recent joint work with Nikolai Nadirashvili constructed a counterexample to the local isometric embedding problem for surfaces. Other work of Yuan's established a Bernstein type result for special Lagrangian equations in all dimensions, under a necessary convexity condition.

Uhlmann's research spans both partial differential equations and inverse problems. His work in PDE has concentrated on microlocal analysis and scattering theory. Microlocal analysis has proven very useful for studying the propagation of singularities for PDE's similar to the wave equation, and Uhlmann has obtained foundational results for singularities for systems like Maxwell's equations for crystals in which there are directions where the wave speeds coalesce.

Folland's research of past fits more properly under the heading of harmonic analysis on lie groups. He recently has focused on scholarly pursuits, including second editions for his widely recognized texts on real analysis and on partial differential equations. He is currently in the early stages of writing a text on quantum fields for mathematicians.

**Inverse Problems.** The department has an active and diverse group working on inverse problems and related topics. This group at present consists of Ken Bube, Edward Curtis, Jim Morrow, John Sylvester and Gunther Uhlmann. Activities of the group include several ongoing research programs, a weekly seminar on inverse problems, and a summer Research Experiences for Undergraduates (REU) program on discrete inverse problems directed by Morrow. In the past six years, 11 students have written PhD theses on different aspects of inverse problems, and there are currently four graduate students working in the field.

Ken Bube has been working for a number of years on inverse problems in reflection seismology and seismic traveltime tomography. The goal is to determine the structure of the subsurface through seismic wave experiments. Bube and his PhD students have worked on several problems in reflection seismology, analyzing and proving convergence for numerical methods in idealized situations in stratified media, and studying the effect of different aspects of the physics of models on our ability to recover material coefficients, such as density and wave speed. Bube also works with colleagues in industry on both numerical and theoretical issues in seismic traveltime tomography, where traveltimes from many source locations to many receiver locations are derived from seismic data.

Ed Curtis and Jim Morrow have been working in the area of discrete inverse problems for the last ten years. Inverse electrical network problems are typical discrete inverse problems. The goal is to recover information about a planar electrical network which can be from information gathered at the boundary of the network. This area of research is elementary enough that talented undergraduates can make genuine contributions. Indeed, the department's REU program directed by Morrow engages undergraduates in this area. Some of these students have continued their work and written senior theses or PhD theses on discrete inverse problem.

John Sylvester has been working on one-dimensional inverse problems motivated by layer-stripping algorithms. Of particular interest are experiments using waves which penetrate deeply into the medium under study, such as microwaves, X-rays, and high frequency sound waves. Sylvester studies mathematical methods for turning a "microwave photograph", made up of a stack of superimposed images, into a stack of individual photographs, each containing the image of a single layer of the medium, which reveals the true structure of the underlying medium.

Together with Dale Winebrenner at the Applied Physics Lab, Sylvester has developed a mathematically rigorous and highly stable inverse scattering algorithm for a 1-D Helmholtz equation, which has successfully treated experimental remote sensing data with high noise levels. They continue to investigate the extensions of these methods to more complicated media. Sylvester is also working with Howard Conway of the Department of Earth and Space Sciences to develop and apply methods for locating strata of ice that correspond to important events in the history of the earth (e.g. volcanic eruptions) using ice penetrating radar.

Gunther Uhlmann's work on inverse problems involves a variety of inverse boundary value problems and inverse scattering problems. An example to which Uhlmann has devoted a lot of attention is electrical impedance tomography (EIT). In this non-invasive inverse method one attempts to determine the conductivity of a medium by making voltage and current measurements at the boundary. This problem arose in the early part of the century in geophysics exploration, but recently it has been proposed as a diagnostic tool in medicine. EIT also arises in non-destructive evaluation of materials. Of particular interest are the problems of crack and corrosion identification and the determination of conductivities of high contrast. Uhlmann and co-authors have developed mathematical methods that lead to analytic reconstruction methods for several of these problems.

Uhlmann has also worked on X-ray tomography, which revolutionized the practice of many parts of medicine. The mathematics of X-ray tomography has traditionally been viewed as a special branch of integral geometry. In recent years, another viewpoint has developed in which it is seen as an inverse boundary value problem for a Boltzmann transport equation. This context also includes single emission tomography and the newer technique of optical tomography, which is based on boundary measurements of near-infrared light transmitted through a body.

