Department of Mathematics
College of Arts and Sciences
University of Washington, Seattle

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Contents

CHAPTER 1

Introduction

1.1. Values, Mission, and Diversity Commitment

We open with a description of the nature of mathematics, taken from the department's strategic planning document prepared in 2000.

Throughout its long history, mathematics has been characterized by universality. It has been developed simultaneously in all major civilizations and cultures, including ancient Egypt, Babylon, India, and China, and it continues to be studied and developed in countries around the world, regardless of their levels of economic or technological development. In addition, mathematics has provided a model for rational thought and a language for science and technology. Mathematics was given a logical foundation by Greek mathematicians over two thousand years ago. Their axiomatic approach was codified in Euclid's *Elements*, perhaps the most widely studied and translated non-religious text in history. Axiom-and-proof as a means of establishing knowledge gives mathematical truth its special character, ensuring that mathematical results obtained over several millennia remain significant today. This gave mathematics its prominence as part of a classical education in the past and its position as part of a liberal arts education today. At the same time, mathematics is the primary tool in the development of the physical sciences, as has been recognized since Isaac Newton developed calculus in the seventeenth century as a means of determining the orbits of the planets. Mathematics underlies the explosive growth in technology of the past two centuries, has spawned the more recent revolution in computation, has gained a fundamental role in the life sciences, and is essential to the social sciences as well.

As part of the department's 1999–2000 planning exercise, we came up with a set of values and a mission statement that continue to describe much of what we do and cherish. We state them below, then offer some updates.

Statement of Values:

(1) Mathematical research, pursued both to meet intrinsic mathematical needs and in the context of potential applications, contributes essentially to society.
(2) K-12 and undergraduate mathematics education creates a technically literate society, fostering advances in mathematics, science, and technology; graduate mathematics education lays a foundation for mathematical research, applications, and teaching.
(3) Mathematical outreach activities contribute to the creation of a broad-based, mathematically literate community in Washington State.

Explanation of Values:

Mathematical research, pursued both to meet intrinsic mathematical needs and in the context of potential applications, contributes essentially to society.

Mathematics has an intricate web of internal interconnections that have given rise to its many theorems and unsolved problems. The best new mathematics arises through the further development of this mysterious web; at the same time, profound applications of mathematics have arisen from mathematical research done initially for intrinsic mathematical purposes, often after a delay of as much as half a century. Research pursued according to the internal logic of mathematics is necessary in order to ensure the existence of tools for further applications. Because mathematics is the underpinning of science, engineering, and technology, the continuing vitality of these fields is tied to mathematical development. In turn, mathematical research benefits by the interplay between mathematics and these fields, with some mathematical research directed towards the application of mathematical tools to scientific and technological problems.

K-12 and undergraduate mathematics education creates a technically literate society, fostering advances in mathematics, science, and technology; graduate mathematics education lays a foundation for mathematical research, applications, and teaching.

A mathematically and technically literate citizenry is essential, both for effective participation in society and as the ground from which new scientific developments can sprout. For such a citizenry to develop, a mathematical foundation must be laid at the K-12 level. Students can build on this foundation as undergraduates to prepare for further study or careers in the physical sciences, life sciences, social sciences, engineering, business, or education. Students receiving graduate degrees in mathematics are the future contributors to mathematics research and applications at universities, in government, and at corporate research centers; they also become teachers at research universities, four-year colleges, community colleges, and schools, where they shape new curricula and educate students.

Mathematical outreach activities contribute to the creation of a broad-based, mathematically literate community in Washington State.

Dialogue between university mathematicians and secondary mathematics teachers is essential, so that secondary teachers can be kept aware of the needs of students entering university and so that university faculty can understand the challenges facing secondary educators. Faculty can help teachers meet these challenges and use developments at the secondary level in the design of university courses. University faculty must also work with elementary educators to ensure understanding of the nature of mathematics and emphasis on suitable mathematical concepts and techniques.

Mission Statement:
The Department of Mathematics is committed to excellence in the development and dissemination of mathematical ideas. In particular, the department will:

(A) Continue a rich tradition of research in mathematics and its applications,
- maintaining and building a broad range of mathematical research groups of international stature while
- improving the quality and vigor of research interactions within the department, with other units on campus, nationally, and internationally.

(B) Offer high-quality mathematical education at all levels,
- providing innovative instruction in entry-level and intermediate courses;
- developing a diverse program of upper-level courses for mathematics majors and other students with mathematical interests; and
- maintaining a vibrant graduate program that prepares students for a variety of mathematical careers.

(C) Pursue opportunities for outreach in the Puget Sound region and Washington State,
- working with schools and community colleges to provide a coherent mathematics education for Washington students while
- strengthening research and educational ties with commercial users of mathematics.

That was our view of ourselves in 2000, and it remains a valid representation of what we do and what we wish to do. However, there is one glaring omission: explicit recognition of the importance of diversity. This was rectified two years ago, when the department adopted the following two-paragraph statement.

Diversity Commitment:
A commitment to diversity is central to the academic mission of our department. We take diversity to be the expression of a wide variety of values, perspectives, and experiences that reflect differences of culture and circumstance. Such differences may include race, ethnicity, religion, gender, age, abilities/disabilities, gender identity, sexual orientation, and socioeconomic status.

A mix of individuals contributes diverse perspectives which enrich the intellectual environment. Science in general and mathematics in particular benefit when confronted with input from different sources. Moreover, a department whose constituency reflects society is in a better position to serve the community at large. We acknowledge the important need to overcome barriers to the recruitment, retention, and advancement of talented students and faculty from historically underrepresented groups.

Another significant change since 2000 has been the explosion in job opportunities for mathematically skilled graduates at all degree levels. Mentioned above is the opportunity to work in government and at corporate research centers, but now many of our best graduates—whatever their intentions when they arrive here—are being recruited by Facebook, Google, Amazon, and many other companies we would once not have imagined as prospective employers, if we even imagined their existence.

1.2. Where We Stand

In this section we will introduce issues that we would like you to have in mind as the site visit approaches, issues that concern us day to day as we plan our programs, prepare our budget, staff our courses, hire new faculty, and raise funds. We organize them under three headings: Faculty Demographics, Student Demographics, Intersection of the Two.

Faculty Demographics. We have four categories of faculty: professors, lecturers, acting assistant professors, and part-time lecturers. Professorial faculty have the usual three ranks: professor, associate professor, and assistant professor. Lecturers are typically appointed via a national search and have three ranks as well: principal lecturer, senior lecturer, and lecturer. These are full-time positions with faculty voting rights and appointment terms ranging from one year to five. All our lecturers have three-year or five-year terms. Acting Assistant Professor is the title we use for the faculty we hire into postdoctoral positions. We should explain that it is the norm in mathematics nationally for new and recent PhDs to take positions in which they do a mix of teaching and research, the teaching load ranging from perhaps half-time if alternative funding is available (an NSF postdoctoral fellowship or other sources) to full-time, which is to say, equal to what our professorial faculty teach. At the moment, several of our postdocs have reduced loads, but most teach the same load as our professorial faculty. We do not put them in our entry-level classes, assigning them to smaller classes at the 300 level or higher. Finally, part-time lecturers are just that: part-time. They do not have voting privileges, longer-term appointments, or a path to promotion.

In 2005–2006, we had 49 professorial faculty: 33 professors, 13 associate professors, and 3 assistant professors. We had 6 faculty in the lecturer ranks: 2 senior lecturers and 4 lecturers. Helping us to teach were 5 postdoctoral acting assistant professors, with another 4 part-time lecturers. In comparison, for 2015–2016, there are 44 professorial faculty: 34 professors, 6 associate professors, and 4 assistant professors. We have 7 faculty in the lecturer ranks: 2 principal lecturers, 3 senior lecturers, and 2 lecturers. Helping us to teach are 12 postdoctoral acting assistant professors, 1 NSF postdoctoral fellow, and 4 part-time lecturers.

Note that these counts are of people, not all of whom are 100% employed or 100% in our department. The count of full-time equivalent (FTE) faculty is a bit lower, given that one professor has been at 2/3-time throughout the decade, and that in this year's count we have one assistant professor split 50-50 between Mathematics and Statistics, one assistant professor split 2/3-1/3 between Mathematics and Computer Science & Engineering, and one senior lecturer who has dropped to 50%. Likewise, some of our current postdoctoral AAPs and the NSF fellow teach 50% time. Thus a comparison of FTE faculty in terms of employment or teaching responsibilities would yield 48.33 professors in 2005–2006 versus 42.83 now, 6 lecturers then versus 6.5 now, and 5 postdocs then versus 10.5 now. Our professorial faculty size has dropped by 5.5 FTE, with much of this shortfall—in terms of

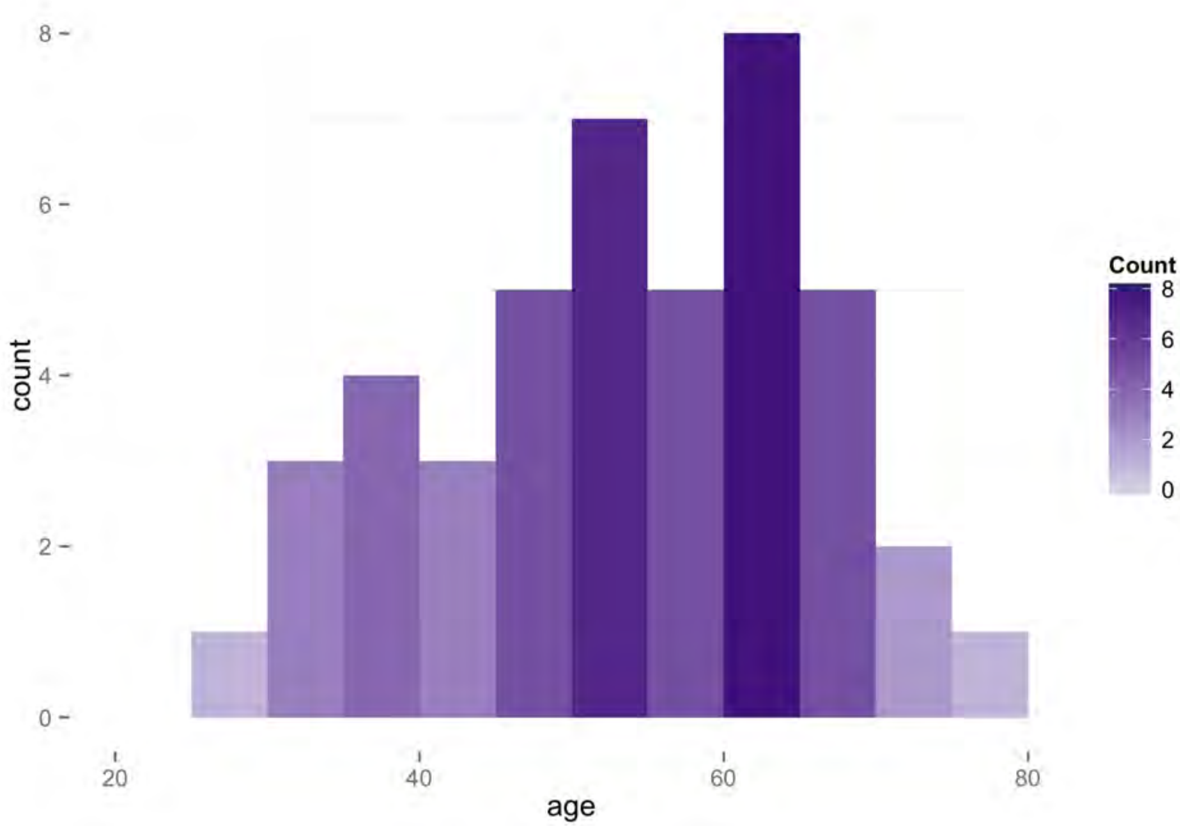

FIGURE 1.2.1. The age of our professorial faculty, December 2015.

undergraduate teaching effort—replaced by postdoctoral hiring through an increase from the College in temporary instructional funds.

We should also note the fragility at any given time of our corps of part-time lecturers. We rely on them to ensure that our courses are taught, but they cannot rely on us for long-term employment. Fortunately, we are now in a period of apparent stability, but if temporary instructional funding were to drop, they might find alternative options and be lost to us.

Figure 1.2.1 shows the age distribution of the professorial faculty. A review of the data suggests that we have a disproportionate share of professors within a decade of retirement and can anticipate one or two retirements per year in that period. We must be (and have been) giving thought to the areas of strength in our department, the extent to which we value maintaining them as areas of strength, and what emerging new areas we should explore as opportunities to build.

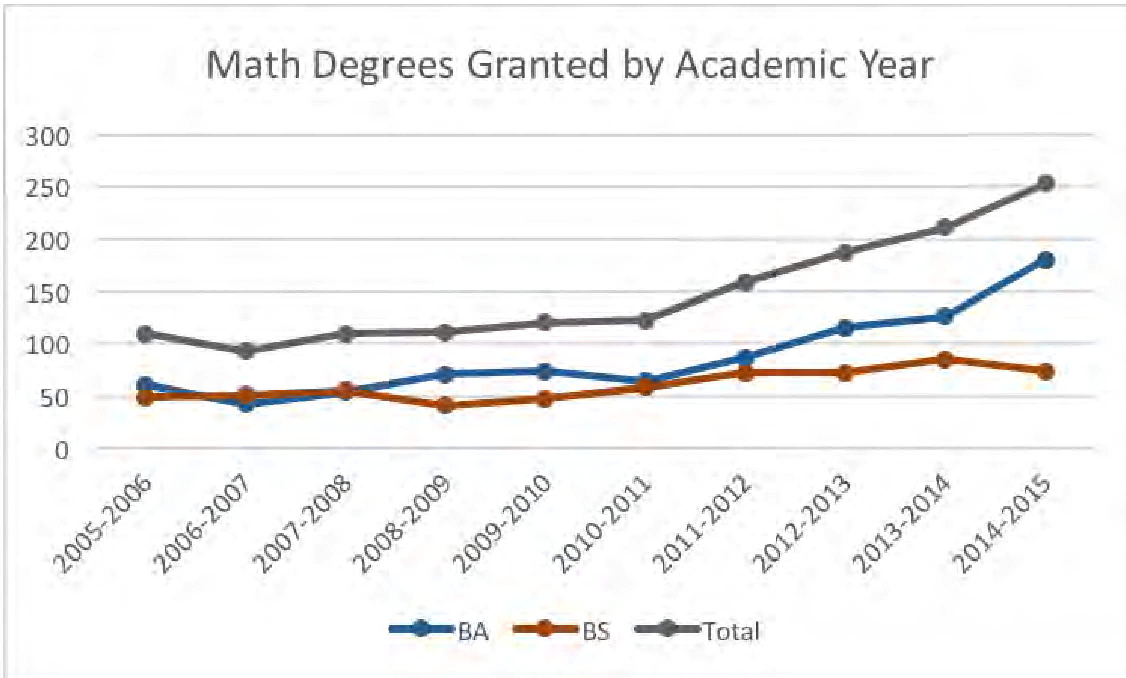

FIGURE 1.2.2. Mathematics degrees awarded, 2006–2015

Student Demographics. We have two BS degree programs, the Comprehensive and Standard, and three BA programs, the Standard and Teacher preparation plus a small Philosophy option. These will be described in more detail in Section 2.2. In addition to these five degrees in mathematics, there is a separate degree program that we offer jointly with the Departments of Applied Mathematics, Statistics, and Computer Science & Engineering, the BS degree in Applied and Computational Mathematical Sciences, or ACMS.

In 2005–2006, we had 109 students completing degrees in Mathematics, divided between 49 BS degrees and 60 BA degrees. In 2014–2015, the numbers had risen to 253 degrees, with 73 BS degrees and 180 BA degrees. Figure 1.2.2 shows the growth year-by-year over the past decade. If we count mathematics majors (choosing Spring Quarter as the moment to do the count) instead of graduates, we find there were 342 in 2006 (237 BS, 105 BA) and 798 in 2015 (365 BS, 433 BA). The numbers year-by-year for the decade are graphed in Figure 1.2.3. The dramatic growth speaks for itself, but of equal significance is how much of the growth has been in the BA degree.

