Brief History of Chemistry @ University of Toronto

From Henry Croft (Professor and Head from 1843 to 1879) through William Lash Miller (*de facto* Head 1920 to 1937), Donald J. LeRoy (Chairman 1960 - 1969), John Polanyi (1955 - present), Martin Moskovits (Chairman 1993 - 1999), and Dave Farrar (Chairman 1999 - 2003), the Department of Chemistry of the University of Toronto has been blessed with strong leaders and outstanding scientists with international reputations, who have created a very favourable internationally recognized reputation for the department.

Henry Croft, a young Englishman with research experience in Germany, **was** the department in its formative years, acting as administrator, researcher, and teacher, lecturing on a variety of topics to a wide spectrum of learners, students, businessmen, women's groups, and society in general, bringing some understanding of Chemistry and science to a generally uneducated population. He did original research in several areas, and became an outstanding forensic chemist, an area which became a Toronto specialty. His efforts set the stage for the future development of a strong chemistry department. His successor, William Pike (1880 – 1900), an Englishman with a German Ph.D., while not a distinguished researcher, introduced original research into the undergraduate chemistry program, which became a hallmark of Toronto's Chemistry curriculum thereafter.

Chemistry was the first department in Canada to establish a doctoral program, graduating its first PhD in 1901 (F.B. Allan) and shortly thereafter to the first woman to earn a PhD at Toronto, (Clara Benson in 1903).

Lash Miller was never formally Head of the department, but as *de facto* Head from 1920 to 1937 he made a major impact on the future of the department. One of his two Ph.D. degrees was obtained with Wilhelm Oswald, who introduced him to the thermodynamics of J. Willard Gibbs, a discipline which dominated teaching and research at Toronto for decades. Miller developed a towering reputation for his research in thermodynamics and electrochemistry. The three Heads of the department who followed him continued the department's emphasis on teaching Gibbsian thermodynamics.

By the beginning of the 1950s the department had grown to number about 13 members with strong research programs in physical, organic and analytical chemistry. Furthermore, it was now expected that all faculty be actively involved in performing and supervising original research. After Don LeRoy became the first departmental Chairman in 1960, he brought about major growth in the department numbers and breadth of research activities, introducing or strengthening activities in polymer chemistry, instrumental research involving NMR and X-ray diffraction spectroscopy and mass spectrometry, reaction dynamics, molecular beams, surface chemistry, inorganic chemistry, and theoretical chemistry. During his tenure, the department grew in numbers from 16 to 38 professorial staff as well as a number of lecturers, and large increases in support staff. In 1948, Chemistry obtained a major increase in space with the completion of the Wallberg Building, but this was not large enough to bring the widely scattered faculty under one roof. The major growth of the late '50s and '60x led to the necessity for more

space and the Lash Miller building was completed in 1963, which allowed all faculty to work in the same building.

The department survived the student turbulence of the late 1960s and '70s with much less disruption than often experienced in the American universities. During this period the highly regarded (by some) undergraduate Honours Programs were replaced by the New Program, which allowed undergraduates much greater freedom in choosing courses towards a degree. Many of the features of the honours programs were retained by the new Specialist Programs such as Chemistry, Biological Chemistry, Physics and Chemistry, Environmental Chemistry, etc. The University of Toronto created two new campuses in the '60s, now called University of Toronto Scarborough (UTSc) and University of Toronto Mississauga (UTM), with distinct undergrad programs, whose faculty hold appointments in the Graduate Department of Chemistry.

The award of the 1986 Nobel Prize in Chemistry to John Polanyi and his co-awardees Dudley Herschbach and Yuan Lee was not only a great honour to the recipients but also provided a major morale boost to the department. As a result, the department gained both nationally and internationally in reputation and respect, and new research funding and research chairs were established. A series of Nobel Lectures given in the university by a number of Nobel Prize winners brought major public attention to Science, Chemistry, and the Chemistry Department.

The imaginative performance of Martin Moskovits as Chair from 1993 to 1999 greatly furthered the advancement of the department. A major gift by the estate of John Davenport, a U of T alumnus, to the department was negotiated, amounting to more than $25 million dollars, taking matching funds into account. This allowed construction of the John and Edna Davenport Chemical Research Laboratories, a two storey addition on top of the undergraduate wing of the Lash Miller building, more than doubling the department's research space, as well as permitting renovation of most of the research space in the Lash Miller Building. These major improvements, with the accompanying modern instrumentation, led to increases in applications by new highly qualified graduate students, increases in the number of post-doctoral fellows, and an ability to attract the very best new young faculty. David Farrar, Moskovits' successor, with other colleagues, significantly modified the undergraduate Chemistry curriculum, resulting in a significant increase in the number of students taking courses leading to a chemistry degree.