**Ergodic Theory and Symbolic Dynamics.** The group in ergodic theory and symbolic dynamics is recognized as a leading group in the area. The four regular faculty were bolstered by the appointment of Manfred Einsiedler in 2002 to a three-year acting assistant professor position. The group organized a concentration year during 2002-2003 with funding from the NSF and the American Institute of Mathematics. The focus of this activity was to further progress on the Furstenberg Conjecture, which asks to characterize the measures on the circle that are simultaneously invariant under multiplication by two multiplicatively independent integers. Klaus Schmidt visited from the University of Vienna for most of the academic year. Other visitors included Elon Lindenstrauss, Anatole Katok and Tom Ward. Some funds remain to continue the visitor program.

The group was also involved in setting up one of the first PIMS Collaborative Research Groups, which was selected for funding by PIMS for a concentration period during 2003-2005. Schmidt was selected as a PIMS Distinguished Chair as a result. In addition, several workshops at the Banff International Research Station are being organized in dynamics. For example, one held in June of 2003 had Lind, Solomyak, and Schmidt on its organizing committee.

Douglas Lind is mainly interested in the dynamics of systems defined using algebra, such as the action of one or several commuting automorphisms of a compact abelian group. In the past fifteen years this has developed into a rich and active area, with fascinating connections with algebra, number theory, and commutative algebra. Most recently, it has led him and Einsiedler to the emerging notion of amoebas; both are invited participants at a focused workshop on this topic at the American Institute of Mathematics. Interestingly, another colleague, Rekha Thomas, is also a participant, and the three are interacting on common interests.

The research interests of Boris Solomyak include tiling dynamics, which is a combination of symbolic dynamics and discrete geometry motivated in part by applications to quasicrystals. Solomyak's work has been significant in elevating the role that ergodic theory plays in this field. He also has important results in the dimension theory of dynamical systems and fractals, which plays a prominent role in harmonic analysis, fractal geometry, probability and physics. His influential 1995 Annals of Mathematics paper on random series is extensively cited. Solomyak spent 1998-99 as Research Scholar at the Hebrew University of Jerusalem on a Fulbright Award.

Selim Tuncel's interests center on classification problems and coding. Classification questions of ergodic theory often lead to problems of a combinatorial or algebraic nature. Most recently, Tuncel studied finitary isomorphims with finite expected code lengths with his PhD student Robbie Mouat, which led them to a collaboration with Einsiedler on positivity questions for rings and modules of polynomials of several variables.

Chris Hoffman's interests have been shifting in the direction of probability, but his past work focused on ergodic theory, and includes several foundational results on isomorphisms of measure preserving endomorphisms. He also studied the possible ergodic theoretic properties of $\mathrm{Z}^2$ subshifts of finite type, and the characterization of expanding endomorphisms of the circle which have multiple absolutely continuous invariant measures.

Manfred Einsiedler's interests lie in the rigidity of higher rank Abelian actions. In his time at UW, he has worked on measure rigidity, disjointness, and connected problems in number theory and algebra. Einsiedler has profited from the concentration year through collaboration with Lindenstrauss extending results for the circle group to the higher dimensional setting, in joint work with Lindenstrauss and Katok on rigidity of lattices in quotients of the special linear group, and work with Kapranov, Ward, and Doug Lind on non-archimedian amoebas — an algebraic object in the variety of an ideal arising from the study of higher rank actions on compact Abelian groups.

**Optimization and Variational Analysis.** Jim Burke, Terry Rockafellar and Paul Tseng have been the core faculty members of our program in theoretical, numerical and applied optimization. Rockafellar retired in 2002 but continues his research, and teaches a reduced load. Lisa Korf was hired as assistant professor in 2002, in response to Rockafellar's retirement. Algebraic computation and optimization also form part of the research of Rekha Thomas.

Current research activities of the optimization group include collaborative activities in the Departments of Statistics (numerical methods for robust statistics), Bioengineering (population analysis and biomedical imaging), Computer Science and Engineering (Markovian decision processes), Finance (portfolio optimization), and the School of Fisheries (hydro-power optimization). Most of these projects have graduate student involvement.

For the past 18 years the Optimization Group has run a yearlong graduate seminar in optimization. In addition, they conduct a semi-annual regional seminar in optimization called the West Coast Optimization Meeting (WCOM) in collaboration with colleagues in British Columbia. The Fall meeting is typically held at the University of Washington while the Spring meeting is held either at UBC or Simon Fraser. Speakers at the WCOM always include at least one internationally renowned expert in optimization from outside the region.