The ACMS program has grown as well, although the growth was momentarily dampened three or four years ago when entry became competitive, with a goal set of 200 majors. The number of degrees rose from 50 in 2005–2006 to 116 in 2011–2012 and 107 in 2012–2013, then dropped to 71 in 2014–2015. Counting ACMS majors instead, we find an increase from 103 in Spring 2006 to 327 in Spring 2011, then a drop over two years to 189, followed by increases the past two years to 204 and 220.

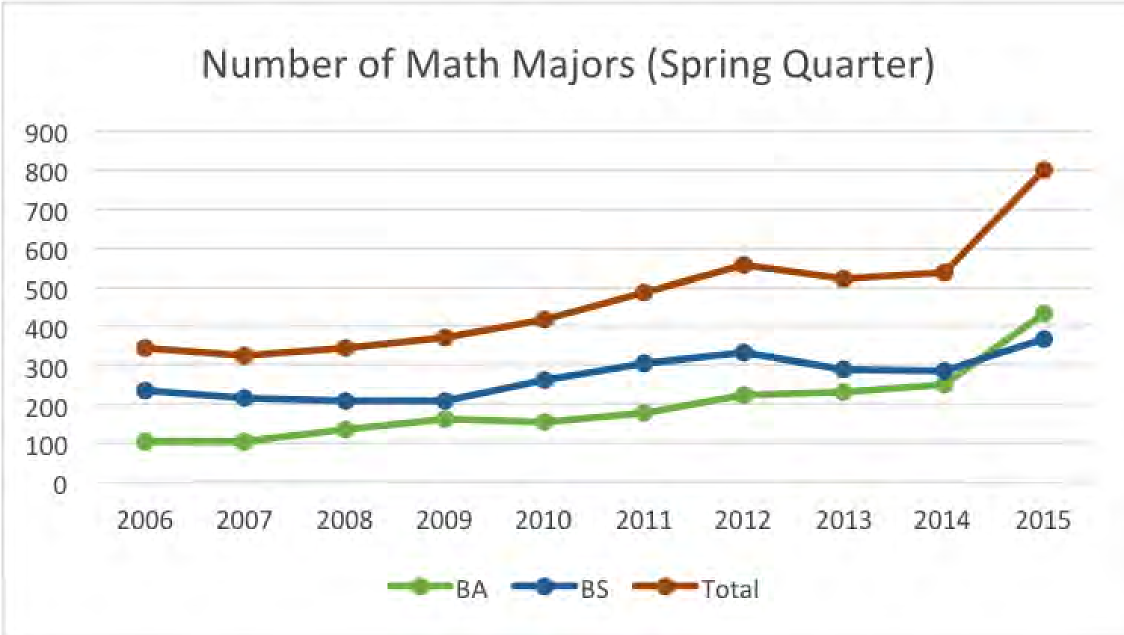

FIGURE 1.2.3. Mathematics majors, 2006–2015

Let's have a look at some peer data on number of Bachelor's degrees awarded. The American Mathematical Society conducts annual surveys in which it collects information about departments, faculties, and students in the mathematical sciences at four-year colleges and universities in the United States. Departments are categorized as public or private and (based on the number of PhDs granted) as large, medium, or small. We are in the Math Public Large category, along with 25 other leading public universities. The AMS aggregates the data, so that institution-to-institution comparisons are not possible, but still, we can compare our growth in undergraduate degrees to aggregate growth.

The 2014 survey has just appeared, as this self-study is being completed. It shows that 28,277 undergraduate degrees were awarded by all mathematics departments combined between July 1, 2013, and June 30, 2014. The 2005 survey found 24,300 degrees awarded, suggesting an increase of a little over 16%. Included in these counts are statistics and computer science degrees offered by mathematics departments, as many do at undergraduate colleges without separate departments in the other fields. More useful would be a count of the increase in undergraduate degrees awarded by Math Public Large departments, but this number is not available, all the more because the American Mathematical Society changed their system for grouping of departments three years ago. While our growth is much faster than across all departments, it may not differ so much compared to our peers.

Fortunately, we do have some peer data, because we were given access to data the AMS collected last year in collaboration with the University of Tennessee in which chairs of large public mathematics departments were surveyed, with the information left unaggregated. Not all institutions responded, but among those that did were UC Berkeley, UC San Diego, UC

	2012-13		
Institution	Female	Male	Total
University of Washington	90	198	288
University of California, Berkeley	75	166	241
University of Michigan, Ann Arbor	85	144	229
University of Minnesota - Twin Cities	63	134	197
University of Illinois, Urbana-Champaign	89	103	192
University of Maryland, College Park	57	131	188
Ohio State University, Columbus	68	100	168
Purdue University	68	99	167
University of Texas at Austin	73	78	151
Pennsylvania State University	33	93	126
University of California, San Diego	48	74	122
University of Wisconsin, Madison	42	77	119
University of California, Santa Barbara	46	72	118
Texas A&M University	48	56	104
Indiana University, Bloomington	35	68	103
University of Iowa	56	32	88
North Carolina State University	24	60	84
University of California, Davis	11	61	72
Michigan State University	24	47	71
University of Illinois at Chicago	18	32	50

FIGURE 1.2.4. Mathematics degrees in 2012–2013 at "Public Large" peers

Santa Barbara, Illinois, Maryland, Michigan, Minnesota, Ohio State, Penn State, Purdue, Wisconsin, and Texas. This forms a meaningful peer data set. Thanks to the survey, we can look at the numbers of degrees awarded in 2012–2013. The table in Figure 1.2.4 shows that we produced 288 degrees (presumably the sum of Math and ACMS), which to our surprise places us #1 among schools responding. It may be that some non-respondents, such as UCLA, are larger, but we are among the largest.

With the growth in our majors, our teaching effort has grown as well. We can measure this in student credit hours, comparing the numbers for 2006–2007 with those for 2014–2015. At the 100 level, our 2006–2007 student credit hours were 44,029. Last year, they had risen to 49,629. In line with the increase in majors, there is more significant growth at the upper undergraduate level. Combining 300- and 400-level courses, we find 15,392 student credit hours taught in 2006–2007 and 27,270 last year, an increase of 77%. Given the unexpectedly large size of this year's freshman class, we may be in for another jump next year.

The overall size of the graduate program has changed little over the decade, but PhD productivity rate has increased. Taking a three-year rolling average over the past twenty years, we find the number of graduating PhDs was typically between 5 and 7 from 1995–1996 to

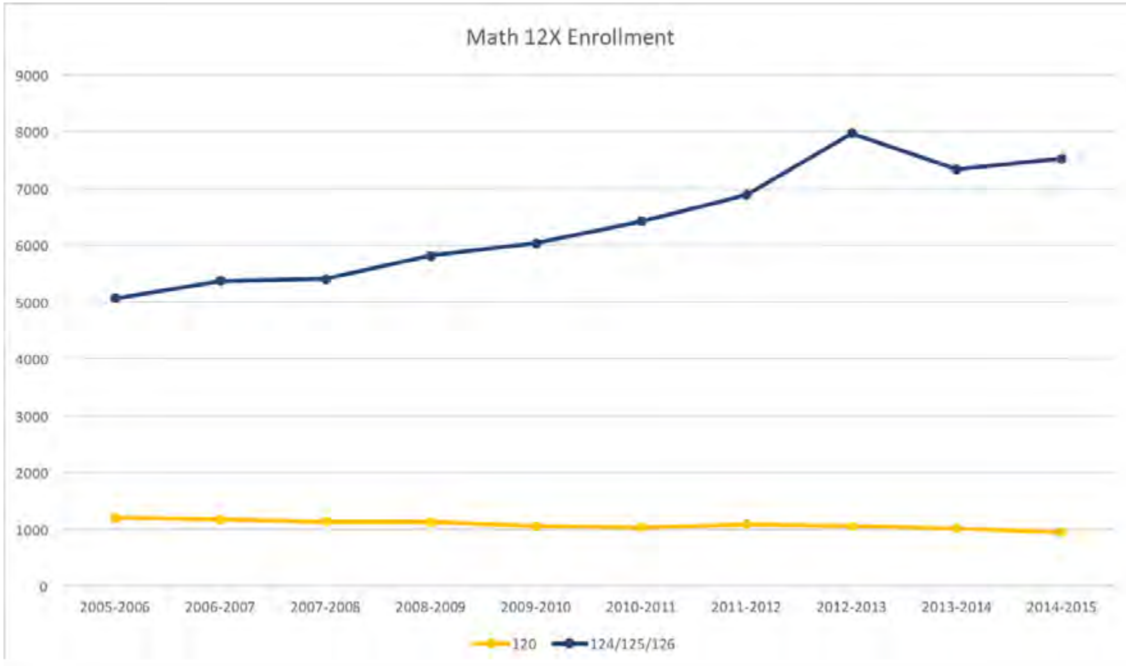

FIGURE 1.2.5. Math 120 and Math 124–125–126 enrollments

2004–2005. It increases to 9.33 in 2005–2006, then 11 in 2006–2007, staying largely in the range of 11 to 13 for the next few years, then increasing to 14.66 in 2013–2014 (based on PhD numbers of 19 in 2013–2014 and 18 in 2014–2015).

The Intersection of the Two. With a significant increase in student credit hours and a parallel decrease in professorial faculty, it is something of a mystery how we have succeeded (for the most part) in meeting demand. Let's take a closer look at some data.

A detailed description of our courses is given in Section 2.3. As described there, our core calculus sequence is Math 124–125–126. One step in a major revision of calculus in the late 1990s, with full support and increased funding from the College, was to reduce class size in Math 124 and Math 125 from 160 to 80, as both underwent a thorough overhaul. We kept Math 126 class size at 160.

Total enrollment in Math 124–125–126 has seen a steady rise over the past decade, as shown in Figure 1.2.5 (putting aside the unexpected bump in 2012–2013). At the same time, there has been a slight drop in enrollment in Math 120, our precalculus course, perhaps explained by the increase in academic quality of our freshmen.

In 2005–2006, across all three academic quarters, we taught 61 sections of Math 124–125–126. Of these, 35 were taught by professors, 10 by lecturers, and another 16 by part-time lecturers and AAPs. As part of our response to cuts following the financial crisis of 2008, we increased Math 124–Math 125 class size to 120. More recently, as you will read later, we added an online calculus option for each of the three calculus courses, with class size this quarter as large as 240. Given the increase in total enrollment in calculus, despite the larger class sizes, we are offering 57 sections this year (in class and online). Of those, 37 are being taught by professors, 19 by lecturers, and 1 by a part-time lecturer. We may conclude from this that our regular faculty—professors and lecturers—are doing much more teaching of calculus than a decade ago.

A more dramatic change is at the 300 level, especially with the growth in the four service courses, Math 307–308–309 and Math 324, which treat differential equations, linear algebra, and multilinear/vector calculus. In 2005–2006, we taught 87 sections of 300-level classes. This year, we are teaching 155 sections. Figure 1.2.6 shows the increase in enrollment in these four classes combined between 2005–2006 and 2014–2015, along with enrollment increases in the 300-level courses for majors and the 400-level courses.

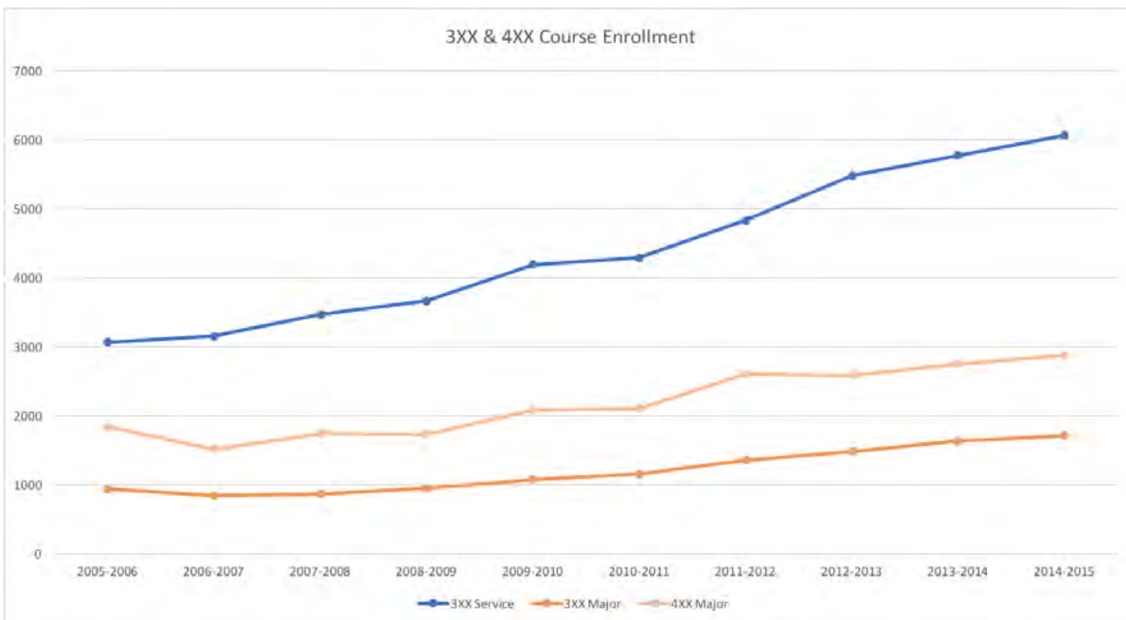

FIGURE 1.2.6. Math 300-level service, 300-level major, and 400-level major enrollments

As already noted, one essential step in accommodating enrollment growth has been an increase in hiring of recent PhDs into postdoctoral positions as acting assistant professors. Figure 1.2.7 illustrates how the distribution of faculty in 300-level courses has changed. Professors taught 41 sections a decade ago, but just 14 this year. To make up this difference and also meet the huge new demand, we have increased the number of sections taught by lecturers from 2 to 14, the number taught by part-time lecturers from 12 to 25, the number taught by AAPs from 8 to 37, and the number taught by TAs from 24 to 65. Much of this increase in instruction is made possible by a mix of new permanent and temporary funding made available to the department since the financial crisis.

During this same decade, there has been a modest decrease in courses taught at the 400 and graduate levels by professors. The essential elements that have changed are increased number of calculus students taught by professors and a significant decrease in sections taught by professors at the 300 level. This is consistent with the drop in professorial FTE from 48.33

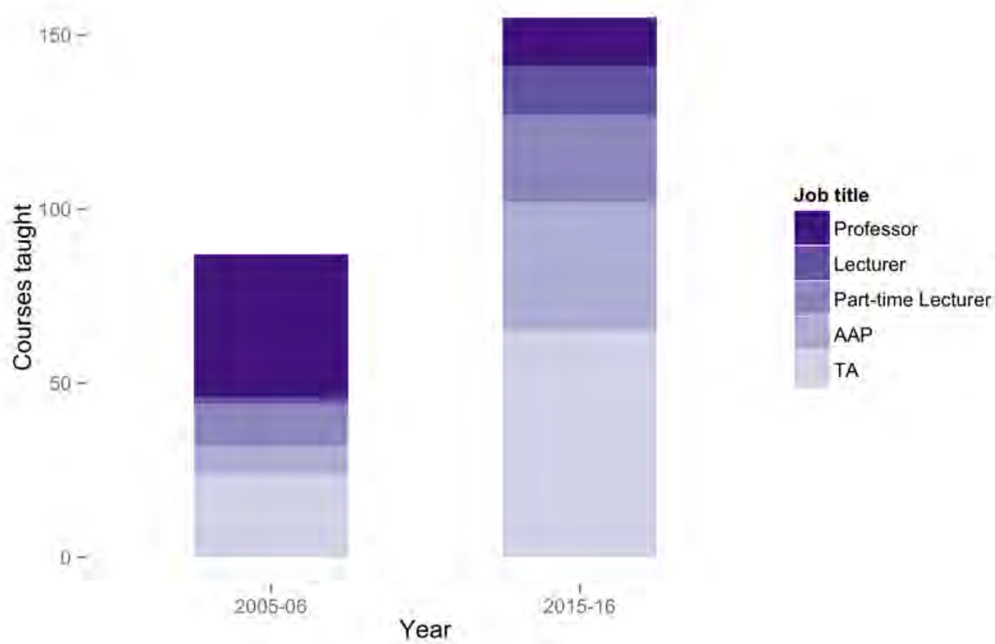

FIGURE 1.2.7. 300-level courses taught by job title, 2005–06 vs 2015–16

to 42.83, or 5.5. As you will learn in Section 4.2, we have a teaching load system that is based on assigning weights to different courses, with the 300-level service courses carrying the minimum weight (and calculus the maximum). Based on our weighting system, 5.5 professors teaching exclusively 300-level service courses would teach 27.92 such courses in a year, almost exactly the dropoff we have seen. In effect, we have concentrated the lost professorial teaching at the 300 level, replacing it largely by an increase in AAP hiring and an increase in TA assignments at this level. One consequence has been that we have not given the 300-level service courses the attention they deserve in terms of possible revisions. This is an area that requires attention, a point to which we will return in Section 2.6.