A more detailed history of the department is found in the recent publication "Historical Distillations – Chemistry at the University of Toronto since 1841" by A.G. Brook and W.A.E. McBryde, Forward by John Polanyi; Dundurn Press 2007, 256 pp.

Chemistry had its last full external review in the Fall of 1992, though it was part of a multi-department cluster review in 1999. The review report written in '93 stated Chemistry had "*achieved national stature and is striving to take its place with the great departments in North America*" while the report from the cluster review in '99 noted steady improvement and if "*ranked within North America, it would fall somewhere in the range of 6-12*." We in Chemistry appreciate the difficulty of such comparisons and remain generally skeptical of overall rankings that attempt to capture such a multi-faceted department in a single number. Ultimately, the most important comparison is to ourselves and what the following self-study demonstrates is that the Department of Chemistry at the University of Toronto is substantially stronger, and in some ways unrecognizable, from that of just ten years ago.

Faculty & Staff Complement

Chemistry's faculty complement is made up of research (tenure-stream) and teaching (lecture-stream) faculty. Research and teaching faculty have primary appointments at one of the three UofT campus-based departments of Chemistry (St. George), Physical and Environmental Sciences (UTSc), and Chemical and Physical Sciences (UTM), with research faculty on all three campuses being members of the Graduate Program in Chemistry. The mandate of this self-study was focused on the undergraduate program at St. George and the overall Chemistry graduate research program, though it is widely recognized the chemistry content of the more interdisciplinary programs at UTSc and UTM are strong and important for those campuses. Faculty complement is determined and allocated at the individual campuses.

Chemistry's research faculty, who typically have an annual teaching load of 1.25 full-course equivalents (FCE), generally consisting of two undergraduate semester long courses and a single semester graduate course every other year. These faculty currently number 44.65 full-time equivalents (FTE) with 32.65 at St. George, 9 at UTM and 4 at UTSc. This compares well with ten years ago when there were 37 tenure and tenure-stream FTE, a relative low-point, given there were 38 FTE in the early 1960s. The growth was largely a result of UTM expansion, allocation of departmental Canada Research Chairs, and junior positions levered by endowed chairs and an NSERC Industrial Research Chair. The teaching faculty ranks in Chemistry (St. George) currently number 8 full time lecturers and one contract limited term appointment (CLTA), thus the overall downtown faculty complement is 41.65 FTE. Supplementing these ranks are a large and active group of emeritus professors, cross-appointed faculty, adjunct, and status-only members of the department.

Research Faculty: Research faculty generally associate with a specific sub-discipline (see **Appendix A)**, though these are highly fluid with many faculty mentoring graduate students from multiple areas. Historically the St. George campus endeavored to represent all the foundational areas of chemistry in its faculty complement while UTSc and UTM intentionally strived more towards specialization. For instance, UTSc garnered a strong international reputation in the area of physical organic chemistry while recently environmental science has been an area of strength. UTM has recently added significant strength in biological areas of chemistry to complement a strong history in materials and polymers. Recent and rapid growth in the two suburban campuses to more than 10,000 students each will likely see a broadening of the areas targeted for faculty hiring. UTM, which recently completed two new hires, is in good shape for handling the undergraduate and graduate demands on faculty and is expected to continue to grow overall complement pending budget and enrolment pressures. UTSc, in contrast, is significantly under-staffed at 4 FTE research faculty with little success, despite great effort, to expand faculty complement over the past five years. The challenges of limited space and overall infrastructure should be significantly improved when the new science building comes on line at UTSc in 2008; two searches will be conducted in chemistry at UTSc this year.