Research interests of Paul Tseng lie in the optimization of algorithms and computation. He has developed, in collaboration with Dimitri Bertsekas at MIT, efficient algorithms for solving nonlinear network flow problems, which have been coded and are available in the public domain. The codes have been used in the industry by, e.g., UPS, Lucent, and Boeing. One was used recently for displaying election results from the British parliamentary election. In addition, Tseng has been collaborating with a statistician, Sylvain Sardy at EPFL in Lausanne, to develop efficient methods for denoising noisy 1-D signals or 2-D images. He has also been working with David Baker at UW Biochemistry on improving the local/global energy minimization routines in their Rosetta code for predicting the 3-D structure of protein from the amino acid sequence.

The research of James Burke concerns itself with the algorithms of optimization theory and their practice. Applications of current interest are optical wavefront reconstruction (funded by NASA), system modeling and model identification in pharmacokinetics and pharmacodynamics (funded by NIH), and robust control in engineering design (funded by NSF). All of Burke's research is conducted in collaboration with laboratories and researchers in the Pacific Northwest. His work in Optical Wavefront Reconstruction is a collaboration with Russell Luke at the UBC. The work in Metabolic and Pharmacological Modeling and System Identification is funded by the NIH through the Resource Facility for Population Kinetics in the Department of Bioengineering. Burke is the team leader for the mathematics and algorithm development group within this lab. His research in Robust Control in Engineering Design is a long term collaboration with Adrian Lewis of Simon Fraser University and Michael Overton of the Courant Institute at NYU. This research was recently highlighted at the 18th International Symposium on Mathematical Programming.

The work of Lisa Korf concerns the investigation of a number of key issues in the area of multistage, or many-stage, stochastic programming. Her research projects include developing new theoretical models that expand the applicability of existing models, to encompass applications such as stochastic optimal control problems, and financial applications. She is also working on approximating continuous time and infinite horizon problems by many-stage problems that are amenable to computational schemes.

The research of Rekha Thomas is centered around combinatorial and computational commutative algebra with strong connections to discrete optimization (integer programming), combinatorics and discrete geometry. She is especially interested in problems that combine tools from several different areas. Symbolic computation and algorithms play a central role in her research. She co-taught with Paul Tseng a course on Combinatorial Optimization in Spring 2003.

**Differential Geometry.** The group in differential geometry covers a broad range of topics, including the study of Einstein's equations of general relativity, the geometry of CR manifolds motivated by complex analysis in higher dimensions, field theories of theoretical physics, and numerical differential geometry.

Robin Graham's research interests revolve around geometric, analytic, and algebraic questions arising in conformal, CR, and related geometries. Recent activity has been centered on understanding Q-curvature and invariant differential operators in conformal and CR geometry, and in the study of conformally compact Einstein metrics. The latter are closely connected to mathematical developments related to the AdS/CFT correspondence in physics, and he has been involved at the forefront of these interactions and developments, including giving invited addresses at a number of conferences and workshops on the subject.

Dan Pollack's research is concerned with the applications of nonlinear partial differential equations to problems in differential geometry and general relativity, particularly with geometric gluing constructions whereby solutions of a nonlinear PDE are analytically combined to form new objects. Two areas in which this work has been extensively pursued are singular Yamabe metrics and surfaces of constant mean curvature in Euclidean three space. This approach has also been applied to the Cauchy problem in general relativity. Here the objects are solutions of the Einstein constraint equations and the results of the gluing constructions, developed by Pollack and his collaborators, yield new solutions to the Einstein field equations.

Jack Lee's recent research has focused on two distinct applications of geometric analysis. The first is to the study of asymptotically hyperbolic Einstein metrics, which arise naturally both in the study of conformal invariants and in the "holography" principle of string theory (by way of the AdS-CFT correspondence). After proving that the conformal infinity of any negatively curved asymptotically hyperbolic Einstein metric can be given an arbitrary (small) perturbation and filled in with a new Einstein metric, Lee and collaborators have shown that under mild restrictions any such metric has a complete asymptotic expansion at infinity. This guarantees that boundary invariants of all orders can be extracted from the behavior at infinity of the interior Einstein metric. Lee is also studying the Neumann boundary problem for the tangential Cauchy-Riemann complex on CR manifolds.