We can discuss at length (and we do) the benefits or disadvantages of this shift, asking what the optimal mix of teaching resources is, how many professors we should have versus lecturers, and so on. But whatever answers come out of such a discussion, what is certainly the case is that the current mix of instructional positions is markedly different from a decade ago. What it should look like in the years to come is very much of central concern as we chart our future course.

As we have changed, so too have our students. The numbers tell only part of the story. The steady drumbeat of STEM education as the path to informed citizenship, employment, and happiness (and who are we to argue—we're living proof that it works) brings an increasing number of students to our door. Many sample our wares before moving on to majors in engineering and across the sciences. Some, who did not intend to stick around, do so when other doors close, realizing that they have already made significant progress toward completion of our degree requirements and so may as well give it a go. This is a likely explanation for why so much of our majors growth is in the BA degree. We are generally happy to have them stay. But some eventually figure out that it is not the best fit, as their interests and our offerings do not match up so well.

Let us add that there are those who, having stumbled in the door, discover that they love and have a talent for mathematics. They go on to major in it or perhaps double major with another field such as computer science, excel in our most demanding courses, and take advantage as well of some of the other research or exploration activities we offer (to be described in Section 2.4). The excellence of our majors is best illustrated by the astonishing fact that 12 of the past 14 recipients of the College of Arts and Sciences Dean's Medal in the Natural Sciences—awarded to the best graduating senior—have been mathematics majors or joint majors.

Some of our majors, especially at the BA level, are focused more on computational courses, anticipating careers in the tech industry or finance where abstract reasoning and theorem proving may be less appreciated. Yet, abstract reasoning and theorem proving are what we do: because it's what we love, because it is fundamental to the nature and beauty of mathematics, and because it underlies mathematics' effectiveness as a tool in service to other disciplines. For the last reason, at the least, we expect students to learn this way of thinking as part of their studies.

The result is a bit of a mismatch between student demand and faculty interest. This is most visible in the unending demand for more computationally based (or more elementary) electives such as Math 394 (first quarter of probability, taught jointly with Statistics) and Math 407 (linear optimization). We have made every effort to increase our offerings of these classes, and we are actively considering ways to increase slots further. But these courses' high demand is a symptom of the more fundamental issue that what many of our students want in selecting mathematics as their major does not align perfectly with what we offer. We must ponder the extent to which we should change what we do to meet existing demand, or align what we think students should learn with what they think they should.

As you will read later, we are exploring ways, at both the undergraduate and graduate levels, to provide data science options. In all likelihood, such options will be in place next year. We have among the strongest faculty groups in the country in probability and in optimization, two areas in great demand. We are not ignoring this demand by any means.

Offering sufficient space in high-demand courses is not our only challenge. Some of our students are not sufficiently strong to perform well in challenging courses in these areas. When faced with the possibility of failing in a program that might lead to a STEM-related job, they become desperate. Faculty who have long taught these classes are finding students less interested in content, more interested in grades, with observed incidents of cheating on the increase. Many of these problems end up at the doorstep of our Student Services Office, whose handling of students not making normal progress has become a larger part of their effort. The office has become strained to its limit.

But let us not dwell on such negatives. Not yet anyway. Many of our undergraduates thrive. In Section 2.4, we will describe our vibrant undergraduate research and exploration options. Also, we have gone from what had been an open major to a minimum requirements major, and now, this year, to a competitive major. We do not intend, in becoming competitive, to shrink the size of the major very much, if at all. We do intend to be more selective, denying entry to a small number of students who previously would have qualified, as we did last autumn in our initial competitive review of major applications and again this quarter, as this sentence is being written. We will closely monitor the effect of this change.

1.3. Questions

Our overview of faculty and student demographics leads to the following overarching questions:

(1) What is the right mix of instructors—professors, lecturers, acting assistant professors, part-time lecturers, graduate student TAs—and how do we head toward this mix in our hiring strategies?
(2) In what areas of mathematics should we look to hire new faculty?
(3) How should we revise our undergraduate and graduate degree programs and course offerings to align our perspective on what students should learn with their needs in a changing job environment?
(4) How should we attract students whose interests would be well served by our programs?

Woven into our answers must be an emphasis on recruiting a more diverse faculty and encouraging a more diverse mix of students to learn mathematics, enter our programs, and join the mathematically-informed workforce. So too, must we integrate into our continuing work K-12 outreach and the development of deeper connections across campus.

1.4. Department Organization

The principal faculty leadership positions and their occupants are:

- Chair, currently Ron Irving, in his third year.
- Associate Chair, currently Tatiana Toro, in her third year.
- Graduate Program Coordinator, currently John Palmieri, in his third year.
- Undergraduate Program Director, currently Rekha Thomas, in her first year.

The chair is appointed by the Dean of the College of Arts and Sciences. The chair appoints the faculty filling the other three positions above, and meets with each of them at least weekly. The chair also appoints the chairs of the other departmental committees, sets the agenda for faculty meetings, and oversees teaching and space assignments. The chair represents the department in interactions with college and university administration, and serves as the primary contact with our alumni and donors.

The staff leadership positions and their occupants are:

- Department Administrator, currently Mike Munz, in his fourth year. He has been a member of the departmental staff since 2002.
- Director of Student Services, currently Brooke Miller, in her 23rd year. She has been on the advising staff since 1991, and has also served for over two decades as the Graduate Program Assistant.

The chair meets with these staff members weekly as well. One other group that meets weekly throughout the year is the Program Committee, consisting of the chair, the graduate program coordinator, the undergraduate program director, and the student services director. They oversee course enrollment and staffing, reviewing trends and preparing for each quarter.

The departmental committees most involved in governance and planning are the following:

- Personnel Committee. This committee advises the chair on all faculty personnel issues: merit review, promotion, retention, salary, professorships and faculty fellowships, other issues as they arise. Members are full professors.
- Executive Committee. This committee advises the chair on departmental policy issues. Depending on the year or chair, the committee has at times coincided with the Personnel Committee, or at other times had overlapping membership. For the past three years, it has consisted of the members of the Personnel Committee plus the graduate program coordinator, the undergraduate program director, and three additional at-large members, chosen from the professors, the associate professors, and the lecturers with the goal of ensuring representation across the faculty.
- Undergraduate Program Committee. This is chaired by the undergraduate program director. It considers undergraduate programs and courses, taking up revisions in degree requirements, the courses themselves, prerequisites, and broad policy issues. The director of student services joins faculty on the committee, as does the graduate student serving for the year as Lead TA.
- Graduate Program Committee. This is chaired by the graduate program director, whom it advises on graduate student appointments and support, on graduate degree courses, graduate degree requirements, and graduate program policy. In addition to faculty, the elected Graduate Student Representative is a member of the committee.
- Planning Committee. This is the successor to the Priorities Committee, which would survey the faculty each year, then come up with a proposal on faculty hiring priorities. With the new name comes the broader mission of acting as the counterpart to the graduate and undergraduate committees in considering the department's research mission broadly construed. Steffen Rohde is in his third year as chair.
- Appointments Committee. This committee, with Dan Pollack in his second year as chair, reviews all applications for tenure-line positions and consults with the faculty in order to come up with a list of candidates to visit the department, after which it prepares the final short list of candidates to be ranked at a department meeting. The committee performs the same work in a second round for our acting assistant professor candidates, with the one difference that we do not invite them to visit.

- Graduate Admissions Committee. This committee works with the graduate admissions director, now John Palmieri (but not always the same person serving as graduate program coordinator), to rate the applicants to the graduate program.
- Diversity Committee. Given that diversity is essential to our mission and interwoven with all our programs, this committee, having developed our statement of diversity commitment two years ago, has since advised many of the committees above on their efforts. In particular, it is working closely with the Appointments Committee this year. Its chair, for a third year, is Tatiana Toro.
- Speakers Committee. This is in its second year, chaired by Sara Billey, with the mission of ensuring that we have a diverse list of speakers in our Colloquium series, in our endowed Milliman lecture series, and elsewhere.

Shared governance is a valued tradition in the department. All faculty in leadership positions consult widely with faculty, staff, and students, with some of that consultation built into the structure of the committees above.

Several committees work with or have members from other departments on campus:

- ACMS Steering Committee. This committee oversees the ACMS degree program. It is headed by the ACMS director, a faculty member chosen from Mathematics, Applied Mathematics, or Statistics. Each of these departments contributes another two members, Computer Science & Engineering contributes one, and our director of student services is a member as well. (The Student Services Office advises ACMS majors and prospective ACMS students as well as mathematics students.)
- Math Services Committee. This committee, currently chaired by Don Marshall, annually surveys other departments on campus whose students take our courses as part of their prerequisites or program requirements. It prepares a report that is reviewed by the chair, the undergraduate program director, and the director of student services, with action taken where needed.
- MathAcrossCampus. This committee oversees a quarterly lecture series of the same name, designed to attract faculty and students from the entire campus to hear a distinguished speaker (UW or from afar) lecture on some topic that uses mathematics in an essential way. The committee consists of Ioana Dumitriu, Chris Hoffman, and Rekha Thomas and works with faculty representatives from departments in Arts & Sciences, Engineering, Medicine, the College of the Environment and other schools, as well as industrial representatives (Boeing, Microsoft) and representatives from our campuses in Bothell and Tacoma.

Each 100-level course has a course coordinator, whose duties will be described in Section 2.3.

1.5. Budget and Resources

The largest portion of the department's budget—as one would expect—is committed to faculty, staff, and graduate student salaries. The College provides us each year with a revised graduate student budget and with a temporary instructional budget, which we combine with faculty salary funds released through leaves or buyouts to create a pool that serves as the basis each year for our hiring of non-permanent faculty. We decide on the number of graduate students supported by TA funding (with a five-year commitment, subject to satisfactory progress), the number of postdocs to hire as acting assistant professors (typically as three-year appointments, subject to annual review), and the number of people to hire as part-time lecturers (with appointments of a year or less). We also hire additional graduate students from Applied Mathematics as TAs.

The distribution of these funds and the number of appointments made are reviewed regularly, in discussions between the chair, the associate chair, the graduate program coordinator, the Graduate Program Committee, and the chair of the appointments committee, as well as in consultation with the department administrator.

Another source of flexible funding is the endowment. Our largest source of endowment income comes in the form of graduate fellowships, representing 47.3% of the endowment. The income is used as support (generally supplemental) for our students at all stages, from awards as recruitment incentives to enhance diversity and attract our strongest applicants to awards for excellence in teaching and research. The graduate program coordinator and graduate admissions director take the lead on this, in consultation with the chair and the Graduate Program Committee. Likewise, our undergraduate scholarships, representing 8.5% of the department's endowment, are distributed based on discussions of the student services director, the undergraduate program director, and the chair.

Recommendations for professorships or faculty fellowships are made by the chair to the dean, in consultation with the Personnel Committee. We have three endowed professorships, representing 18.7% of the endowment, plus a non-endowed term professorship and two self-funded term faculty fellowships. Prospects for more are under active discussion between the chair and the college advancement office. The final component of the endowment is program support, distributed at the discretion of the chair, and representing 25.5% of the endowment.

There is also ongoing programmatic support for the department, the graduate and undergraduate programs, and certain outreach programs—Mathday, Math Circle, and SIMUW—through annual giving. These last three will be discussed in Section 4.3. Each budget is managed by the director of the given program.

CHAPTER 2

Undergraduate Program

2.1. Administration

The department's Undergraduate Program Committee is in charge of all undergraduate affairs. It consists of ten to twelve faculty of all ranks along with the director of student services, Brooke Miller, and is chaired by the undergraduate program director, Rekha Thomas. The committee meets once or twice a quarter to deal with policy and curricular issues. In Sections 2.5 and 2.6, we discuss several changes to our program that were initiated by the committee over the past decade, as well as new ideas for the committee to discuss in the coming years.

Rekha Thomas and Brooke Miller handle all day-to-day business, such as responding to student petitions and addressing issues with instructors and their classes or complaints from students and faculty. The department's Program Committee—comprising the department chair, the directors of the graduate and undergraduate programs, and the student services director—decides teaching schedules, TA assignments, and other issues regarding teaching.

Our students depend heavily on the department's Student Services Office. The primary role of this office is to advise and assist students, faculty, and staff regarding the academic programs and courses we offer. The office works with ACMS majors as well as mathematics students and majors. We currently have 1018 undergraduate majors between Math and ACMS, all of whom come through the office several times in their years here.

In addition to Brooke, the office has two more advisors and an office assistant. The majority of their effort is devoted to talking with undergraduate and graduate students about their academic programs. The office is responsible for assigning graders, ordering textbooks, creating the quarterly time schedule, working with faculty on curriculum changes and updates, facilitating the review and acceptance of transfer credits, coordinating the common final exams for all calculus classes, and working with the department's Program Committee on TA and teaching assignments. Each of these jobs is done quarterly. The office also maintains the undergraduate web pages.

The office, in collaboration with an admissions subcommittee of the Undergraduate Program Committee, handles undergraduate admissions to the major. In Spring 2015, our admissions process became competitive, which gives us more control over the quality of students we admit to our program. Admissions are done each autumn and winter.

The department has a satisfactory progress policy that applies to all our majors. Overseeing the policy is labor-intensive, with advisors monitoring student progress quarterly. The number of students not making normal progress has grown each quarter since we began this process in Autumn 2012, in tandem with the growth of majors. We anticipate that this number will decrease with our new competitive admissions process.

2.2. Degrees

We offer five undergraduate degree programs in mathematics: the BS Comprehensive and BS Standard, the BA Standard, the BA Teacher Preparation, and the BA Philosophy. The BS comprehensive has the most theoretical flavor and is aimed at students who wish to pursue graduate study in mathematics, while the BS standard offers more flexibility to shape a program. The BA standard is a versatile degree in mathematics without the focus on a math-centric career. The other two BA options are designed for future secondary school mathematics teachers and for students interested in studying philosophy jointly with mathematics. Complete descriptions and the requirements for each degree are available at our website (https://www.math.washington.edu/Undergrad/Handbook/degreereq.php). The number of majors and the number of degrees awarded in these programs have both grown steadily in the last ten years, as summarized in Section 1.2. We currently have a total of 798 majors in the five degree options.

The department also offers the BS degree in Applied and Computational Mathematical Sciences, as already mentioned, in collaboration with the Departments of Statistics, Applied Mathematics, and Computer Science & Engineering. A complete description of the program is available at its website (https://www.math.washington.edu/acms/). This interdisciplinary and applications-focused degree program offers a selection of pathways from which students choose: Biological and Life Sciences, Discrete Math and Algorithms, Engineering and Physical Sciences, Mathematical Economics, Operations Research, Symbolic Computation and Numerical Analysis, Social and Behavioral Sciences and Statistics. ACMS currently has 220 majors.

2.3. Courses

We offer service courses to students preparing to major in a wide range of degree programs and classes for our own majors. Our course catalog can be found at http://www.washington.edu/students/crscat/math.html. We give brief descriptions below, placing the courses in three groups: precalculus and calculus, 300-level service courses, and 300/400-level major courses.

2.3.1. Precalculus and Calculus. The largest component of our service teaching is calculus. We offer three calculus tracks. Math 111–112 is our Business precalculus/calculus sequence. Math 124–125–126 is directed to future science or engineering majors, with some students taking the precalculus course Math 120 first. Math 134–135–136 is an honors sequence for advanced freshmen. Typical class size is 90 or 120 for Math 124 and Math 125, but 160 for Math 111, 112, and 126. Sometimes class size goes up to 200.

Each class has lectures with the course instructor on Monday, Wednesday, and Friday, with recitation sections of size 30 (Math 124 and 125) or 40 (Math 111, 112, 126) led by graduate student teaching assistants on Tuesday and Thursday. Each course has preset syllabus, homework, schedule, and course webpage, along with a faculty member appointed for the year as course coordinator. Coordinators meet regularly with the faculty to ensure uniformity across the sections, introduce faculty teaching the course for the first time to its curriculum and goals, and work with faculty to prepare a common final exam and common grading rubric. Course webpages for calculus classes can be found at https://www.math.washington.edu/Undergrad/menu-courses.php.