The research faculty complement on St. George is relatively small, compared to other large science departments, at 32.65 FTE and fairly young with a median age of 45 years. This is striking compared to the median of 54 years, just 10 years ago. This reflects the hiring of 10 new research faculty, over the past 4 years, only two of which were mid-career appointments. This recent intensive hiring activity was spawned, in part, by the willingness of three other departments to trade their external Canada Research Chair (CRC) positions for unfilled internal CRCs that Chemistry had open. A pair of industrial research chairs, both garnered by Lautens,

generated two junior positions. The balance of positions were obtained through previous retirements and the need to replace two faculty (Manners to Bristol; Lidar to USC) who relocated. One search started this year (polymers) to replace the position of Farrar who very recently took up the job of Provost at UBC.

Overall, St. George Chemistry has 9 Canada Research Chair holders, of which five are Tier I Senior CRCs and four are Tier II Junior CRCs. Pending successful renewal, Tier I CRCs may be held for multiple 7-year terms, while the Tier II CRCs are confined to a maximum of two terms of five years. Chemistry will need to carefully plan complement to prepare for when the Tier IIs are converted to regular salary lines, while clearly advocating for retention of the individual CRC position based on the principle that allocation is ultimately tied to success in Federal granting council competitions.

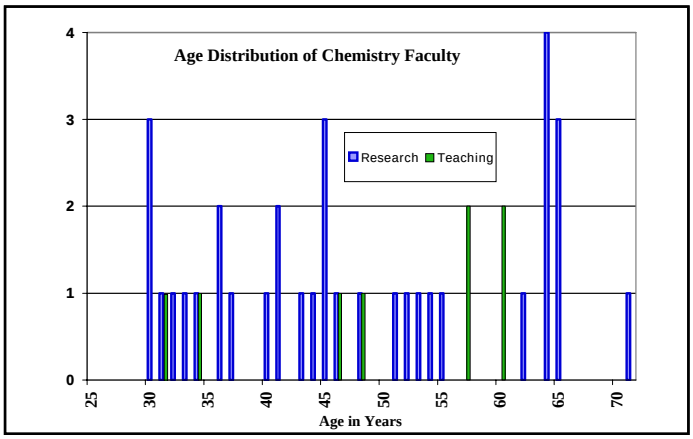
Teaching Faculty: The teaching faculty ranks in Chemistry at Toronto are significant in number and the overall balance between research and teaching faculty is largely unique in comparison to science departments at major public or private universities. This was a specific initiative put forth in Chemistry's 1999 Raising Our Sights (ROS) academic plan by then chair Martin Moskovits. This was in response to intense enrollment and space pressures, the recognition that 29% of all undergraduate teaching was being done through costly contract appointments (1996/97), and the feeling that permanent teaching staff were underutilized. Instead of simply hiring more research faculty to address teaching needs the ROS plan (with emphasis added) stated: *"Instead we propose a different complement strategy that will **(i)** ensure the high level of research and scholarship activities of the department, **(ii)** resolve, once and for all, the problem of systemic CLTAs (Contract Limited Term Appointments), **(iii)** actively address the challenge of providing an outstanding undergraduate program to students numbering in the thousands, and **(iv)** assure the close coupling of the undergraduate and research programs. This complement strategy would re-engineer and **strengthen** the **link between teaching** and **research**. By regularizing the systemic CLTA positions we would simultaneously **take control of teaching resources** and establish a level of **heightened participation** in **scholarship** on the part of our senior lecturers that is currently impossible to sustain with contract appointments."* The results of this bold initiative have been nothing short of spectacular in every area of departmental operation, including dramatic improvements in student experience, enhanced budgetary control on costs, optimization of research faculty teaching, and an overall increase in chemical education involvement by all faculty.

In 1999 Chemistry had 5 tutor/lecturer appointments (largely involved in laboratory instruction) while currently there are 9 teaching faculty in the lecturer and senior lecturer ranks who are fully engaged in the gamut of undergraduate education and scholarship. Teaching Faculty carry roughly a 2.5 FCE annual instructional commitment, which generally includes some combination of classroom lecturing and laboratory instruction at the undergraduate and sometimes the graduate level. Beyond the obvious assumption of excellence and leadership in teaching, expectations for scholarship are also high for promotion and PTR (annual merit based salary increases). Following a similar time-line and process of review for tenure, Lecturers are assessed for promotion to Senior Lecturer, which grants a continuing appointment. Scholarship is evidenced by peer-review publications in the chemical education or chemistry literature, significant effort at enhancing course and lab content, and supervision of undergraduate research students. Chemistry endeavors to provide direct support for the scholarly activities of its teaching faculty since, unlike the United States, there are no external sources of funds available to support these activities. This support comes in the form of modest start-up packages, annual