Tom Duchamp's recent research has focused on applications of geometric analysis to geometric problems in statistics and computer science, particularly to the *manifold reconstruction problem*: given a collection of points in Euclidean $n$-space, find a smooth $m$-dimensional submanifold $M$ passing on or near the points. In the special case where $M$ is a surface in 3-space and the points are obtained from a laser scan of a physical object, such as a machine part or a sculpture, this problem is of considerable practical significance. Duchamp and his colleagues in Statistics and in Computer Science and Engineering (CSE) have made major contributions towards the solution of the manifold reconstruction problem for this case.

One outgrowth of this work is a framework for performing numerical differential geometry on compact surfaces. Duchamp and Werner Stuetzle (UW Department of Statistics) have recently applied this approach to the problem of function smoothing on smooth surfaces. Together with Nira Dyn (Tel-Aviv), Duchamp is studying extensions of the theory to 3-dimensional manifolds, and together with colleagues in CSE, Duchamp is exploring possible applications to the real-time solution of problems in elastodynamics.

**Algebraic Topology.** The algebraic topology group currently comprises Ethan Devinatz, Steve Mitchell and John Palmieri. Palmieri was hired in 1999, in response to the departure of professor Paul Goerss to Northwestern. The group has been running an informal student topology seminar for several years, and is host to a large number of PhD theses for a group of its size.

The research of John Palmieri focuses on stable homotopy theory and its applications to algebraic problems. The Steenrod algebra plays a role in a significant part of his work, and provides a connection to the study of modular representations of groups and Hopf algebras. He has recently been collaborating with James Zhang (of algebra) on several papers on $A_\infty$-algebras.

The research of Devinatz focuses on stable homotopy theory; In particular, his work is advancing the understanding and use of homotopy fixed point spectra arising from the action of the Morava stabilizer groups on certain spectra which play an important role in the "chromatic approach" to stable homotopy theory. The goal is to use these homotopy fixed point spectra to detect certain phenomena in stable homotopy theory.

The research of Steve Mitchell lies at the interface of homotopy theory, algebraic K-theory, and algebraic number theory. In particular, most of his recent work is related in one way or another to the Lichtenbaum-Quillen conjectures on the algebraic K-theory of number rings. In addition to recent research papers, he is author of a broad survey paper "K(1)-local homotopy theory, Iwasawa theory and algebraic K-theory", solicited for the forthcoming "Handbook of Algebraic K-theory", which in addition to containing new results presents a vision for the development of this topic.

**Probability.** The Mathematics Department continues to maintain an active group in probability theory. Historically, probability has had a strong representation in the department, including some top researchers in the field, such as Birnbaum, Blumenthal and Pyke. The recent hiring of Zhenqing Chen in 1998 helped reinvigorate the group. The probabilists collaborate with a large number of researchers at other universities in the US and worldwide. They organize the annual Pacific Northwest Probability Seminar, attracting faculty and graduate students from British Columbia, Oregon and Washington. Burdzy and Chen organized a major conference in probability, "Seminar on Stochastic Processes", in the spring of 2003.

The interests of Chris Burdzy lie in Brownian motion and related issues in classical potential theory. His most noted recent work is a counterexample to the so-called "Hot Spots" conjecture, concerning maxima for the second eigenfunction of the Neumann Laplacian on bounded domains in the plane. Burdzy also researches reflected Brownian motion, path properties of Brownian motion and related processes, multiparticle models, continuous branching models, and questions from mathematical physics.

The research interests of Zhenqing Chen lie in stochastic analysis, Markov processes, and their interplay with classical analysis. He has done research on stochastic differential equations, on stochastic models related to reflected Brownian motions, diffusions and stable processes, and on conditional gauge theory and non-local Feynman-Kac perturbations. In recent years, a large portion of his research has been in the study of Markov processes with possibly discontinuous sample paths. This area has seen increased activity due to its applicability to model phenomena with high variability, such as those arising in physics, finance and communications.

The current research interests of Bruce Erickson concern equilibrium results in renewal theory and random walks. Renewal theory concerns time evolution of lattices of particles, where rebirth rates are allowed to depend on the age of nearby particles. Erickson's work involves studying the properties of the large-time limit distributions of such systems. His recent work also includes subordinated random walks and Levy processes, and renewal limit theory for random walks on affine spaces.

Chris Hoffman's research focus has shifted from ergodic theory to discrete probability, with emphasis on models from statistical mechanics. In this area he has established phase transition in a model of dependent percolation, the possibility of mutual unbounded growth in the Richardson growth model, and analyzed simple random walk on supercritical percolation clusters. He has also calculated the mixing time of Markov chains related to the Metropolis algorithm. Hoffman has worked extensively with the Microsoft Theory group. He has co-authored papers with Itai Benjamini, Noam Berger, Elchanan Mossel, and Yuval Peres, while they were visitors or postdocs at Microsoft.