For the past three years, we have offered online sections of Math 124–125–126 in order to meet the increased demand for these classes and provide more flexibility in enrollment management while at the same time providing matriculated students the opportunity to deal with scheduling challenges. We will comment more fully on this in Section 2.5.

All calculus students have access to the Math Study Center, a study space run by the department at which students can study in groups or individually. Its director is Matt Conroy, a senior lecturer in the department. It is designed for students to work on mathematics whether or not they need help, providing a comfortable place and a supportive atmosphere for students to come together and study, in groups or individually. The tutors (both graduate student TAs and advanced undergraduates) sit with students and answer questions in order to help them get unstuck, but do not provide long blocks of uninterrupted one-on-one tutoring.

2.3.2. 300-level service courses. In addition to calculus, we offer four service classes at the 300 level. Math 307–308–309 is our sequence on differential equations and linear algebra for students intending to major in the physical sciences and engineering. Math 324 covers advanced multivariable and vector calculus. These classes run in sections of size fifty, providing a different experience from that of our calculus courses.

In addition, we teach an honors advanced calculus sequence, Math 334–335–336, taken by some of the best students on campus. It has been taught for years by Jim Morrow, who continues to work with many of the course alumni on a variety of research opportunities, to be described in Section 2.4.

2.3.3. 300- and 400-level majors courses. The other classes at the 300 level and all our 400-level offerings are aimed at Math or ACMS majors. Most have a standard curriculum, but some are topics courses with content changing from year to year depending on the instructor.

Math 300 covers proof writing and is required of all of our majors. It is also a prerequisite for almost all of our advanced undergraduate classes. Demand for it has gone up dramatically in the last ten years. Math 327–328 is an introductory real analysis sequence, with Math 327 a prerequisite for many advanced classes. Two of the classes in our program in highest demand are Math 381, on discrete modeling, and Math 394, the first quarter of a three-quarter probability sequence. Both are taken by many ACMS students. We cannot offer enough sections of these classes at the moment. Math 301 is an elementary number theory course, Math 340 an advanced linear algebra course, and Math 380 a topics course with varying content from quarter to quarter. Many of our 300-level majors classes can be taken as electives by our increasing BA population, which explains why these classes are in such high demand.

Our core pure mathematics sequences are Math 402–403–404 on abstract algebra, Math 424–425–426 on real analysis, Math 427–428 on complex analysis, and Math 441–442–443 on topology and differential geometry. Math 407–408–409 is a sequence in optimization. This is another of our very high demand classes, taken by both Math and ACMS majors. Math 407 (linear programming) is being taught every quarter this year for the first time, but this expansion still does not meet the demand. Its popularity stems from the fact that the subject matter is relevant for almost everyone in a mathematics-related applied field. Math 461–462 covers combinatorics and Math 491–492 covers stochastic processes. Two special sequences aimed at majors in the BA teacher preparation track are Math 411–412, on algebra, and Math 444–445, on geometry. We teach several additional classes at the 400-level, including Math 480, a topics course with varying content.

2.4. Research and Exploration

There has been tremendous growth over the past decade in faculty engagement with undergraduates on research or other forms of mathematical exploration. Many undergraduates know by reputation that we encourage interaction with faculty and they seek us out at early stages of their education. Much of this has been driven by Jim Morrow, who is routinely approached by first-year students asking to work with him and for suggestions of other avenues to do independent research. His amazing efforts have been recognized through local and national teaching and mentoring awards. But Jim is joined in these efforts by many other faculty members, such as Sara Billey, William Stein, Ioana Dumitriu, and Julia Pevtsova. Jim has directed 29 undergraduate theses and is currently meeting weekly with five students on different subjects. As Jim observes, undergraduate mathematics research is a serious endeavor at UW.

Another avenue for engaging our students in research is Jim Morrow's NSF Research Experiences for Undergraduates program, which has run since 1988. Participants are introduced to research problems related to finding the resistors in a network from boundary measurements, leading to investigating and formulating discrete problems involving planar and non-planar networks and their relation to continuous inverse problems. The program was an important component of our successful application a few years ago for an NSF Research Training Groups in the Mathematical Sciences grant on inverse problems. Students come from all over the US, many from UW. Alumni have gone on to study and become faculty at top-ranked universities, and they return to be TAs in the program or to lecture on their current interests.

Ioana Dumitriu and Julia Pevtsova work with many talented students across campus each fall on problem solving, in part to prepare them for the William Lowell Putnam Mathematical

Competition. The Putnam, organized by the Mathematical Association of America, is the oldest and most prestigious college-level mathematical competition in North America, taken each year by thousands of undergraduates. The top five performers each year (and by the way, the median score on the test typically is 0) are named Putnam Fellows. Past fellows include many distinguished mathematicians and scientists, among them recipients of the Fields Medal (John Milnor, David Mumford, Daniel Quillen) and the Nobel Prize in Physics (Richard Feynman, Kenneth Wilson). Another past fellow is Ioana, who in 1996 became the first female Putnam Fellow. Doing well on the Putnam is a badge of honor. Getting undergraduates involved in the competition is a great way to strengthen the community of math majors.

Ioana and Julia offer weekly two-hour problem-solving sessions for the competition during Autumn Quarter (the Putnam is held on the first Saturday in December). These sessions are quite popular, attracting a large group of talented students that include many of our best mathematics and computer science majors. Sometimes, as a result of their participation in these sessions and at the Putnam, strong computer science majors decide to double-major in mathematics. We make efforts to increase the participation of women through early identification of potential candidates and by encouraging them to attend the sessions and present solutions. They also have the examples of Ioana and Julia (who never competed in the Putnam, but won a silver medal at the International Mathematical Olympiad). Since they took over the Putnam prep sessions, the UW team has placed among the top fifteen twice, has had a Putnam Fellow, and consistently places four or five students in the top 500.

In parallel with the Putnam prep sessions, Ioana and Julia offer a problem-solving class each autumn in which students interested in developing their abilities are exposed to interesting mathematical techniques and tricks as well as to topics that would not necessarily be represented in the regular curriculum. They learn to argue rigorously and improve their proof-writing skills. The class attracts both majors and students across campus.

Another competition, one with international reach, is the annual Mathematical Contest in Modeling, organized by the Consortium for Mathematics and its Applications and sponsored by the Society for Industrial and Applied Mathematics, the Institute for Operations Research and the Management Sciences, and the NSA. It runs for 96 hours over an extended weekend each February, with teams of three choosing one of two problems on which to work. The problems are concrete modeling problems requiring research, a choice of mathematical methods to apply, and the writing of a research paper. We have entered teams every year since 2001, with Jim Morrow serving as the primary coach. In the early years, we had striking success, with eight teams earning the distinction of outstanding winner. Seventeen teams have earned the designation of meritorious (top 17%). It has gotten much harder to win, since the number of winning teams has been fixed at less than six while the number of entrants has exploded to more than 10,000. But many of our students continue to commit to preparation and participation. Three teams will participate this year.

Another opportunity for students to engage in research projects is our mathematical modeling class, Math 381, and a topics version that Sara Billey often teaches in which students work with community partners. The focus of Sara's course is a service-learning project in which students study a real-world problem inspired by some of the challenges faced by non-profit organizations, government agencies, small businesses, or universities. The projects are done in teams, the climax being the presentation of the results as a written document and in a poster session. Students are treated like graduate students starting a research project, and are encouraged to use any mathematical tools they find helpful. Many have gone on to graduate school or jobs related to their projects and modeling in general. In one example, a student team worked with the Pacific Science Center to find the optimal number of cashiers to employ at their entry gates. The PSC is interested in serving their customers well, but they have limited finances, so they cannot have idle cashiers on duty. For a variety of expected arrival rates, the modeling team used Monte Carlo simulations to find the minimum number of cashiers needed to ensure that 95% of their customers would not have to wait in line more than a few minutes. The PSC was very happy to learn that they had been staffing the cash registers at very close to the optimal way. For another project, a team worked with Young Adults in Transition to find a fair job rotation scheme at a living facility, one that also would be perceived as fair by all the residents. The students suggested a schedule based on a combination of a Latin square, incorporating a fair system for substitutes that gave the schedule the required robustness.

As this discussion suggests, we have a rich history of engaging our undergraduates in research, with many faculty involved. But we have lacked an organized way to connect faculty and students. A systematic approach would be most welcome. And to our great good fortune, such an approach has arrived, along with our new faculty member Jayadev Athreya.

At the University of Illinois, while a junior faculty member, Jayadev created the Illinois Geometry Lab, which successfully brought faculty, graduate students, and undergraduates together on research projects. He has now established the Washington Experimental Math Lab (WXML), with the aim of enhancing opportunities for undergraduate mathematics research at UW. WXML starts its work this spring. It will create a vertically integrated community of researchers and explorers in mathematics, with each team consisting of a faculty member who sets the broad outlines of the project, two to three undergraduate students, and a graduate student mentor who meets regularly with both the faculty member and the students. The undergraduate students receive independent study credit for participation, and are required to present at lab meetings at the mid-point and the end of the quarter, as well as creating posters and interactive computer exhibits for open house events and for permanent inclusion on our website. WXML members will also participate in community outreach events, such as Mathday and Math Hours, hosting field trips and summer programs. Given the absence of a lab culture in mathematics, WXML has the potential to create an exciting research environment for our students, exposing them to the thrill of research at an early stage of their studies.

2.5. Changes

In this section, we highlight changes in the undergraduate program over the past decade.

In 2000, when we revised our primary calculus sequence, focusing especially on Math 124–125, we did not adopt computer-graded homework. We found online grading platforms to be promising, but not fully mature. In Winter Quarter of 2010, we began testing WebAssign, an online mathematics homework grading system. The system offered several potential benefits: an archive of coded problems (currently over 8000) from our adopted textbook, the ability to code our own problem-solving oriented homework, and immediate feedback to the students. Initial testing was accompanied by the use of Small Group Interactive Diagnostics, facilitated by Karen Freisem from the university's Center for Instructional Development and Research. After testing, the department adopted the uniform use of WebAssign in all sections of Math 124–125–126, beginning Autumn 2010.

Another large service course taught by our department is Math 308, the introductory linear algebra course. In a typical year, we teach 45 sections in classes of size 50. In an effort to uniformize the Math 308 experience for our students, we began testing textbooks with integrated WebAssign homework in the summer of 2010, continuing for several years to try out four different texts. In Autumn 2014, the department adopted a new textbook and a standardized syllabus with specified WebAssign online homework. WebAssign has been a success so far in Math 124–125–126 and Math 308. We are considering expanding its use to other classes.

Our cumulative curricular reforms for Math 124–125–126 have ensured a uniform student experience in terms of content and expected levels of mastery. During the 2011–12 academic year, a discussion related to calculus grading patterns led to the question of how similar the course grades were in different sections of a Math 12X course. Based on a review of historical grade data, a new policy on grading was proposed and adopted. The policy specifies a target range for the median grades in a given calculus lecture section of 2.9 ± 0.2, ensuring that student course grades are comparable across all sections.

That same year, the Undergraduate Program Committee began discussing admission requirements to the major. At the time, our goal was to identify the courses that can serve to predict success for our majors. Out of that study, we developed and adopted a satisfactory progress policy for our majors. This policy lays out a clear process through which the Student Services Office monitors the progress of all of majors and provides necessary feedback when concerns arise.

Also during the 2011–2012 academic year, a small group of faculty and then chair Selim Tuncel began discussions with UW's Professional and Continuing Education office regarding the creation of online calculus courses. In Spring 2013, online versions of Math 124 and Math 125 were launched, followed by Math 126 in Autumn 2013. We are now in our third full year of teaching online versions of all three. In Spring 2015, we started working with the university's Office of Educational Assessment to study the extent to which these online courses are successful. They are certainly a success in helping us meet student demand. Essentially everyone who wishes to register for one of the classes can do so. But we also wish to know whether or not online calculus students are learning as well as students in our traditional in-class courses. We anticipate a preliminary report on online course effectiveness this spring, which will allow us, in consultation with the deans, to decide on the online courses' future.

As highlighted in Section 1.2, the demand for mathematics elective courses at the 300- and 400-levels has increased over the years. With this in mind, beginning with the 2014–15 academic year, three sections of an outdated second course in multivariable calculus (Math 326) were dropped, to be replaced by two long-dormant courses, Elementary Number Theory, Math 301, which had been taught in the summer but not the regular academic year, and Abstract Linear Algebra, Math 340. In addition, we opted to maintain and occasionally increase the number of undergraduate topics courses (Math 380/480).

In mid-2011, a small group of faculty, along with the chair, began discussions with WebAssign and the Center for Commercialization to implement WebAssign in Math 120, our precalculus course. For twenty years, the department has used its own locally produced textbook for this problem-solving based course. Our idea was to duplicate the benefits observed with online homework grading of our calculus classes. This required a substantial investment by WebAssign to code the textbook problems, leading to a royalty agreement that now provides a small fund to support teaching and technology innovations within the department.

In order to manage the size of our program, admission to the major became competitive in 2015. This change is expected to improve access to key courses (and thus progress toward the degree), timely and quality advising and monitoring of student progress by the Student Services Office, and the ability to maintain an appropriate quality level in our upper-division courses.

2.6. Possibilities

Having reviewed changes in the past decade, we now survey possibilities for further change.

2.6.1. A re-evaluation and possible revision of Math 307–8–9. We have devoted significant effort over the past fifteen or twenty years to revising our 100-level classes. We believe they are now in good shape. Our next goal is to examine our 300-level service courses, especially the Math 307–308–309 sequence on differential equations and linear algebra.

We would like to modernize the syllabi for these classes with new instructional materials. For instance, we would like to experiment with combining theory with hands-on computational experience. Since many of the students taking these classes are headed toward majors in engineering or the sciences, a change in the instructional approach in these classes that better suits the audience is overdue. We plan to consult with our client departments to decide what changes will benefit their students most.

We are also considering experimenting with the teaching structure of these classes. They are currently taught in multiple sections of size 50, many with graduate students, postdocs, and part-time lecturers as instructors. We would like to evaluate the benefits of larger class size—following our calculus model—with TA-led sections supplementing the lectures, which may be given by more professors. The Math Study Center is currently not available to students in 300-level service classes due to space limitations. Providing contact with both professors and TAs may be beneficial. The Undergraduate Program Committee will study these issues and pilot a few changes in the coming years.

2.6.2. A data science option. The eScience Institute at the University of Washington is spearheading an effort to bring data science into the university's STEM degree programs, with the help of an inter-departmental working group on data science education. This group is in the process of creating a list of core courses in data science that departments can incorporate into their existing degree programs. Students will be required to take six or seven classes in machine learning, data management and visualization, and programming. We plan to make this option available to our BA and BS majors, with the specific details to be discussed and decided on by the Undergraduate Program Committee in the coming months. We expect that this new direction will greatly help our students who wish to work in industry. It also would provide the department with a structured way to bring data science into our program with minimal impact on our resources.

2.6.3. Better meeting the demand for our majors classes. The growth in majors has greatly increased pressure on some of our 300- and 400-level majors classes. This pressure may grow further through a new pathway in statistics and data science that the ACMS program is in the process of adding. This revision, which is likely to be popular, will require several of our already high demand majors classes.

Meeting increasing demand has been challenging, given that our professorial faculty size has decreased over the last decade, this being precisely the pool of faculty members who ordinarily teach our 400-level courses. We already saw the change in the composition of instructors in our 300- and 400-level classes between 2005–2006 and 2015–2016 in Figure 1.2.7.

The department, with advice from the Undergraduate Program Committee, plans to experiment with ideas for meeting this increased demand. Our first experiment will be to see if increasing the size of our service classes at the 300 level will free up faculty and TAs, thereby allowing us to teach larger sections of a few high-demand majors classes. Some of the heavily subscribed courses we have in mind are Math 301 (number theory), Math 381 (discrete modeling), and Math 407 (linear optimization). The demand for these classes is so large now that whenever we open up a new section during registration, it fills immediately.