competitive scholarship and equipment RFPs targeted at Teaching Faculty, and provision of lab space. Chemistry has funded these initiatives entirely from its own budget, which going forward needs to evolve beyond the department in recognition of the 'value' these positions bring to the student learning and education scholarship. The impact of these individuals, on the overall teaching capacity in Chemistry, is profound since they represent the equivalent complement of 18 research faculty. **Chemistry now has only a few odd courses (1% of total) taught by contract teachers, and then generally only in the summer semester**. In comparison to other A&S departments, Chemistry is unique in the degree to which it optimizes the impact of Teaching Faculty with other units having, at most, only a few lecturer stream appointments, often with concomitantly large numbers of contract teaching appointments.

Awards: The department has a strong record of faculty being recognized locally, nationally, and internationally for their research and teaching scholarship and impact. Chemistry has five faculty members (Winnik, Ozin, Polanyi, Miller, and Brumer) who have earned prestigious promotion to University Professor at the University of Toronto. UofT limits this promotion to 1 to 2% of the total tenured faculty who demonstrated significant international impact in scholarship, with the current group comprising 35 notable individuals; Chemistry has the largest number of any department and two additional emeritus members (Brook & Jones). Chemistry has 14 members of the Royal Society of Canada (FRSC), comprising over 65% of those presumably eligible (e.g. Full Professors). In recent years Chemistry faculty have won highly competitive Sloans (Zamble, Scholes, Lidar), Steacies (Scholes), Brockhouse (Ozin), in addition to the 9 Canada Research Chairs noted above. In the most recent year alone faculty have been awarded a Rutherford (Scholes), three Leaders in Faculty Teaching Award (Miller, Poe, Mabury), an NSERC Accelerator (Abbatt), Ontario Early Researcher Award (Wheeler), ASMS Research Award (Jockusch), three of the Canadian-wide NSERC Top 50 Discoveries of 2006 (Abbatt, Stephan, Mabury) and others. The impressive full listing of awards held by faculty can be found in **Appendix B**.

Age & Gender Distribution: The figure below provides a synopsis of the age distribution for all research and teaching faculty, on the St. George campus, and highlighting earlier hiring patterns and the potential impact of the phase-out of mandatory retirement. In the current academic plan (see **Appendix C**), Chemistry was allocated 5 faculty salary lines (4 research and 1 teaching) and six technical and administrative staff positions in recognition of the eight faculty who were expected to retire during the current planning cycle; only two have elected to take retirement to date, with one of these a not yet completed phased retirement. It is generally expected for UofT, that the median age for retirement will shift from the 'normal retirement date' of 65 to two to three years later. Whether this holds in Chemistry, where the current post-60 group includes some of the most active and robust research programs, remains to be seen. Currently, there are eleven individuals 60 or older in the faculty ranks.



The Graduate Faculty of Chemistry, including research faculty, is currently under-represented in female faculty with only 20% female (9 of 44.65) across the three campuses. The situation is

slightly better on St. George with 22% and, if all research and teaching faculty are combined, the value is 28%. Sadly, these compare well with the Top-50 U.S. research intensive universities where the number of female faculty in chemistry departments averages 14% (range 8 to 25%) with only Rutgers and UCLA ahead of Toronto for research faculty (C&EN Dec 18, 2006 pp 59). The situation is improving slowly with 5 women chemists hired over the past 12 successful research faculty recruitments (10 on St. George & 2 at UTM).

Faculty Complement & Recruitment: Similar to descriptions found in the last three Chair's Reports, Chemistry has generally not automatically hired into the subject area vacated through retirement, relying instead on an overall assessment of departmental research and teaching needs. Over more than the past decade it has been normal practice to define recruitment priorities broadly and make appointments based on the superior intellectual strength and ideas of the individual recruited. It is our belief that talented people define scholarly evolution of a discipline not the other way around. The Department will rely on these basic strategies, and our current academic plan, to respond to retirements as they arise. Similarly, the John C. Polanyi Chair in Chemistry, a fully endowed Chair resulting from the generosity of the Mary Jackman and the Jackman Foundation, will, in time, be used to recruit an eminent addition to the Department in an area of chemistry deemed to be the highest priority for the department at that time.