**Numerical Analysis.** The math department has a very active group in numerical analysis, comprising Ken Bube, Anne Greenbaum, and David Ragozin. The group works closely with colleagues in Applied Mathematics. Randy Leveque is a collaborator of Anne Greenbaum, and actively participates in the numerical analysis seminars and conferences. (LeVeque held a joint appointment between Mathematics and Applied Mathematics until becoming full time to Applied Mathematics about two years ago.) Leveque, Bube, Greenbaum, and Loyce Adams of Applied Mathematics were recently co-principal investigators on a DOE grant.

The numerical analysis group organizes the Pacific Northwest Numerical Analysis Seminar, an annual one-day conference for numerical analysts in the Pacific Northwest, usually with one or two outside invited speakers, as well as the Numerical Analysis Research Club. The latter is an informal seminar for graduate students and faculty to read papers and report on them or on topics from their own research.

The research interests of Anne Greenbaum lie in numerical linear algebra and the numerical solution of partial differential equations and integral equations. She has worked on fast methods for solving Poisson's equation and related equations on arbitrary three dimensional domains. Her recent work has focused on nonnormal matrices and what to look at besides eigenvalues to describe the behavior of such matrices. This work involves collaborations with applied mathematicians as well as interactions with people working in areas such as functional analysis and complex analysis. In 1997, Greenbaum received the Bolzano Honorary Medal for Merit in the Mathematical Sciences, from the Academy of Sciences of the Czech Republic. She will co-host a BIRS Workshop on Model Reduction Problems and Matrix Methods, to be held April 3–8, 2004, at the Banff International Research Station.

The research interests of Ken Bube lie in the numerical solution of inverse problems for partial differential equations and related numerical and theoretical problems. One focus of his recent work has been the numerical solution of partial differential equations with discontinuous coefficients. His collaborations include both academic and industrial research geophysicists. In 2002, Bube was elected to the European Academy of Sciences for his work on seismic tomography.

Bube has recently consulted for the Chevron-Texaco Exploration and Production Technology Company, the Z-Seis Corporation of Houston, and the 4th Wave Imaging company. Bube and Greenbaum are supported by a DOE grant for Numerical Methods for Forward and Inverse Problems in Discontinuous Media.

**String Theory.** String Theory has developed in the past decade into an area of tremendous importance in theoretical physics. Its strong dependence on advanced mathematical theory has led to extensive and fruitful interaction between mathematicians and physicists. In mathematics, string theory has led to significant developments, among other areas, in Riemann surface theory, moduli space theory, and Calabi-Yau manifolds.

In 1999, the Department of Physics approached our department with the idea of applying for a University Initiative Fund grant to develop a joint group in string theory. While the grant was ultimately not funded, the idea of developing such a group was regarded favorably by the College, and we were encouraged to pursue the matter through regular hiring channels. String theory was adopted by the department as a priority area, with the goal of hiring two faculty members in Mathematics, preferably one of them senior, to connect to faculty to be appointed in physics.

Physics has made three appointments in string theory, with the hiring of Andreas Karch in 2000-2001, and of Matt Strassler and Mina Aganagic the subsequent year. It has proven more difficult to make an appointment in Mathematics, due to significant competition for a smaller pool of candidates. We were successful in hiring Charles Doran in the 2002-2003 academic year. Doran is spending the current year at Columbia, and will arrive at UW in 2004.

Charles Doran's research focuses on mathematics motivated by the "string dualities" discovered by physicists over the last fifteen years (e.g., Mirror Symmetry). The mathematical structures he studies include Calabi-Yau manifolds, their periods, moduli, and underlying variations of Hodge structure. Doran also investigates arithmetic aspects of these theories, and the emerging relationships between number theory and physics.

With the appointment of Doran in September of 2003, the foundation has been laid for a truly interdepartmental math/physics string theory research group at UW. Doran co-organized, with colleagues in the UW physics department, the first Pacific Northwest String Seminar to be held in Seattle (December of 2003). This event was funded by the Pacific Institute of Mathematical Sciences, the Milliman Fund at the UW Department of Mathematics, the U.S. Department of Energy, and the UW College of Arts and Sciences.