2.6.4. Recruiting underrepresented minorities. The department has a number of activities aimed at undergraduates passionate about mathematics, such as the Mathematical Contest in Modeling, the REU program, and the Putnam prep class, all discussed in Section 2.4. However, the participation of underrepresented minorities in these is low. We should consider putting mechanisms in place that would allow us to track underrepresented minorities performing well in introductory mathematics courses, then encourage them to take more advanced courses and participate in some of these enrichment activities. Studies show that women and underrepresented minorities tend to underestimate their performance with respect to their classmates. Pointing out that they are doing well can have a large impact. We may also wish to pay greater attention to transfer students, as this pool will contain a large number of underrepresented minorities. Indeed, we may do well to develop strong connections with selected campuses of the state's community college system.

Here on campus, we have worked over the years with several programs in the College of Engineering, such as the Minority Scholars Engineering Program and, starting this year, the STARS (Washington STate Academic RedShirt) program. For STARS, we made arrangements for their current freshman cohort to be kept together in specific precalculus and calculus classes. Soumik Pal has had conversations this year with Sheldon Levias, the assistant director of the Engineering Academic Center, about ideas to improve the experience of calculus students coming from backgrounds that are underrepresented in STEM fields.

Beyond calculus, there may be opportunities to build a partnership between more advanced minority engineering students and WXML, which has as one of its goals the recruitment and retention of underrepresented minority students in STEM fields. There is a growing body of survey-based education research suggesting that exposure to research experiences in STEM fields as an undergraduate is a strongly positive factor in recruitment and retention of students. Engagement in rich research experiences allows for the further development of interest in, competence in, and identification with STEM.

CHAPTER 3

Graduate Program

The mission of our graduate program is to train students to do cutting-edge research in mathematics. Our graduates should emerge from the program able to conduct research, learn new mathematics, and effectively communicate mathematics at all levels. While they are here, our graduate students participate in our research and are a key part of our teaching efforts.

3.1. Administration

The Mathematics Department has two faculty positions that deal with the graduate program: the Graduate Program Coordinator (GPC) and the Director of Graduate Admissions, both appointed by the department chair. The GPC leads the Graduate Program Committee, which oversees all current graduate students and issues related to the graduate program. For instance, the committee determines the outcome of our preliminary exams, decides on whether to continue support (in the form of teaching assistantships) for each student, recommends to the chair which graduate courses to run, and considers revisions to graduate courses or graduate degree requirements. The Director of Graduate Admissions runs the Graduate Admissions Committee, whose members read and rank files of graduate program applicants. John Palmieri has both roles now, but at times they are taken by different faculty members.

The Graduate Program Administrator, currently Brooke Miller, maintains academic records for each student, so we know who has fulfilled which requirements. She also does almost all of the work in assigning teaching jobs to the Teaching Assistants. In graduate admissions, she is the first point of contact for our applicants, and she alerts the Graduate Admissions Director if there are unusual issues in any particular case.

3.2. Admissions

Our recruiting process is mostly informal. Our program is listed with the American Mathematical Society[1]. Beyond that advertisement, we mainly rely on word of mouth and outreach from our faculty. We have participated in the SACNAS national conference and the Joint Mathematical Meetings (of the American Mathematical Society and the Mathematical Association of America). This year, we used the National Name Exchange and the California Diversity Forum to identify potential applicants from underrepresented groups.

[1] `http://www.ams.org/programs/students/findgradprograms/`

The Graduate Admissions Committee reviews applications each year, the bulk of the reading being done in January. They focus on each applicant's academic record, research experience, statement of purpose, letters of recommendation, GRE scores, and—for international students—TOEFL scores. Each file is read and ranked by two committee members, and then the admissions director combines the ranks to give a final ranking to each candidate.

When we admit students to the PhD program, we offer them support for five years as teaching assistants. In practice, we provide support for a sixth year as long as a student's work is progressing. Support beyond that depends on availability of departmental funding and other issues. Students may also receive research assistantship support, but this depends on availability of grant funds from their advisor or another faculty member.

We have had about 400 applicants per year in recent years. We usually aim at a class size of 15–20, and we admit four to five times as many to get this yield. Different graduate admissions directors have defined terms like "admission" in different ways, so year-to-year statistics are not as useful as they might be, but in the admissions season for students starting in Autumn 2015, the most liberal use of "admission" was used: all highly ranked students were counted, even if they withdrew their application before we could officially admit them. We had 370 total applications, we admitted 86 students, and we got 17 acceptances. We had 78 female applicants (21% of total), offered admission to 18 of them (22% of total offered admission), and got 3 acceptances (18% of incoming class). We had 22 applicants from members of underrepresented minorities, most of whom did not rank highly. We made offers to 3 of them and got one acceptance.

We offer most of our highly ranked domestic applicants, and all of our highly ranked domestic applicants who are women or underrepresented minorities, the opportunity to visit. We also have some fellowship money: in many years, we have access to at least one ARCS Fellowship, we occasionally receive a Natural Sciences Dean's Fellowship, and we have some departmental endowments that we use for recruitment awards. Combined, these give us three or four major awards, supplementing basic support with an additional \$5,000–\$7,500 per year for three years, and about six minor awards, which are one-time payments of \$1,500. In the last admissions season we had two ARCS Fellowships, one of which went to a woman, one to a Hispanic American.

We use the Master's program to admit and support students who we believe have the potential and desire to get a PhD, but whose background is weak. The goal is for such students to spend a year or two in the Master's program and then apply to transfer to the PhD program. This has been pretty successful: see Section 3.7. About ten years ago, we enrolled roughly three MS students per year. In recent years we have seen a great increase in the number of qualified PhD applicants, and we have dropped the number of MS students to zero or one per year.

This leads to several questions that the Graduate Program Committee will be taking up: Should we revitalize our MS program? How do we identify the best candidates for it? If we admit students with weak backgrounds, how do we give them a fair chance to succeed?

Another question, linked to the admissions process, is how large our graduate program should be. Inevitably, the size of the program is driven more by instructional needs and College funding of TAs than by any abstract considerations. As long as we have enough professorial faculty to teach and advise the resulting number of students with success, all is well. The principal danger would be if we took more students than we could successfully shepherd to success, or if we found ourselves taking students not strong enough to complete our program. But this has not been the case. As we have seen, PhD completion numbers have steadily risen over the past decade. But should the number of professors drop, or graduate students increase, then this may become a more urgent matter.

3.3. The Student Experience

In September of their first year, graduate students go through a departmental orientation and extensive TA training. They are assigned a preliminary advisor, a faculty member who helps them decide which courses to take. They also meet individually with the GPC during the first week of classes.

We have four core first-year math classes: Algebra, Real Analysis, Complex Analysis, and Topology and Manifolds. Each is a three-quarter sequence. There is a preliminary exam (prelim) associated with each course; the prelims are offered once a year, in September a few weeks before classes start. In order to maintain normal progress, students must pass two prelims by the start of their second year.

This system was changed in December 2015, reducing the requirements from three prelim passes to two. Moreover, it is possible to earn a pass through sufficiently strong performance in one of the allied courses, making this a less onerous requirement than it might initially appear to be. The hope is that with the new system, students will be able to make a smoother and faster transition from coursework to research. Looking back, the self-study from our 2004 review said, "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." The new prelim requirements are designed precisely to address this issue.

Our graduate students spend their first year taking courses; we expect most students to take two core courses plus a third course each quarter. In their second year, they will take some standard courses, but also reading courses and independent studies in order to determine a research direction and potential PhD advisor. By Winter Quarter of the third year, students need to have signed up with a PhD advisor, and by this point, they may be taking very few courses, registering primarily for independent study with their advisor. By Winter Quarter of the fourth year, students need to have completed their General Exam, which consists of a paper on a research area and an oral presentation and exam . The only requirement after this is the Final Exam, the thesis defense.

Students need to pass one language exam—we recently decreased this from two—and it can be either a foreign language or a computer programming exam. A student decides which in consultation with the advisor.

First-year students act as teaching assistants for calculus classes (Math 124 and 125). They are assigned TA mentors, these being advanced TAs who meet with them regularly and observe their teaching several times. The instructor for their course also observes them. There are weekly meetings for TAs for each of our calculus courses in which they go over upcoming material. All of these activities provide ample supervision and training for our TAs, and it works: our TAs do a good, often great, job in the classroom. This helps to maintain a culture in the department that high-quality teaching is valued.

More advanced TAs may get more challenging assignments, for example being a TA for Math 111 or 112. By the time they are in their third year, they may be teaching their own section of a 300-level course: Math 307, Math 308, Math 309, or Math 324. Not only do our TAs do a good job teaching these, which helps our teaching endeavors, but they also gain valuable experience.

3.4. The Student Community

We have a strong community of graduate students, built and maintained in a variety ways. Students are not competing with each other for support. We want all of them to get through prelims, find an advisor, and complete a PhD, and this is built into our funding model. Soon after they arrive, we have a departmental orientation and TA training for new students, and also a picnic for all graduate students and faculty.

Once the quarter starts, students have frequent teaching-related contact: weekly TA meetings and contact with their TA mentors. We encourage collaboration in classwork for first-year graduate classes, and it is a common to find groups of students working on their homework in the math lounge. We have afternoon tea for graduate students and faculty every day at 3:30.

On the research front, when there is a colloquium, a group of graduate students takes the speaker to lunch. At least three of the department's weekly seminars have pre-seminars, which provide background and context for the seminar talk. These are designed to help graduate students get the most out of the talks.

The department has recently been scheduling "beer bashes" about once a quarter as a general social gathering. We present our graduate student awards at the autumn beer bash.

The department has two important graduate student roles: the Graduate Student Representative and the Lead TA. The representative is elected by the graduate students each year. he or she serves on the Graduate Program Committee, attends department meetings, and helps in many ways to support the graduate student community, for example by organizing the daily tea and lunch with the colloquium speaker. The Lead TA is chosen by the TA coordinator and serves on the Undergraduate Program Committee.

Last year, we formed a student chapter of the Association for Women in Mathematics, with Sara Billey as faculty sponsor. They have been busy: ice cream social, meet-and-greet for undergraduates to meet graduate students and discuss the next career step, lunches with colloquium speakers, a showing of the movie about Julia Robinson, a coffee hour with the current president of the AWM, Kristin Lauter, and more.

Another aspect of the community is the value placed on good teaching, for graduate students serving as TAs and as instructors responsible for their own classes. Especially noteworthy in this regard was the receipt last year by our graduate student Matt Junge of one of the two university Excellence in Teaching Awards given each year to two graduate students. Matt has done inspiring work at every level: as TA, instructor, TA mentor, Lead TA, and in outreach. For the past two years, he has been teaching at the Washington Correctional Center for Women through the Freedom Education Project Puget Sound, joined more recently by one of our lecturers, Jonah Ostroff, and one of our acting assistant professors, Annie Raymond.

Overall, our activities for graduate students contribute to a collaborative, supportive environment.

3.5. Career Preparation

In recent years, Sara Billey, together with the Graduate Student Representative, has organized several events each year related to career-training: a jobs lunch in autumn for those who are preparing to apply for jobs; an industrial math panel in winter; and a panel on applying for academic jobs, held in spring for students who just went through the application process, to pass on their knowledge to the next generation.

About one-fourth to one-third of our PhD recipients enter non-academic careers. To help prepare them, we are likely to add an Advanced Data Science option to the PhD program, in the hope that the training and the credentials this provides will be helpful to students entering non-academic careers. The Graduate Program Committee has approved the option and it is about to be voted on by the full faculty. Once this is in place, the committee will consider possible additional paths, and whether they should be formalized as options in the PhD program.

3.6. Quality and Improvement

Compared to where we were at our last ten-year review, the graduate program has made great strides. In admissions, our typical applicant pool ten or twelve years ago consisted of around 150 students, one-third of whom were highly-ranked by our Graduate Admissions Committee. About half of our entering class, on average, came from this top group of applicants. We have seen a steady rise in the number of applicants, without an apparent decrease in overall quality: since 2000, we have had more than 200 applicants each year, and since 2010, we have had more than 350 applicants each year. Around one-third each year are highly ranked. With two exceptions in 2012, every member of our last ten entering classes has come from the group of highly-ranked applicants. This is reflected in the increase in our production of PhDs: see Section 3.7.

Another indicator of quality is the following anecdotal information: three of our recent and current graduate students (Richard Robinson, Cris Negron, and Emily Dinan) have had NSF

Graduate Research Fellowships. A number of our PhD students in the past ten years have been offered NSF Postdoctoral Research Fellowships: Matthew Badger, Toby Johnson, Matt Kahle (declined), Daniel Meyer, Chris Negron, Elliot Paquette, Austin Roberts (declined), Karl Schwede, Micah Warren, and Catherine Williams. Also, Micah Warren was awarded a Clay Mathematics Institute Liftoff Fellowship in 2008, and Matt Kahle and Karl Schwede received Sloan Fellowships in 2012.

3.7. Data: Enrollment and Degrees

Our graduate enrollment over the past ten years has been in the range of 85–100 supported students, typically 5 or fewer in the Master's program, the rest PhD students. (Sometimes graduate students from other UW departments enroll with us as unsupported Master's students—maybe one or two a year. They play a minor role in the department and are not part of the discussion here.)

Focusing on our PhD students who entered the program in the period 2002–2013, we have the following data:

Initial program	Gender	Total	Received PhD	Median years	Avg years	Left program	Still enrolled
PhD	female	36	14	6	6.0	15	7
PhD	male	163	79	6	5.7	41	43
MS	female	7	5	7	6.4	0	2
MS	male	8	5	6	5.8	2	1

The "Median years" and "Avg years" columns represent time to PhD. "Left program" counts the students who left the program without a PhD. Also, there were 23 supported MS students in this period, 15 of whom transferred to the PhD program. Those 15 are represented in the table.

Our degree production has increased since the last ten-year review. In Section 1.2, we reviewed the change calculated as a three-year rolling average, rising from around 5 to 7 per year in the period 1996–2005 to the low- to mid-teens in the past decade. The annual average from 1996 to 2005 was about 7, compared to 11.5 from 2006 to 2015, with a total for the last three years of 46, the highest three-year total. We expect to surpass this number at the end of this year.

3.8. Demographics and Diversity

We currently have 86 full-time PhD students, 47 domestic (9 female, 38 male), 39 international (8 female, 31 male). We have no current Master's students. Of the domestic students, five—all Hispanic—are from underrepresented minorities. Among the international students, we have 3 from Latin America (1 each from Chile, Colombia, El Salvador) and 3 from the Middle East (1 from Egypt, 2 from Lebanon).

For the 2015 admissions season, there were 388 applicants, 86 female and 302 male (22% female). 230 of the applicants were U.S. citizens (59%). 20 of the U.S. citizens were from underrepresented minorities (9%): 3 African American, 1 Native American, 16 Hispanic Americans. Of the international students, 4 were from Latin America (1 each from Brazil, Chile, Colombia, Costa Rica) and 3 were from the Middle East and Africa (1 from Morocco, 2 from Turkey).

Regarding the female/male ratio, we can numbers to the medians for programs at other Public Large universities[2], using self-reported data collected by the American Mathematical Society[3] in Spring 2015:

Institution	# grads	# female grads	%female grads
UW	95	17	18%
median	125	26.5	21%

We are slightly behind the median in percentage of female students. It is our goal to do better in this, and also to improve the number of underrepresented minorities in the graduate program. Only 4 of our 87 grad students are Hispanic American (4.5%, slightly better than the 4% of our applicant pool who are Hispanic American, but 4 out of 87 is a very small sample size). Also, 4 of our international grad students are from Latin American. Another 3 are from the Middle East and Africa (Lebanon and Egypt). Compared to our applicant pool last year (4 out of 388 from Latin America, 3 out of 388 from the Middle East and Africa), our department's numbers look reasonable.

We are exploring options that would help us, in the long-term, to increase the number of underrepresented minorities. These include broadening our participation in the National Name Exchange, SACNAS (which our graduate program director attended a year ago), and similar organizations, and officially targeting some recruitment awards at women and underrepresented minority students. We will explore the possibility of establishing relationships with institutions traditionally serving underrepresented minorities by visiting them, giving talks aimed at undergraduates, and discussing our graduate program. Students may not think of a PhD in mathematics as a financially sound option. Thus we also need to advertise the attractions of a Master's or PhD in mathematics in the current job market. The data science option that we are close to adopting may serve as an additional tool to recruit from a broader pool. Another possibility is the use of our Master's program to increase diversity.