Annual searches for one or more positions have been routine in Chemistry for at the last decade or more. Over the past four years Chemistry on St. George has conducted 11 total searches, from which we have hired 8 junior and 2 senior faculty. Significant effort is expended on optimizing every component of the interview, evaluation, and recruitment process. Carefully chosen search committees communicate widely in the academic community while searches are typically carried out in the early Autumn. Candidates, who are scheduled in quick succession, meet broadly with the chemistry community of students and faculty during their visit. Both a general audience research seminar and a more focused discussion of research plans with the search committee are scheduled. Every effort is made to highlight the outstanding scholarly life faculty can build here at Toronto. The search committee meets within days of the last candidate and, once a strong consensus is reached, their recommendation is taken before a full faculty meeting to seek unanimity in making an offer. The selected candidate is invited back for the 'recruitment visit' to discuss start-up requirements, be shown research space, meet with groups of students, faculty, staff and the Dean, be toured around Toronto, and typically spend significant time with recent hires to calibrate potential. Similar steps are taken for 'teaching faculty' hires.

Our recent recruitment success is testament to the positive research climate in Canada, the significant infrastructure funds available from Federal and Provincial programs (CFI and ORF respectively, and overall provide 80% of infrastructure costs), the breadth and quality of our infrastructure following ~$40M in new and newly renovated space, competitive salaries, quality of students, strong support expressed by the Dean and University for the department, quality of life issues in Toronto and Canada, and the overall positive vibe that exists in Chemistry. Ten years ago the issues of research space, small and of poor quality, low start-up packages, and immigration issues, were notable in the Chair's report in explaining the relative paucity of success in recruitment. Recently, total start-up packages have increased up to 10-fold, space is expansive and of high quality, and UofT expends significant resources to ensure a smooth transition to Canada.

Staff Complement: Chemistry has an exceptional group of base-budget supported technical and administrative support staff. Administrative staff number 13, which are spread across the business office, library, and the undergraduate, graduate, and chairs office. Technical staff

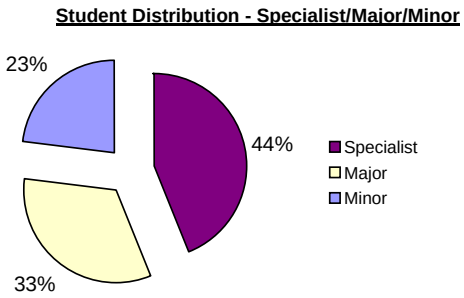
number 23 and ensure the proper operation of instrument facilities (NMR, Mass Spec, X-Ray, Analest), glass blowing, machine shop, electronics and computing, chemical services and stores. There are 7 'teaching technical' that provide essential services for the delivery of laboratory courses. Faculty members further employ 18 research group assistants and technicians to support their individual operations.

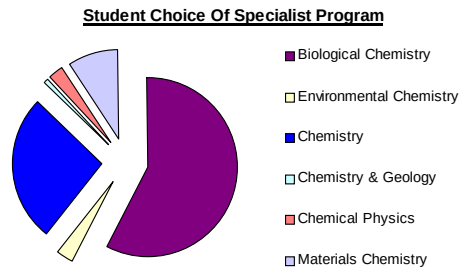
These administrative and technical staff, ably support a department expending $15M annually in research funds, supporting over 350 graduate students, PDFs, and Research Associates, and teaching over 8,000 semester course equivalents. They are demonstratively too few in number and significantly less plentiful than comparisons to our competitor institutions suggest. For instance there is currently one full-time staff member in the department's Mass Spec lab though *seven* major systems are in operation – similar narratives exist for multiple other areas in the department. Despite the express difficulty in doing direct comparisons, all the top Chemistry departments we contacted reported *technical and administrative base-budget support staff* of between 50 and 60 individuals; our total of 36 pales in comparison.

Chemistry staff are widely recognized for quality of work and positive impact in support of the research and teaching mission of the department. Chemistry created an Outstanding Staff Award four years ago to recognize impact broadly in the department while three of our staff (Mathers, Marquez, Ford) have been recognized with competitive Arts & Science-wide staff awards.