## 6. Relationships With Other Units

The department made a conscious move in the direction of interdisciplinary research, prompted by our 1981 decennial review. Seeking out such opportunities has now become part of departmental culture. The department collaborates with many units and organizations, both on and off campus. Many of our joint projects have already been described in this document; we will not repeat them here, though we will mention a few of them without going into detail.

The ACMS undergraduate degree program is a partnership with the Departments of Applied Mathematics, Statistics, and Computer Science and Engineering.

We are currently in the fifth year of a joint VIGRE grant with Applied Mathematics and Statistics. This grant has brought the three mathematical sciences departments together by joint planning for certain courses, jointly sponsoring VIGRE-sponsored workshops and forums, and forming cross-departmental committees of VIGRE graduate fellows to carry out VIGRE activities. The three departments recently submitted an application to the NSF for another five-year VIGRE grant.

The department's researchers in numerical analysis collaborate with colleagues in Applied Mathematics, on both research and instruction. Probabilists work with colleagues in Statistics. The optimization group has ties to the departments of Applied Mathematics, Industrial Engineering and Business. Researchers in inverse problems work with colleagues in Applied Mathematics, Radiology, and Earth and Space Sciences. Members of the department also work with other units on campus such as the Center for Bioengineering, the Applied Physics Laboratory, and Genome Sciences.

We are working with Physics to build a strong interdepartmental group in string theory.

One of the most exciting developments of the past decade has been the emergence of the Theory Group at Microsoft Research as a partner in mathematics research. Department faculty in several research areas, in particular combinatorics, probability and complex analysis, work closely with the group and visitors. The group contributes to our graduate program through the courses they teach, seminars, and other support.

Department members cooperate with colleagues in other universities in the region, and with industrial mathematicians. Pacific Northwest Seminars have long been a tradition in differential geometry, probability, optimization, numerical analysis and combinatorics, among other areas. These meetings are typically held twice a year, often over a weekend.

In only seven years, PIMS has become a major international mathematical force. It is a distributed institute based at the University of British Columbia that also has operations at the University of Victoria, Simon Fraser University and four other western Canadian universities. Members of our department have long had ties with colleagues at these institutions. Since joining PIMS three years ago, we have strengthened those ties by forming PIMS Collaborative Research Groups, broadening the Pacific Northwest Seminars, starting exchange programs and training workshops for graduate students. Banff International Research Station is a recent collaboration between PIMS and the Mathematical Sciences Research Institute (MSRI) in Berkeley. Members of the department have been active in MSRI since its inception over twenty years ago. (We were among the original eight academic sponsors, which now number 72.) The partnership between MSRI and PIMS represented by BIRS is a natural fit for us, and the University of Washington took the lead by helping to organize 11 of the 40 workshops held during the first year of operation of BIRS in 2003. The successful collaboration of US and Canadian mathematical communities in BIRS is a model we intend to emulate with the rest of our participation in PIMS. Our recently submitted VIGRE proposal, if funded, would be a major step in this direction.

Several members of the department have had long-term consulting relationships with companies such as Chevron and Boeing. Department faculty are involved in collaborations with colleagues all over the world. These collaborations are too numerous to list here.

The department's outreach to K-12 education involves many local partnerships, as well as some national ones. The annual Mathday, currently in its fourteenth year, brings 1200 high school students to campus for a day of lectures, demonstrations and other activities related to mathematics and its applications. The NSF-supported Research Experiences for Undergraduates (REU) summer program has been an annual event since 1988. Both activities are led by Jim Morrow. The REU has a national reputation and attracts students from all over the country. Several UW undergraduates participate as students each year, and some return as assistants. The VIGRE grant has contributed to the participation of UW students during recent years. The REU program has been very successful in introducing students to research, encouraging independence in developing research projects, and training students to communicate their ideas. The great majority of participants go on to graduate school in science or mathematics, and some point to the REU experience as a turning point.

The department has partnered with other UW units and six school districts in two major NSF-funded projects, Creating a Community of Mathematics Learners (CCML) and Expanding the Community of Mathematics Learners (ECML). CCML focused on middle and high school education. ECML concentrates on elementary schools. In each case, the project aims to establish and sustain a community of teachers for the purpose of improving the instruction and learning of mathematics.