As important as recruitment is retention. Some students recruited from institutions traditionally serving underrepresented minorities may lack the mathematical background necessary to succeed in graduate school. We need to be sure that a support structure is in place to help them transition successfully into the PhD program. This structure might consist of peer mentoring by other graduate students and faculty mentoring. We might wish to copy UC Berkeley's Mathematics Opportunity Committee. Through outreach, admissions, financial support, and academic advising and support, it provides opportunities for graduate study

[2] as listed at `http://www.ams.org/profession/data/annual-survey/groups`

[3] `http://www.ams.org/programs/students/findgradprograms/`

at Berkeley for students who have demonstrated exceptional mathematical promise despite having encountered limited resources or other circumstances that may have affected their preparation in their previous studies.

CHAPTER 4

Faculty

4.1. Research

We begin this chapter with a survey of the department's activities, adopting the listing of mathematical areas used by the Division of Mathematical Sciences at the National Science Foundation: Algebra and Number Theory, Analysis, Applied Mathematics, Combinatorics, Computational Mathematics, Foundations, Geometric Analysis, Mathematical Biology, Probability, Statistics, and Topology. We have combined Applied and Computational Mathematics, while omitting Foundations, Mathematical Biology, and Statistics. Inasmuch as some of the material in this section was provided by faculty in their own disciplinary areas, you will find a variety of voices and views.

4.1.1. Algebra and Number Theory. Our department has a long history in algebra, algebraic geometry, and number theory. At present, we have groups or individuals in algebraic geometry, arithmetic geometry, number theory, computational number theory, cryptography, non-commutative algebra, non-commutative geometry, and representation theory. The primary faculty in these areas are Max Lieblich and Sándor Kovács in algebraic geometry; Ralph Greenberg, Neal Koblitz, William Stein, and Bianca Viray in number theory; and Ron Irving, Monty McGovern, Julia Pevtsova, Paul Smith, and James Zhang in non-commutative algebra and representation theory.

Kovács is a leading figure in the theory of moduli spaces of higher-dimensional algebraic varieties, a project that has been a major focus of algebraic geometry for at least three decades. Lieblich is an expert on moduli of sheaves and vector bundles, with a particular emphasis on their applications to problems in algebra and number theory. Both Kovács and Lieblich have also done important work on the geometry of K3 surfaces and their moduli, a topic that has been of great interest in the last several years.

Pevtsova is one of the world's leading figures in modular representation theory. Her work with Friedlander, Benson, Carlson, Suslin, and others has built a crucial edifice in the modern theory, creating striking connections between objects of classical algebraic geometry and exotic aspects of representation theory in positive characteristic.

Smith and Zhang have made important contributions to non-commutative algebraic geometry. Zhang's papers with Artin and Yekutieli are foundational. A great deal of Smith's work concerns specific examples, especially Sklyanin algebras, which play a central role in this area of mathematics, where prototypes are difficult to come by. Like many of the algebras

Smith has studied, these involve a great deal of algebraic geometry. Much of Zhang's recent work concerns Hopf algebras.

Palmieri and Zhang have written several joint papers about A_∞-algebras and A_∞-categories. These are complicated objects that appear as an essential part of Kontsevich's homological mirror symmetry conjectures. They also arise in the study of symplectic manifolds and in low-dimensional topology as important invariants.

The department has played an important role in the development of computational number theory and cryptography. Koblitz invented elliptic curve cryptography, which is rapidly becoming the international standard for secure electronic communications and encryption. Viray has done key work on next-generation cryptographic techniques in collaboration with mathematicians at Microsoft Research. Stein runs Sage, the world's most ambitious open-source computational mathematics project. His own background in number theory means that Sage has outstanding support for number-theoretic computations.

Greenberg is one of the leading figures in the study of p-adic L-functions and their use in understanding representations of the Galois group of the rational numbers. These techniques lie at the heart of modern number theory and have played crucial roles in the proof of Fermat's Last Theorem and the most important conjectures in the subject. He alone makes the UW a destination for people interested in this subject.

We are well positioned to capitalize on trends in algebra, algebraic geometry, and number theory. For example, higher topos theory and derived algebraic geometry is rapidly becoming a key tool in the solution of numerous problems in algebra, number theory, and algebraic geometry. A hire in this area would dovetail perfectly with the existing strengths in A_∞-algebras, moduli theory, and representation theory, and keep us at the forefront of developments in algebraic topology and algebraic geometry. In a different direction, the work of Scholze and Bhatt on perfectoid spaces and perfect schemes is rapidly building into a revolution in arithmetic algebraic geometry. A hire in this area would allow the UW to remain a key institution in modern number number theory and enhance our standing in arithmetic geometry.

4.1.2. Analysis. Mathematical analysis has its origins in the differential and integral calculus of Leibniz and Newton. It covers a large number of subdisciplines, including complex analysis, dynamical systems, harmonic analysis, and partial differential equations. In our department, Jayadev Athreya, Ken Bube, Robin Graham, Don Marshall, Steffen Rohde, Hart Smith, John Sylvester, Tatiana Toro, Selim Tuncel, Gunther Uhlmann, and Yu Yuan fit under this heading.

Several years ago, faculty who organized the complex analysis seminar and the Rainwater Seminar, which was previously focused on dynamics and ergodic theory, joined forces with Toro, whose research is in geometric measure theory and partial differential equations, to establish a new Rainwater Seminar with a broadened scope. The revitalized seminar has contributed to the education of our graduate students and encouraged the formation of new research connections within the analysis group.

It was soon recognized that these loose connections could be significantly strengthened, with a more powerful group formed, through an appointment of a faculty member bridging the diverse mathematical backgrounds of Marshall, Rohde, Boris Solomyak, and Toro. The recommendation put forth by this group for priority hiring in *non-smooth analysis* was adopted by the department eight years ago. However, the financial crisis, the need to replace retirements in key areas, and hiring opportunities in other areas has led to this priority remaining open. In the meantime, Solomyak left our department for a position in Israel and Don Marshall is nearing retirement. Simultaneously the number of graduate students interested in the area has grown dramatically, partially due to the success of the new Rainwater seminar, which has contributed to the creation of a vibrant research group.

As one of the oldest disciplines in mathematics, analysis rarely experiences transformational breakthroughs. However, the last decade has seen tremendous advances. The Ricci flow, close to Yuan's interests, is an active topic of research in differential geometry and is discussed in the Geometric Analysis section, but has close ties to analysis and partial differential equations (PDE). The related areas of hyperbolic geometry, Teichmüller theory, and dynamics have celebrated successes such as proofs of the tameness conjecture and the ergodicity of Thurston's earthquake flow. The field of Teichmüller dynamics continues to grow and expand its connections. Starting from simple one- and two-dimensional almost integrable dynamical systems, the area now has deep connections to topological string theory, algebraic geometry, and algebraic combinatorics. The work of Eskin-Mirzakhani, McMullen, Moeller, Matheus, and others has expanded the horizons of the field. The Fields Medal for Maryam Mirzakhani (a collaborator of our recent hire, Athreya) in 2014 and Ian Agol's recent Breakthrough Prize bear witness to the appreciation within mathematics that these results enjoy. The Schramm-Loewner Evolution, Rohde's area of research and close to Marshall's interests, continues to produce headlines, as witnessed by the Fields Medals for Wendelin Werner in 2006 and Stas Smirnov in 2010.

Toro works in Geometric Measure Theory. This area, which has been one of the pillars in the development of Geometric Analysis, has seen an enormous revival worldwide thanks to new connections being found to areas like metric analysis and free boundary regularity problems. She has been instrumental in leading this effort in the US and her work in free boundary regularity problems has provided a new outlet for this classical and fundamental area of mathematics.

Uhlmann is a world leader in the area of inverse problems. At each step his work has been foundational and groundbreaking. Inverse problems has provided a venue where developments that were once only theoretical questions in PDE now have very important ramifications in applied physics and engineering, especially medical imaging. The work of Uhlmann and his collaborators on invisibility is a compelling example of pure mathematics that has made its way into the laboratory and is becoming mainstream applied science.

4.1.3. Applied and Computational Mathematics. Mathematical optimization addresses the question of how to either minimize or maximize some objective function subject to restrictions on the actions that can be taken in order to achieve an optimal outcome. The subject has experienced explosive growth over the past thirty years. Contributing factors include the advent of the internet, advances in computational power and computing architectures, the availability of very large data sets, as well as advances in science, engineering, communication, and business. These developments have created a fertile ground for the emergence of new applications and data acquisition modalities, in addition to new methods for data management, interpretation, and modeling. These are the driving forces behind big data and machine learning research. In addition, there is a greater urgency in many disciplines to address new and old questions concerning design, efficiency, risk and inference, as well as model selection, system identification, and error and uncertainty quantification. Much of the progress in this research leans heavily on underlying optimization tools, including model development, the design of a numerical solution procedures, the assessment and quantification of model validity, sensitivity, robustness, and uncertainty.

The department's optimization group includes James Burke, Dmitriy Drusvyatskiy, Thomas Rothvoss, and Rekha Thomas. Burke and Drusvyatskiy work primarily on problems having continuous variables, using techniques from variational analysis. Rothvoss and Thomas work on problems having semialgebraic structure or discrete variables, using algebraic and combinatorial techniques.

Burke's research focuses on theory and methods for smooth and nonsmooth optimization and variational analysis. Recent work includes contributions to parameter identification in dynamical systems, smoothing methods for nonsmooth and non-finite-valued functions, numerical methods for large scale convex and non-convex optimization problems, as well as the variational analysis of spectral functions for non-symmetric matrices.

Drusvyatskiy conducts research in nonsmooth optimization and variational analysis. His recent focus is on the role of underlying problem structure and conditioning in efficient computation. A parallel focus is on problems involving eigenvalues and polynomials. A mix of theory and applications is central to his research.

Rothvoss works in discrete optimization and theoretical computer science, with strong ties to combinatorics and discrete geometry. Some of his recent work involves discrepancy theory and lower bounds on the size of linear programs. As part of his joint position with Computer Science & Engineering, he is also a member of their theory group.

The research of Rekha Thomas is centered on algebraic methods in optimization and computational algebra, with strong connections to discrete geometry, combinatorics and algebraic geometry. She is especially interested in problems that combine tools from different areas of mathematics. Recently, she has been applying her research methods to problems in computer vision.

Other faculty members whose work fits under the heading of applied and computational mathematics are Ken Bube and Hari Narayanan. Bube works on the numerical solution of inverse problems, the theory and numerical solution of differential equations, and robust methods for solving ill-posed inverse problems numerically, with applications in geophysics. Recent work includes analysis of and robust regularization methods for seismic traveltime tomography, and analysis of the instabilities in popular acoustic approximations to the differential equations for anisotropic elasticity.

Narayanan works primarily in manifold learning, which is a subfield of Machine Learning. The hypothesis underlying manifold learning is that high- (even infinite-) dimensional data lie in the vicinity of a low-dimensional embedded manifold. The research involves testing this hypothesis, and, in cases for which it holds, fitting manifolds to the data. Another direction involves recovering the Riemannian metric of a Riemannian manifold given a large graph and noisy pairwise distances between points on the manifold. Narayanan is also investigating the question of fitting a function with Lipschitz gradients to noisy data when the noise is assumed to be Gaussian.

4.1.4. Combinatorics. Combinatorics is the study of finite or countable discrete structures, which are ubiquitous in mathematics, science, and industry. It is a field that has been rapidly growing in our lifetime. For example, combinatorics is used frequently in computer science in the analysis of algorithms and in mathematical biology in phylogenetics. It also appears in the work of many recent Fields Medalists, including Andrei Okounkov, Terry Tao, and Tim Gowers. Ten years ago, combinatorics was included under the umbrella of the "Algebra, Combinatorics, and Number Theory" at the NSF. Today, combinatorics is an NSF program in its own right.

Our department has a long history of excellence in combinatorics, going back a century ago to E.T. Bell. During the latter half of the twentieth century, Branko Grünbaum and Victor Klee played an important role in establishing the field of combinatorics through their seminal work on geometric combinatorics and the connections to computer science, operations research, and pure mathematics. With the retirements of Grünbaum and Klee in 1997 and 2000, the department placed a high priority on maintaining this strong reputation through selective hiring in algebraic and geometric combinatorics. Currently, the primary faculty in this area are Sara Billey (hired in 2002) and Isabella Novik (hired in 2004). They have collaborated with other faculty in the department in optimization, probability, and algebraic topology and with researchers outside the department at Microsoft and at the Fred Hutchinson Cancer Research Center in mathematical biology. Other faculty whose interests touch on combinatorics include Ioana Dumitriu, Chris Hoffman, and Rekha Thomas.

Billey is a leading researcher at the intersection of algebraic combinatorics, Lie theory, computational algebraic geometry, probability and experimental mathematics. More specifically, her work focuses on affine Grassmannians, Schubert varieties, Schubert polynomials, flag manifolds, symmetric functions, root systems, Coxeter groups, diagonal harmonics, computer aided combinatorics, stochastic processes, complexity theory, fingerprint databases for theorems, and machine learning algorithms for combinatorics. Novik is a leading figure in the theory of polytopes and combinatorics of triangulations of manifolds, upholding the traditional strengths of UW in this area. Her research interests lie in combinatorics of simplicial complexes, and in connections between combinatorics, commutative algebra, and algebraic topology. Hoffman's work in combinatorics has been focused on random simplicial complexes.

Our department is well positioned to capitalize on the growing trends in combinatorics, given the strength and history of our program. One promising direction for growth is combinatorial algebraic geometry, at the intersection of combinatorics, algebra, and geometry. An appointment in this area—for instance someone in the enumerative aspects of toric varieties, moduli spaces, and quantum cohomology—would unify areas in which we are already strong. A second direction is enumeration, extremal combinatorics, and graph theory. Big data is an emerging area of strategic national interest and of great interest to members of our department. The backbone of "big data" is graph theory, the study of networks and connections. A new hire in this area would be well placed to collaborate with many other researchers around the university, as well as at related research facilities and local companies.

4.1.5. Geometric Analysis. Faculty in the area of differential geometry and geometric analysis are Judith Arms, Tom Duchamp, Robin Graham, Jack Lee, Daniel Pollack, and Yu Yuan. They do research on geometric mechanics (Arms), numerical approximation and computational geometry (Duchamp), CR geometry (Duchamp, Graham, Lee), analysis and geometry on conformal and asymptotically hyperbolic manifolds (Graham, Lee), mathematical general relativity (Lee, Pollack), and geometric flows and fully nonlinear equations (Yuan). The research of Graham, Lee, Pollack, and Yuan typically involves analysis of partial differential equations that arise in differential-geometric problems, so is usually classified as geometric analysis. There are numerous connections to the work of faculty working on partial differential equations (PDE), such as Hart Smith, Tatiana Toro, and Gunther Uhlmann. The work of Arms, Duchamp, Graham, Lee, and Pollack is connected to mathematical physics.

Retirements of some members of the group are anticipated in the near future. Arms is considering retiring sometime in the next few years, Duchamp is expected to retire in a year and a half, and Lee in approximately five years. The other three are all full professors. These demographics suggest that there will be opportunities for new hires in forthcoming years to continue and to rejuvenate the department's excellence in this area.

The group and the department will need to give careful thought to the best directions to take the group. There are many possibilities, given the numerous exciting developments in geometric analysis in recent years. The solution of the Poincaré and Geometrization Conjectures by Perelman using Hamilton's Ricci flow has led to an explosion of research in geometric flows, with applications to many areas. Blow-up techniques involving Gromov-Hausdorff limits have led to striking classification and structure results in a variety of geometric settings. Recently there has been dramatic progress in Kähler geometry, including applications to algebraic geometry. New ideas have been introduced into the classical subject of minimal surfaces, for instance min-max theory, which have led to spectacular results such as the solution by Marques and Neves of the fifty-year-old Willmore Conjecture. There are and will continue to be outstanding researchers on the market who work on each of these topics. Appointment of such geometric analysts could complement the strengths of the group.

Also under discussion has been the possibility of hiring in symplectic or hyperbolic geometry. Current research activity in these areas often interfaces with low-dimensional topology. These are very active research fields that have not been not represented in our department, though the work of our newest faculty member, Athreya, is related to hyperbolic geometry.