Academic Programs - Undergraduate

Chemistry's Undergraduate Program Descriptions: In the Faculty of Arts and Science, students take a "general science" first-year curriculum of physics, chemistry, biology and mathematics (two semesters of each). They then select their university subject POSt ("Program Of Study") and subsequently take courses towards a specific degree. Chemistry students have a choice between six subject POSts that are classed as "specialist" programs (see figure below) which comprise between 12 and 14 full credits out of 20 – students take five full credits per year during a four-year degree; **Appendix D** provides details on each of the Specialists Programs. The Biological Chemistry Specialist is the most popular and has been for the last decade. Students may also enroll in a Chemistry major (8 full credits out of 20; 30 – 40 students graduating per year), a Chemistry minor (4 credits; 30 – 40 students per year) or an Environmental Chemistry minor (4 credits; 10 – 20 students per year). The distribution of students in each program is shown above.



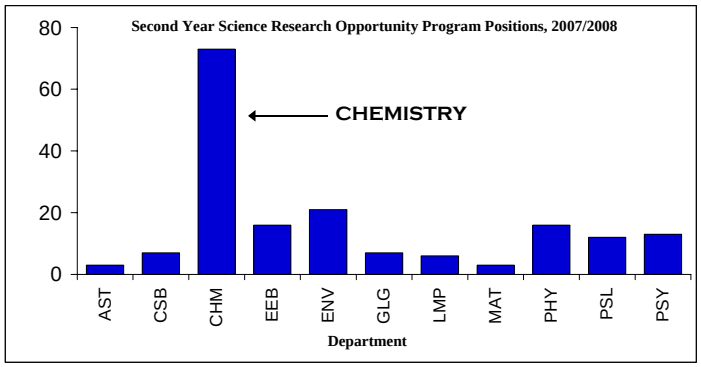


Overall, Chemistry is blessed with dedicated and talented undergraduate students who contribute significantly to the scholarly life of the department and who then go on to make major contributions in chemical fields. Though by no means an annual occurrence, one story to illustrate this is the fourth-year bio-organic course taught by Kluger in 1993. Of the 36 students

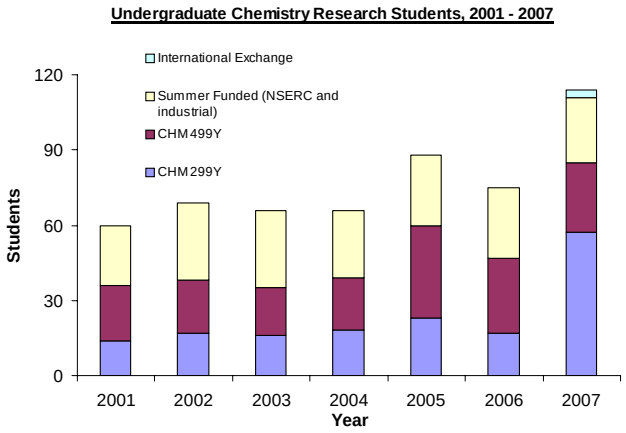
enrolled, at least five have now gone on to impressive academic careers in top chemistry departments - Toste (Berkeley), Johnson (Michigan), Nagar (McGill), Rovis (Colorado State), and Zamble (Toronto) while many others have done well in ancillary fields, for instance as an orthopedic surgeon (Masnyk).

Undergraduate Course Delivery: Research faculty are scheduled to teach one full course equivalent per year (typically 52 hours student contact @ St. George). This is mainly made up by lecture time although several research faculty currently teach upper-level laboratory courses (Walker, Zamble). Teaching faculty deliver the bulk of course laboratory components and additionally lecture at every level of the undergraduate curriculum to both chemistry program students and life science students. Teaching faculty student contact hours are two or three times that of research faculty. In 1997, stipendiary instructors offered 29% of the total undergraduate teaching. In 2007, that number is now less than 1% and is completely reflective of the successful teaching stream model introduced to Chemistry in 2000. Large first- and second-year courses (often 800 – 1100 students) are typically "team-taught" in several smaller lecture sections by a combination of teaching and research faculty members. When considering these courses, several instructors routinely score greater than 6 out of 7 on the Arts and Science question "all things considered, performs effectively as a university instructor" (the Faculty-wide average is 5.6/7). These faculty come from both the research and teaching "pool". Two faculty members (Dicks, Zamble) have won faculty Outstanding Teaching Awards since 2003 and three faculty members, two research and one teaching, won the inaugural provincial Leadership in Faculty Teaching Award in 2007. The 2007/2008 Chemistry courses, faculty assigned to the lecture and lab components, and the enrollment can be found in **Appendix E**.