Another NSF-funded program, the GK-12 project, has been a successful part of our outreach for four years. The program partners graduate students with elementary and middle school teachers in two local school districts, Seattle and Northshore, to develop and implement mathematics curricula. Loyce Adams of Applied Mathematics is the PI of the project. The success of the project motivated us to propose expanding it in a proposal submitted last spring to the NSF. Ginger Warfield, who has been a Co-PI all along, will devote more time to the project, as will faculty from other UW units. There will also be release time of 5% for several other department faculty. In addition to its obvious importance to the K-12 community, this program provides a valuable broadening experience for the graduate students who wish to participate.

From 1994 to 2002 the department engaged in Preparing Future Faculty (PFF), an activity that was funded first by a grant from the NSF then by a grant from the Pew Charitable Trust. PFF partnered graduate students with faculty at Seattle University and Central Seattle Community College to observe and work on teaching and educational issues at those institutions. A very popular and effective PFF activity consisted of dinners that brought department faculty and graduate students together for informal discussions at a local restaurant. We are continuing these dinners with department funds. We are also continuing the community college interaction through the participation of students enrolled in Math 501/2/3, the graduate special topics course in teaching and learning mathematics.

The Community College Educator's Sabbatical Program brings community college faculty to the department during their sabbatical leaves. The participants typically teach one calculus course per quarter, bringing their salary up to 100%. The resulting dialog between participants and department members is of benefit to both parties. Five community college instructors have participated in this program, now in its third year. During the current 2003-04 academic year, Debbie Nichol (Skagit County Community College) and Rick Downs (South Seattle Community College) are involved in the program.

The department collaborates with a group of secondary mathematics teachers from all over the state on Northwest Mathematics Interaction (NWMI). NWMI organizes a summer training program for high school teachers of geometry, as well as workshops during the academic year. This program, led by Jim King and supported by an Eisenhower grant from the Washington Superintendent for Public Education, is in its ninth year. It is affiliated with the IAS/Park City Mathematics Institute. Jim King and Ginger Warfield also lead the department's participation in the Teaching/Learning Partnership of the College of Education.

Summer Institute for Mathematics at the University of Washington debuted in the summer of 2003. It brings twenty-four high school students from Washington, British Columbia, Oregon, Idaho and Alaska to UW for six weeks of mathematics courses, special lectures and other mathematical activities. This privately-funded program will continue in 2004.

# 7. Diversity

The department recognizes that in order to maintain excellence, we have to recruit the most talented research mathematicians and students that we can. Subpopulations that are underrepresented within the mathematics community form a vast, largely untapped source, and our department is continually exploring ways to recruit from these.

Nationally, about 20% of recent PhD recipients in mathematics are women, and women constitute close to 30% of our graduate applicant pool. In contrast, members of minorities form a very small percentage of each group, and the competition to recruit them is fierce. We have focused our diversity efforts on increasing the representation of women on our faculty and in our graduate program, and on recruiting members of minorities into our undergraduate program. We believe that this approach is the most effective use of the resources available to us.

**Diversity of the Faculty.** The department has made a significant effort towards increasing the number of women tenure-track faculty. With the support of the college and university administration, we have increased this number from one in 1992, to six in 2003. The number is still smaller than we would like, and hiring women remains a priority. Table 1 gives the composition of department faculty by rank and gender.

| | All tenure track | Prof | Assoc. Prof. | Asst. Prof. | Lecturer | AAP |
|---|---|---|---|---|---|---|
| Men | 45 (88%) | 34 (94%) | 9 (75%) | 2 (67%) | 1 (25%) | 2 (67%) |
| Women | 6 (12%) | 2 (6%) | 3 (25%) | 1 (33%) | 3 (75%) | 1 (33%) |

Table 1. Current composition of faculty of Mathematics.

To successfully recruit women mathematicians of high research caliber has required extra efforts above and beyond our usual hiring procedures. One of our senior faculty was originally hired at the tenure track level as part of a joint offer. The College assisted in this hire by making an extra position available to the department, as part of its policy to assist in the hiring of couples. Subsequently, the department took the rare step of hiring at the level of Professor, and was able to attract a woman candidate from a research position at a prominent university.

Three women faculty members were hired within the past four years. Two were appointed at the level of assistant professor, one of whom has since been promoted to associate professor. In this case, we were able to attract the candidate from a tenure track position at a respected institution; her spouse was offered a postdoctoral position in another department. Most recently, the department succeeded in recruiting a candidate from an associate professor position at MIT, by offering a tenured position at the Associate Professor level. We also competed in this case with an offer from a top quality public university. The administration worked with the department by making available a position, and offering a salary commensurate with the other offer.