4.1.6. Probability. The University of Washington has a long and distinguished history in probability, starting with Bill Birnbaum and Ed Hewitt over half a century ago and continuing to the present day. Currently the University of Washington hosts one of the most vibrant atmospheres for probability research anywhere in the world. The UW probability group includes four core faculty members—Krzysztof Burdzy, Zhen-Qing Chen, Chris Hoffman and Soumik Pal—who work in a broad range of both continuous and discrete probability, with Ioana Dumitriu, Hari Narayanan and Steffen Rohde doing research that touches on probability in a significant way. Three of these faculty members—Pal, Dumitriu, and Narayanan—joined the department in the last decade.

The probability group has many connections with other departments on campus, including Statistics, Sociology, and Applied Mathematics. It is also part of a very rich probability program throughout the Pacific Northwest, with other large groups of outstanding probabilists in Microsoft Research's Theory Group in Redmond, at the University of British Columbia in Vancouver, and across western Canada. All these groups are linked through the Pacific Institute for the Mathematical Sciences, which consists of all the major universities of western Canada and UW, with Yuval Peres of the Microsoft Theory Group serving as a PIMS board member. The recent renewal of PIMS funding by Canada's Natural Sciences and Engineering Research Council provided for the establishment of the PIMS Postdoctoral Training Centre in Stochastics. This funding is for Canadian members only. In parallel, our own probability group, under the leadership of Hoffman, applied for and received a five-year grant from the NSF to establish our own probability postdoctoral training center, with the first appointment arriving last September.

4.1.7. Topology. Topology is the mathematical study of shapes. In contrast to geometry, it is concerned with properties that are invariant under continuous deformation, as opposed to rigid motions. At the same time it has many connections with geometry and other branches of mathematics, including algebra, analysis and combinatorics. Highlights of the subject in the current millennium include Perelman's solution of the Poincaré conjecture and the solution of the Kervaire invariant problem by Hill, Hopkins and Ravenel. Recently, Ian Agol at Berkeley was awarded the Breakthrough Prize for work in topology and geometry.

The three topologists at the University of Washington—Steve Mitchell, Ethan Devinatz, and John Palmieri, in order of seniority—work in algebraic topology, the field in which the work of Hill, Hopkins and Ravenel lies. The work of Ethan Devinatz falls squarely into this area, and has been fundamental for over thirty years. Connections with other branches of mathematics are evident in joint work of Palmieri with algebraist James Zhang, and of Mitchell with combinatorialist Sara Billey.

As already mentioned in the algebra section, an exciting future direction for the group would be to hire someone working in derived algebraic geometry, as pioneered by Lurie and others. This would benefit both algebraic topologists and algebraic geometers. Or, we may wish to hire someone working directly in algebraic topology. The topology group has not had a new appointment in many years, and the senior member may not be too many years from retirement. It will be important to hire someone new in this area if we are to maintain—and rejuvenate—the department's long tradition of excellence in algebraic topology.

4.2. Teaching

The standard teaching load for professors is 4+ courses per year. Typically, over their careers, professors teach at all levels, from calculus to advanced graduate courses. It is a long tradition for our professors to take an active interest in calculus, as is the case for mathematics departments nationally. Dave Collingwood took on a major revision of the pre-calculus course twenty years ago, ultimately writing a book that still serves as our text (with revisions along the way, prepared in part by Dave Prince in Engineering and Matt Conroy). However, for over a decade, pre-calculus has been taught exclusively by our lecturers, as is the case with Math 111–112, the business algebra and calculus courses.

In determining teaching load, we attach weights to all our classes, with calculus having the largest weight, our service courses at the 300 level the lowest, and all other courses weighted somewhere in-between. The expected load is a fixed number of teaching credits that equals fractionally less than the sum of the weights of four calculus courses or fractionally more than five of the 300-level service courses.

There are two ways to earn teaching credit besides in-class teaching. One is through successful advising of students, with fractional credit given for advising a student completing an undergraduate or Master's thesis or passing the general exam, and a significant credit awarded when an advisee completes the PhD. The other is for certain service duties. For example, year-long coordinators of the 100-level classes receive credit equal to almost one course, and the major leadership jobs in the department yield large teaching credits.

When all sources of credit are taken into account, we find that a typical teaching load is indeed very close to 4 courses per year, with those having a large number of graduate students teaching quite a bit less on average, and with others teaching more. Someone doing a modest amount of service (that yields teaching credit) or student advising is likely to teach 4 courses most years and 5 courses on occasion. This is how we arrive at the figure of 4+.

The lecturer teaching load is 8 courses per year. They, too, get partial credit for certain service duties, such as course coordination, which allows them to teach 7 courses in some years. Courses are assigned so that they never have more than two different courses in the same quarter. In quarters when they teach two, the two are the same.

4.3. Outreach

Since 1991, the department has run an annual Mathday for high school students and their teachers across the state. Started by our former colleague Dick Hain based on a program he attended as a high school student in Australia, Mathday has been run for over two decades

FIGURE 4.3.1. Math Hour audience

by Jim Morrow. It now welcomes 1500 students each year, with space filling up the day registration opens. The day begins with a plenary lecture by a UW mathematician or scientist after which students disperse across campus for concurrent lectures by faculty on topics in the mathematical sciences, panel discussions on careers in mathematics or the experiences of undergraduate mathematics students, or field trips to laboratories and facilities where mathematics is put to use every day. Mathday receives partial support from Wells Fargo and Boeing, as well as from a fund recently created in memory of UW alumnus and frequent Mathday contributor Ernie Esser, whose presentation on boomerangs was always popular.

Under the leadership of Julia Pevtsova, the department runs several outreach programs for middle and junior high school students in the Seattle area. The common goal of the activities is to enrich the experience of talented students in mathematics and its applications and to provide a continuous mathematical path throughout the school years to let that interest flourish.

The UW Math Circle is a weekly math enrichment program at UW serving Seattle students in grades 7 to 9 since 2010. It offers either two or three levels each year: first-year circle, intermediate circle, and advanced circle. In the spring, we offer Math Hour Talks, a series of popular Sunday lectures taking place on campus once a month. These lead up to the Math Hour Olympiad, a Russian-style oral mathematical competition for 5th to 10th graders in which the students have the valuable opportunity to discuss their solutions and approaches to highly non-trivial problems with volunteer mathematicians who help out with the event. For many students this is their first introduction to rigorous mathematical thinking. Moreover, they are introduced to it by doing it themselves. By the end of the event, students are doing mathematical proofs without even realizing it!

The Math Hour and Olympiad have been very popular among both students and parents. (See Figure 4.3.1.) The audience for Math Hour talks averages between 100 and 150. The Math Hour Olympiad had over 150 registered participants in 2015, as well as 80 volunteers (graduate students, professors, local high-tech professionals with advanced math or computer science degrees), and has been growing steadily.

Since 2003, we have run the Summer Institute for Mathematics at UW (SIMUW), a six-week residential program for talented high school students in the Pacific Northwest that provides them with the opportunity to acquire a full appreciation of the nature of mathematics: its wide-ranging content, the intrinsic beauty of its ideas, the nature of mathematical argument and rigorous proof, the surprising power of mathematics within the sciences and beyond. Acquiring a profound understanding of the depth and beauty of mathematics can be a transforming experience for a student, whatever interests the student may intend to pursue in the future, and this is the experience SIMUW is designed to provide. The mathematical topics and ideas studied are accessible, yet sophisticated and challenging, allowing every student to participate fully in mathematical inquiry and to be immersed in the world of mathematics.

The program includes six intensive two-week courses taught by university professors on topics that change from year to year. In the past, students have studied methods of argument, combinatorics, hyperbolic geometry, game theory, group theory, coding theory, and much more. In addition, there are twelve guest lectures on a wide variety of subjects and in many different formats, allowing students to glimpse even more mathematical areas as well as participate in hands-on mathematical activities. When not in class, students work on problems in groups or individually, have mathematical discussions with the teaching assistant counselors, and participate in social events, sports, and weekly Saturday outings.

For its first dozen years, SIMUW was fully funded through the generosity of an anonymous donor couple. They have now reduced their funding, and we are actively engaged in broadening our donor base. Key donors last summer were some alumni parents and the American Mathematical Society's Epsilon Fund.

Neal Koblitz is a co-founder of the Kovalevskaia Fund, whose main objective is to encourage women scientists in developing countries. The Fund's activities range from scholarships for high school girls in low-income areas of Peru to giving prizes for accomplishments in math and science in Vietnam, Mexico, Cuba, and southern Africa. In addition to providing concrete support for women researchers, students, and educators, the Fund has had a major influence at the institutional level: as a direct result of its activities, the Mexican Mathematical Society formed an "Equity and Gender Commission," the Cuban Academy of Sciences formed a "Women's Commission," and the Vietnam Women's Union formed an "Association of Intellectual Women."

Last April, the *Latinos in the Mathematical Sciences* conference was held in Los Angeles at the Institute for Pure & Applied Mathematics. The brainchild of Tatiana Toro, it was organized with the goal of encouraging Latina/os to pursue careers in the mathematical sciences, to promote the advancement of Latina/os currently in the discipline, to showcase research being conducted by Latina/os at the forefront of their fields, and to build a community around shared academic interests. Ana Mari Cauce, the current UW president, was one of the invited speakers.

Among Toro's other activities, she is a member of the Board of Directors of the Kovalevskaia Fund, and she recently joined the board of the College Assistance Migrant Program (CAMP) at UW. CAMP provides academic support and retention services to college students from migrant and seasonal farm working families, working with campus faculty, student services, and community-based agencies to help CAMP students complete their first year of college and graduate with baccalaureate degrees.

A different sort of outreach opportunity is provided through William Stein's efforts in developing the open-source mathematical software package Sage, which he has done for the last decade with a worldwide network of collaborators. Sage Days workshops take place ten or more times per year around the world, including Women in Sage workshops annually.

One source of outreach within the university, already mentioned in Section 1.4, is our lecture series MathAcrossCampus, which features prominent speakers from UW and elsewhere. The goals of the series are to expose students and faculty to the widespread use of mathematics in applications and to create a community of mathematics users and experts within the UW community who might otherwise not be aware of each other's presence. Faculty representatives from over 30 departments, schools, and colleges advise the organizing committee of Ioana Dumitriu, Chris Hoffman, and Rekha Thomas on speaker selection. The next speaker will be Taylor Perron, a geologist at MIT. He will talk about river networks on Earth, Mars, and Titan, showing how mathematical and computational descriptions of slow-acting geological processes, combined with measurements of today's landscapes, have provided a new perspective on the origin and evolution of river networks. Past speakers include Roger Myerson (Chicago, Economics), Margaret Wright (NYU, Optimization), Tom Daniel (UW, Biology), Simon Levin (Princeton, Mathematical Ecology), and Daniel Spielman (Yale, Computer Science).

As long as we are describing lecture series, we should also mention the Milliman Lectures, which are given annually by a prominent mathematician invited to spend a week in the department and deliver three talks. The lectures are widely advertised, with some speakers attracting a wider audience than others. The funds to bring in our speakers are provided by one of our earliest endowments, the Milliman Fund, given by Grace Milliman Pollock and her husband in honor of her brother, Wendell Milliman. Wendell received his degree in mathematics from us in 1926, founded the actuarial firm that bears his name, and went on to serve as president of the Academy of Actuaries and the Actuarial Society of America. The list of Milliman Lecturers is filled with Fields Medalists and Abel Prize winners. What it has not been filled with is women. For almost two decades, only Ingrid Daubechies graced the list. But last autumn, Laure Saint-Raymond came from Paris to give a lecture series with the title *From Particle Systems to Kinetic Equations*. This spring, Fields Medalist Curt McMullen will come from Harvard, and next autumn we will host another woman, Fan Chung of UC San Diego. We anticipate that her lectures, bridging mathematics and computer science, will attract a very large audience from across campus.

4.4. Quality

We highlight here some of the awards and honors our faculty have received since 2000.

- Member, Washington State Academy of Sciences: Gunther Uhlmann, 2011, Chris Burdzy, 2013.
- Foreign Member, Finnish Academy of Sciences, Gunther Uhlmann 2013.
- Fellow, American Academy of Arts and Sciences: Gunther Uhlmann 2009.
- Corresponding Member, Chilean Academy of Sciences, Gunther Uhlmann 2001.
- Bocher Prize, American Mathematical Society: Gunther Uhlmann, 2011.
- Stefan Bergman Prize, American Mathematical Society: Jack Lee 2012.
- Ralph Kleinman Prize, Society for Industrial and Applied Mathematics: Gunther Uhlmann 2011.
- John Simon Guggenheim Fellow: Gunther Uhlmann 2001; Tatiana Toro 2015.
- Simons Fellow: Tatiana Toro 2012, Hart Smith 2013, Gunther Uhlmann 2013, Sándor Kovács 2014, Chris Hoffman 2016.
- International Congress of Mathematicians invited speaker: Ralph Greenberg 2010, Tatiana Toro 2010.
- AFOSR Young Investigator grant: Dmitriy Drusvyatskiy 2015.
- NSF CAREER grant: Sara Billey 2000, Sándor Kovács 2001, Ioana Dumitriu 2009, Ioana Pevtsova 2010, Max Lieblich 2011, Jayadev Athreya 2014.
- NSF PECASE award: Sara Billey 2000.
- Sloan Research Fellow: Sándor Kovács 2002, Yu Yuan 2002, Isabella Novik 2006, Max Lieblich 2010, Thomas Rothvoss 2015.
- American Mathematical Society Centennial Fellow: Chris Hoffman 2008
- University of Washington Distinguished Teaching Award: Dave Collingwood 1999, Ron Irving 2001, Jim Morrow 2003, Andy Loveless 2012.
- Pacific Institute for the Mathematical Sciences Education Prize: Jim Morrow 2005, Virginia Warfield 2007.
- Louise Hay Award for mathematics education, Association for Women in Mathematics: Virginia Warfield, 2007.
- M. Gweneth Humphreys Award for outstanding mentorship, Association for Women in Mathematics: Jim Morrow, 2013.
- Haimo Award for distinguished teaching of mathematics, Mathematical Association of America: Jim Morrow, 2008.

There are many other measures of our faculty's quality too numerous to list, such as invitations to give plenary lectures at major international conferences, editorships of leading journals, appointments or elections to important committees of the American Mathematical Society and other professional organizations, or memberships on scientific and governing boards of the major North American mathematical institutes (MSRI, PIMS, AIM, IPAM).

4.5. Hiring

A fundamental issue, as previewed in Section 1.2, is how to interpret the changing faculty and student demographics in a way that allows us to plan effectively for the upcoming decade with regard to faculty hiring and revisions to curricula and degree programs. It is tempting to argue, given that we are doing more (much more!) with less, that we are in need of more resources. But the College has provided ongoing temporary and in some cases permanent resources in recent years, partly to hire more lecturers and AAPs, and partly to maintain the size of the graduate program in the face of significant TA salary increases. The more subtle issue is just what resources we need. More professors? Lecturers? Postdocs? Graduate students? Advising staff? Rather than simply saying yes to all—tempting though it is to do so—let us instead turn to how we should proceed with faculty hiring, assuming we continue to receive resources at something like current levels.

Due partially to a five-year state hiring freeze starting in 2008, our faculty has become top heavy, as illustrated in Figure 1.2.1. We have 44 people in the professorial ranks (representing 42 5/6 FTE), with 34 professors (one at 2/3 time), 6 associate professors, and 4 assistant professors (2 with joint appointments, one in Statistics and one in CSE). There are 28 faculty aged 50 and above, 16 below 50. It is reasonable to expect about 15 retirements over the next decade. Adding in other potential departures, it is possible that close to 20 appointments will be needed over the next decade to keep our faculty size stable.

Over the past twenty years, hiring has been guided by two complementary principles: building in areas of department priority and taking advantage of targets of opportunity. Priorities are determined through a now standard process, which starts with a call from the Planning (formerly Priorities) Committee to the faculty to submit recommendations. On occasion, specific groups are encouraged to put forward a proposal, if an exciting emerging field close to their interest has been identified by the committee as an area of potential growth. The submitted proposals are discussed by the committee, with a select few brought to the faculty for a vote. Once approved, a research hiring priority stays active for up to three years, after which it is reconsidered if no appointment in the area has been made. These priorities serve as a guideline to the Appointments Committee, but outstanding candidates in all areas of research are given full consideration. The department is committed to creating a diverse environment, and therefore diversity broadly understood has always been a priority in its own right.