Chemistry Undergraduate Research Opportunities*;* Undergraduate chemistry students are able to participate in research for credit via four mechanisms: **(a)** CHM 299Y (***Research Opportunity Program***) - this faculty-wide program allows undergraduates who have taken between 4 and 9 full credits to participate in a full-year research course under the supervision of professorial or teaching faculty. Chemistry made 73 positions available to students and filled 59 of them. Of these, 32 are being supervised by teaching faculty and 27 by research faculty; **(b)** ***Summer Research Opportunities*** – typically 25 – 30 undergraduates annually receive scholarships (NSERC or industrially funded) to undertake research full-time during the summer. These are granted on a highly competitive basis (usually 150 – 200 applications are received) with ongoing industrial sponsors including DuPont Canada, and the Xerox Research Centre of Canada. In addition, the Richard Ivey Foundation and the graduate-run Chemistry Club both fund one position each year; **(c)** ***International Student Exchange Program*** – 2007 saw inaugural Chemistry participation in the Ontario/Baden-Wurttemberg Student Exchange Program. This involved three Toronto students spending four summer months at a German university (Konstanz/Freiburg) undertaking research, with each gaining a half-course credit (course CHM 398H). A second pilot program has been established for summer 2008 allowing exchange of students between Toronto and SUNY Buffalo. More informal exchanges with Mainz and Bristol have been successfully running for years with ~7 students annually taking courses and joining groups for advanced research projects; **(d)** ***CHM***



499Y Research Course – open to chemistry specialists and outstanding majors wishing to take a research course in their final year of study. The course is not a mandatory requirement (except for Environmental Chemistry and Materials Chemistry programs). Professorial and teaching faculty supervise students for a minimum of 260 hours during the academic year. A substantial thesis is written in April at the conclusion of practical work and graded by three faculty members (the supervisor + two others). Twenty to thirty students routinely take the course annually.



The total number of Chemistry undergraduates undertaking research has almost doubled in six years – from 60 in 2001 to 116 in 2007. A significant proportion of all undergraduate research opportunities in A&S are offered by Chemistry.

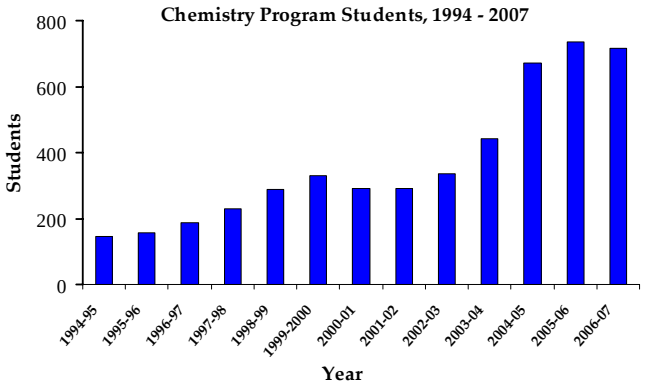
Chemistry Curriculum Changes, 2000 – 2007: In the 1999/2000 academic year, new undergraduates enrolling in a first-year chemistry course had two choices: to take CHM 137Y ("General Chemistry") or CHM 151Y ("Chemistry – The Molecular Science"). CHM 137Y was a year long two-semester "service course" for life science students with a typical annual enrollment of ~ 1200 students. It essentially covered enhanced high-school material, did not discuss organic chemistry in any detail and had an average *retake rate* (percentage of students saying they would take the course again disregarding program requirements) of 65%. In comparison, CHM 151Y was a "cutting-edge" course for chemistry specialists, with a typical enrollment of ~ 120 students. It contained a roughly equal amount of organic/inorganic/physical/materials chemistry, had an advanced laboratory component and an average retake rate of 85%. At that time organic chemistry was taught at the 200-level in course CHM 240Y ("Introductory Organic Chemistry") – often taken by life science undergraduates as a preparation for professional schools with an enrollment of ~ 1000 and an average retake rate of 30%!

This low retake rate prediction led to the realization that a lot of high school material was (re)covered in CHM 137Y and that not all students needed a full year of organic chemistry for their life science programs. In addition, the Biochemistry department began to teach a lot of third-year material at the second-year level, creating a demand for a single-semester 100-level course in the fundamental organic principles. It became logical to introduce organic chemistry into the first-year curriculum and develop two single-semester courses (carrying an 'H' designation) from more traditional year-long ones ('Y' courses).