We made a tenured offer last year in an effort to attract a candidate from a major private university. This offer was at a very competitive salary, and included a number of other incentives. It was made possible by combining support from the mathematics department, the physics department, additional College and Provost funds, as well as support from the ADVANCE Center for Institutional Change. Ultimately the candidate chose to remain at her university.

Table 2 gives a complete list of appointments made since 1990.

| **Year** | **Women** | **Men** |
|---|---|---|
| 1990 | — | Monty McGovern |
| | — | Paul Tseng |
| 1991 | — | Ethan Devinatz |
| | — | Hart Smith |
| 1992 | — | Boris Solomyak |
| 1993 | — | — |
| 1994 | — | James Zhang |
| 1995 | — | — |
| 1996 | Tatiana Toro | Daniel Pollack |
| 1997 | Anne Greenbaum | — |
| 1998 | — | Eric Babson |
| | — | Zhen-Qing Chen |
| | — | Steffen Rohde |
| 1999 | — | Christopher Hoffman |
| | — | John Palmieri |
| 2000 | Rekha Thomas | Sándor Kovács |
| 2001 | — | Yuan Yu |
| 2002 | Lisa Korf | — |
| | Sara Billey | — |
| 2003 | — | Charles Doran |

Table 2. Recent tenure-track appointments in Mathematics.

As we have already indicated, our recruitment and retention efforts benefit from participation in the NSF-funded ADVANCE Center for Institutional Change (`http://www.engr.washington.edu/advance/`). In addition to assistance with the above offer, ADVANCE funds have been used to support a tenure track professor, and more recently to provide teaching release time to a professor with a newborn child.

**Diversity of Graduate Students.** At the graduate level, recruiting and retaining qualified women applicants to our graduate program continues to be a priority. Currently, 21 of 83 full-time students in our program are women, and 2 students declare themselves as being members of a US minority.

| | US | International | All |
|---|---|---|---|
| Men | 42 | 21 | 63 |
| Women | 10 | 10 | 20 |

Table 3. Composition of current grad student population.

These figures are consistent with the composition of the applicant pool, which for 2002-2003 was as follows. Of a total of 127 US citizens, 27 were women, 6 Asian-American (3 women), 2 were Hispanic-American men, 89 were Caucasian, and 30 were“not indicated”.

In order to increase minority representation in future entering classes, we plan to make better use of the national database of McNair Scholars. By targeting the mathematics majors among them in the fall quarter, we hope to significantly increase minority representation in our applicant pool. We will also target recipients of the UW CSEMS scholarships (see below) for possible recruitment to our graduate program.

The Department is also an active participant in the Graduate Opportunities & Minority Achievement Program (GO-MAP) at University of Washington, and in recent years we have been able to award one GO-MAP fellowship to an entering female graduate student in mathematics. We are grateful for this support for helping us to compete for highly qualified women applicants with other universities that in many cases offer multi-year fellowships. The main focus of our diversity efforts at the graduate level is to increase the representation of highly qualified women in the program. Currently, 25% of our graduate students are female. This is close to the national average of 30%.

**Developing an Atmosphere of Inclusiveness.** The department facilitates inclusion of graduate students in its mathematical life in a number of ways, which we have described in earlier sections. In addition, the department has a tradition of daily afternoon teas at which students and faculty can interact in an informal setting. A fortnightly Women in Math luncheon, initiated and run by Lisa Korf, is in its third year. This activity is designed to provide an opportunity for graduate students and faculty to discuss issues pertaining to being a woman mathematician, and create a sense of community among the women within and outside the department who are working in mathematics. The department's Diversity Committee, chaired by the graduate program coordinator, oversees our diversity efforts.

**Diversity of Undergraduate Students.** UW was awarded NSF Computer Science, Engineering, and Mathematics Scholarship (CSEMS) grants in 2000 and in 2003, with Ed Lazowska of CSE as PI and Tom Duchamp of Mathematics as a co-PI. The UW CSEMS scholarship program is managed by the Student and Community Relations (SCORE) advising center in the College of Engineering. Applicants must be enrolled in one of the ten engineering disciplines or a mathematical science (ACMS, Computer Science, Mathematics, or Statistics). The program grants scholarship awards on a competitive basis to 40 needy, that is, Pell Grant eligible, students each year. Of the recipients, about 33% are women and about 16% are either African American or Hispanic. Six of the scholarships awarded last year went to students in ACMS or Mathematics.