In addition to priority candidates, we are always on the lookout for targets of opportunity. This has allowed us over the years to make outstanding hires. In the more distant past, if we identified strong candidates, we would encourage them to apply, and might be able to make an offer even if we did not have a search allocated. More recently, we have sometimes been able to take advantage of a target of opportunity by making more than one offer, even when just one position was initially allocated, especially if in so doing, we enhanced our diversity goals.

Our last four appointments reflect the success of this dual approach. Dmitriy Drusvyatskiy and Thomas Rothvoss work in optimization, which had long been a priority. Three years ago, we made simultaneous offers to them, although we were allocated only one position. A year later, we were given permission to hire Bianca Viray as a target of opportunity despite not having a search underway. And last year, based on an exceptionally strong shortlist of candidates outside our priority areas, we were given the opportunity by the College to make four simultaneous offers, successfully attracting Jayadev Athreya from Illinois.

We have been very successful in hiring and retaining talented women in tenure lines. We now have 8 women among our 44 professorial faculty (and 3 among our 7 lecturers). At nearly 20%, this compares quite favorably with our peers. Although we are a long way from establishing equality, hiring and retaining women is not an exception but the norm.

However, we have not had comparable success in hiring faculty members from traditionally underrepresented groups. Of the two Latinos on the faculty, the most recently hired arrived twenty years ago. Besides implicit biases, we face several difficulties in this area. One is the fact that the pool of applicants from these groups is small. Another difficulty is that we lack mechanisms to identify such candidates. To address the identification issue, this year we added to the job application an optional diversity statement, which has already proved useful. To address implicit biases, the chair of the Appointments Committee has provided each member of the committee with guidelines and a table of categories along which each candidate should be evaluated. Each committee member is asked to rate each candidate from the long short list on a scale from “exceptional” to “poor” for each category. Furthermore, this year the chair of the Diversity Committee looked at all tenure-line applicants, with the goal of identifying all applicants from underrepresented minorities. Two candidates were brought to the attention of the Appointments Committee.

It is important to note that diversity in our hiring means not only hiring individuals from underrepresented groups, but also recruiting faculty who have demonstrated a commitment to increase representation of traditionally underrepresented groups at all levels. On this count, our recent appointment of Athreya may be regarded as a diversity hire, given that several of his outreach activities address inequality issues in education. For example, as part of his work through the Illinois Geometry Lab that he created, Athreya taught a course at the Danville Correctional Center through the Education Justice project, and worked with the Chicago Prep college preparatory academy for Chicago Public School students to develop hands-on mathematics activities

In hiring of postdoctoral acting assistant professors, we have been less successful in enhancing diversity. Indeed, only one of our 13 current postdoctoral fellows is a woman, an unacceptable number. Our selection process may account for it. The Appointments Committee solicits suggestions from faculty members for candidates whom they wish to work with as mentors, but only the committee sees the full list of suggestions. If the list is short on women or underrepresented minorities—as it often is—faculty are not given the opportunity to re-think their suggestions. We will be changing our procedure to have the chair of the

Diversity Committee communicate with the faculty before they start looking at postdoctoral candidates, urging them to be mindful of the many ways to evaluate strengths of candidates before making their recommendations.

Returning to our hiring of tenure-line faculty, the procedure we described earlier in the section has worked well, notwithstanding budget cuts and hiring freezes. Two years ago, the Planning Committee was established to replace what had been called the Priorities Committee, in order to refocus our attention on long-term planning. The Priorities Committee traditionally produced a document each year on current hiring priorities, with little discussion of long-term options. Mathematics is a changing field and therefore we should periodically revisit our portfolio, exploring whether there are new areas that we should be moving into or areas that are not so active anymore in which we should abandon further hiring.

The limited hiring we did for much of the last decade led us to defer long-term plans or investment in new research directions in favor of addressing pressing priorities (in optimization) and seizing exciting opportunities. Our hope in the coming decade is to more actively shape the future of the department, with a better balance between strategic long-term planning and the hiring strategies employed in the past decade. To be able to make useful long-term projections—from five to ten years out—it would be helpful to know that we will be able to hire at a steady pace, one for instance that keeps up with retirements. Without the expectation that we can form a new group within a reasonable amount of time, and do so without jeopardizing a successful group in the department that we wish to maintain, it will be more difficult to take the step of moving into an emerging field.

The trust and support extended to us by the College last year, when we were given permission to make multiple simultaneous offers, increased our competitiveness and resulted in an appointment of extraordinary quality while simultaneously boosting the morale of the faculty. Continuous investment in faculty positions in the department over the next decade—combined with flexibility on the College's part in permitting us to take risks with simultaneous offers—would allow us to perform more effective long-term strategic planning while making appointments that improve our quality, diversify our research portfolio, and maintain our vibrancy.

CHAPTER 5

Closing Invitation

In Section 1.2, we introduced "issues that we would like you to have in mind as the site visit approaches, issues that concern us day to day as we plan our programs, prepare our budget, staff our courses, hire new faculty, and raise funds." We organized them under three headings: faculty demographics, student demographics, and the intersection of the two. Under faculty demographics, we observed how the distribution of the faculty across ranks and types has changed over the last decade, and we noted the importance of considering areas of strength in our department, the extent to which we value maintaining them as areas of strength, and what emerging new areas we should explore as potential areas in which to build. Under student demographics, we reviewed the growth in the number of students completing degrees and the diversification in their interests and career goals. Our discussion of the intersection of the two led to the overarching questions of Section 1.3:

(1) What is the right mix of instructors—professors, lecturers, acting assistant professors, part-time lecturers, graduate student TAs—and how do we head toward this mix in our hiring strategies?
(2) In what areas of mathematics should we look to hire new faculty?
(3) How should we revise our undergraduate and graduate degree programs and course offerings to align our perspective on what students should learn with their needs in a changing job environment?
(4) How should we attract students whose interests would be well served by our programs?

We also observed that our answers, whatever they may be, must take into account how to recruit a more diverse faculty; encourage a more diverse mix of students to learn mathematics, enter our programs, and join the mathematically-informed workforce; and integrate into our activities continuing K-12 outreach while building deeper connections across campus.

We have discussed these questions throughout the self-study, but without offering definitive answers. Nor will we do so now, inasmuch as definitive answers do not exist. They are an on-going work in progress: it's about the journey, not the destination. We invite you now to join us on this journey. We very much welcome your thoughts.

CHAPTER 6

Appendices

6.1. Appendix A: Organizational Chart

Faculty	
Chair:	Ron Irving
Associate Chair:	Tatiana Toro
Graduate Program Coordinator:	John Palmieri
Undergraduate Program Director:	Rekha Thomas
Math Study Center Director:	Matt Conroy
Staff	
Administration	
Department Administrator:	Michael Munz
Assistant to the Chair:	Rose Choi
Fiscal Specialist:	Pamela Kelley Elend
Student Services	
Director of Student Services:	Brooke Miller
Academic Counselor:	Ryan Kozu
Academic Counselor:	Katharine Swigart-Harris
Office Assistant:	Garrett Yoshitomi
Computing	
Senior Computing Specialist:	Steve Sheetz
Software Engineer:	Kevin Loranger
Graduate Students	
Graduate Student Representative:	Matt Junge
Lead TA:	Kristin DeVleming

6.2. Appendix B: Budget Summary

The State of Washington has a biennial budget cycle, enacting two-year budgets that begin on July 1 of each odd-numbered year and end two years later on June 30. Figure 6.2.1 summarizes our department's budgets for the biennia that ended on June 30, 2013, and June 30, 2015. The university's General Operating Fund, or GOF, is a combination of the funds allocated by the state and those obtained through the operating fee portion of student tuition. This is the core of our instructional budget. The university's Designated Operating Fund, or DOF, represents money obtained from Summer Quarter revenue, miscellaneous fees, and assorted other sources. A modest portion of our budget is allocated by the College as DOF. The other principal sources of funding are our indirect cost returns from grants (Research Cost Recovery, or RCR), direct gifts to departmental funds such as Friends of Math, and income earned from our endowments.

GOF budgets must be spent in full during a given biennium. They cannot be carried over. Other budgets carry over beyond the end of a biennium. This makes it a bit of a challenge to decide when to take a snapshot of our budget within a biennium. The tables in Figure 6.2.1 list biennial end dates, but the GOF budget numbers shown are the totals allocated for the given biennium. We have divided GOF into five categories: faculty salaries, teaching assistant salaries, staff salaries, operations, and benefits. Under operations are such items as equipment, supplies, and hourly salaries of student graders or tutors in the Math Study Center.

Much of the DOF budget consists of funds allocated to us by the College as their portion of start-up agreements for new faculty. The number listed in the table is the closing balance at the end of the biennium. Likewise, the number listed as RCR is the closing balance. These figures include commitments on our part for start-ups and a modest amount of staff salary support, plus funds encumbered to pay for faculty travel, graduate student travel, and other research expenses.

The non-endowment gift budget balances wax and wane with the arrival of gifts and their use to support departmental programs. The numbers listed, once again, represent the figures at the end of each biennium. This is the case as well for the endowment operating funds, much of which are encumbered for such items as graduate fellowships to incoming students and professorship expenses for faculty holding the given professorships.

The current budget is summarized in Figure 6.2.2. It does not match up smoothly with the budgets for the previous biennia, since we are only one-fourth of the way into the biennium. In particular, the College has yet to transfer all the funding for benefits into our budget, which is why the current biennium's figure is so much lower than the others. We are also awaiting additional College transfers into the operations budget. Once we receive our full allocation in these categories, the benefits figure should be higher (proportional to the increase in salaries) and the operations figure may be roughly the same.

A summary of our endowments can be found in Figure 6.2.3. All endowment gifts are invested in the university's Consolidated Endowment Fund, whose value is calculated four times annually, on the first day of each quarter. Thus, the amounts listed in the table are out of phase. We list the balances on the last days of the previous two biennia and the last day of the last quarter, but these represent the balances calculated for April 1, 2013, for April 1, 2015, and for October 1, 2015. The figure for January 1, 2016 is not yet available.

MATHEMATICS BUDGETS

June 30, 2013	
Category	**Amount**
GOF budget - Faculty Salaries *(biennium total)*	$10,228,879
GOF budget - TA Salaries *(biennium total)*	$2,460,193
GOF budget - Staff Salaries *(biennium total)*	$923,059
GOF budget - Operations *(biennium total)*	$547,549
GOF budget - Benefits *(biennium total)*	$3,485,366
DOF budget - *biennium total*	$244,012
RCR budget - *biennium total*	$519,607
Miscellaneous Funding (non-gift)	$28,759
Non-Endowment Gift Budgets	$366,997
Endowment Operating Funds - Professorships	$23,720
Endowment Operating Funds - Graduate Fellowships	$137,849
Endowment Operating Funds - Undergraduate Scholarships	$33,377
Endowment Operating Funds - Program Support	$80,482
Total	**$19,079,848**

June 30, 2015	
Category	**Amount**
GOF budget - Faculty Salaries *(biennium total)*	$11,753,510
GOF budget - TA Salaries *(biennium total)*	$2,663,578
GOF budget - Staff Salaries *(biennium total)*	$1,004,518
GOF budget - Operations *(biennium total)*	$607,883
GOF budget - Benefits *(biennium total)*	$3,600,004
DOF budget - *biennium total*	$329,672
RCR budget - *biennium total*	$641,323
Miscellaneous Funding (non-gift)	$45,923
Non-Endowment Gift Budgets	$499,611
Endowment Operating Funds - Professorships	$22,678
Endowment Operating Funds - Graduate Fellowships	$193,120
Endowment Operating Funds - Undergraduate Scholarships	$41,162
Endowment Operating Funds - Program Support	$100,280
Total	**$21,503,263**

Figure 6.2.1. Department budget, past two biennia

MATHEMATICS BUDGETS

December 31, 2015	
Category	**Amount**
GOF budget - Faculty Salaries *(biennium total)*	$12,492,413
GOF budget - TA Salaries *(biennium total)*	$3,306,367
GOF budget - Staff Salaries *(biennium total)*	$1,018,731
GOF budget - Operations *(biennium total)*	$497,496
GOF budget - Benefits *(biennium total)*	$2,085,944
DOF budget - *biennium total*	$207,464
RCR budget - *biennium total*	$767,643
Miscellaneous Funding (non-gift)	$47,461
Non-Endowment Gift Budgets	$375,720
Endowment Operating Funds - Professorships	$27,799
Endowment Operating Funds - Graduate Fellowships	$169,706
Endowment Operating Funds - Undergraduate Scholarships	$41,269
Endowment Operating Funds - Program Support	$83,409
Total	**$21,121,421**

Figure 6.2.2. Department budget, current biennium

June 30, 2013		
Category	**# of Endowments**	**Total Category Market Value**
Faculty Support	3	$1,218,213
Graduate Support	16	$2,870,683
Undergraduate Support	3	$497,495
Program Support	3	$1,286,961
Total	**25**	**$5,873,352**

June 30, 2015		
Category	**# of Endowments**	**Total Category Market Value**
Faculty Support	3	$1,366,569
Graduate Support	16	$3,605,106
Undergraduate Support	4	$622,809
Program Support	5	$1,846,227
Total	**28**	**$7,440,711**

December 31, 2015		
Category	**# of Endowments**	**Total Category Market Value**
Faculty Support	3	$1,284,761
Graduate Support	16	$3,243,577
Undergraduate Support	4	$585,524
Program Support	5	$1,749,294
Total	**28**	**$6,863,156**

FIGURE 6.2.3. Department endowments, past two biennia and this one

6.3. Appendix C: Faculty

Professors
Sara Billey
Ken Bube
Chris Burdzy
Jim Burke
Zhen-Qing Chen
Dave Collingwood
Tom Duchamp
Robin Graham (2/3)
Ralph Greenberg
Chris Hoffman
Ron Irving
Neal Koblitz
Sándor Kovács
John Lee
Max Lieblich
Don Marshall
Monty McGovern
Steve Mitchell
Jim Morrow
Isabella Novik
John Palmieri
Dan Pollack
Steffen Rohde
Hart Smith
Paul Smith
William Stein
John Sylvester
Rekha Thomas
Tatiana Toro
Selim Tuncel
Gunther Uhlmann
Garth Warner
Yu Yuan
James Zhang

Associate Professors
Judith Arms
Jayadev Athreya
Ethan Devinatz
Ioana Dumitriu

Soumik Pal
Julia Pevtsova

Assistant Professors
Dmitriy Drusvyatskiy
Hari Narayanan (1/2 Mathematics, 1/2 Statistics)
Thomas Rothvoss (2/3 Mathematics, 1/3 Computer Science & Engineering)
Bianca Viray

Principal Lecturers
Andrew Loveless
Jenni Taggart

Senior Lecturers
Matt Conroy
Alexandra Nichifor
Patrick Perkins (1/2)

Lecturers
Ebru Bekyel
Jonah Ostroff

Acting Assistant Professors
Shawn Baland
Alex Chirvasitu
Chih-Chi Chou
Jeremy Leach
Matthew McGonagle
Carlos Montalto
Francisco Munoz
Annie Raymond
Nicholas Reichert
Vasu Tewari
Yiran Wang
Zhenan Wang (NSF probability postdoc)

NSF Postdoctoral Fellow
Brent Werness

Part-Time Lecturers
Fanny Dos Reis
Andrea Heald
Natalie Naehrig
Elena Pezzoli

Adjunct Faculty

Adjunct faculty have appointments in other departments on the Seattle campus or on the UW Bothell or UW Tacoma campus. Below are our adjunct faculty, listed with their home units.

Bernard Deconinck	Applied Mathematics
Maryam Fazel	Electrical Engineering
Anne Greenbaum	Applied Mathematics
Randy LeVeque	Applied Mathematics
Mehran Mesbahi	Aeronautics & Astronautics
Linda Simonsen	UW Bothell, Mathematics

Affiliate Faculty

Affiliate faculty have appointments outside the university. Or, in some cases they are UW staff. Below are our affiliate faculty, listed with their home institutions.

John Garnett	UCLA
Ken Goodearl	UC Santa Barbara
Alexander Holroyd	Microsoft Research
Arnie Kas	University of Washington
Steve Klee	Seattle University
Kristin Lauter	Microsoft Research
Eyal Lubetzky	Courant Institute of Mathematical Sciences, NYU
Asaf Nachmias	University of British Columbia
Boris Solomyak	Bar-Ilan University
David Wilson	Microsoft Research