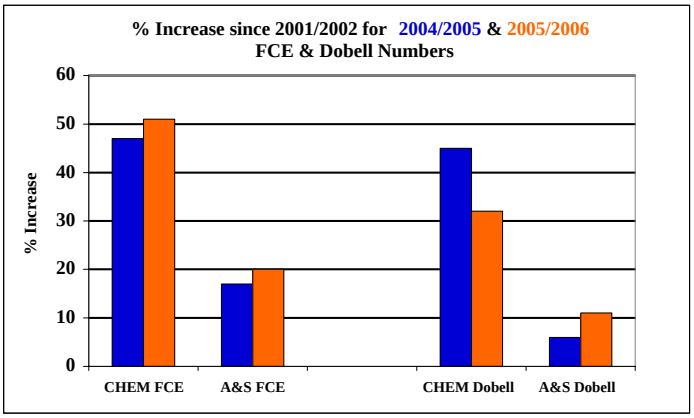
In 2000/2001 the department implemented the changes: 2 full credits (CHM 137Y and CHM 240Y) became 1.5 (CHM 138H, CHM 139H and CHM 247H). General chemistry was taught *only* in CHM 139H ("Chemistry – Physical Principles") and organic chemistry became split between first-year (CHM 138H – "Introductory Organic Chemistry I") and second-year (CHM 247H – "Introductory Organic Chemistry II"). Curricular flexibility was introduced – CHM 138H and CHM 139H could be taken in any order in first-year but not in the same semester. All

three new courses were offered in fall, spring and summer semesters with typical enrollments being ~ 2000 (CHM 138H), ~ 1700 (CHM 139H) and ~ 1300 (CHM 247H). These figures show two important points: (i) not all students need both first-year courses – some transfer from other universities or have Advanced Placement/International Baccalaureate qualifications in general chemistry that are equivalent to CHM 139H; (ii) not all students do in fact take or need a full year of organic chemistry. Both CHM 138H and CHM 247H are routinely "team-taught" by three instructors lecturing all course sections for one month to ensure consistency. A typical maximum lecture section consists of ~ 400 students although laboratory groups range in size between 16 – 24 students. The coordinator of each course is often (but not always) a teaching-stream faculty member.

2007 ~ Impact of These Changes: Course retake rates have improved to ~ 75% in CHM 138H and ~ 50% in CHM 247H, representing a major increase in student satisfaction with organic chemistry (c.f. CHM 240Y retake rate of 30%) without a significant change in course content. The total number of Chemistry program students (those enrolled in a specialist, major or minor) almost **tripled** from 274 in 2001/02 to 735 in 2005/06 – a growth that cannot be accounted for by the elimination of Grade 13 in Ontario schools and the infamous "double cohort" of 2003/04. At least 75% of Chemistry program students come from taking CHM 138H/CHM 139H rather than CHM 151Y (which still operates in a similar way as in 1999/2000). Students clearly choose to take a Chemistry program because of their first-year experience, rather than because they "liked it at high school".



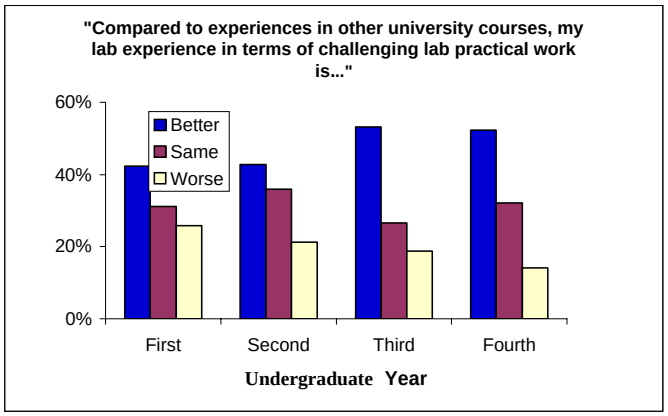
Enrollment Changes since 2001-2002: Chemistry has experienced dramatic enrollment increases since the year before the 'double cohort' hit Ontario universities. These increases were well in excess of simple enrollment "bulge" with total FCE rising 51%, in Chemistry, for the 05/06 over 01/02 while the value for A&S overall was only 20%; Chemistry was #3 overall in A&S in this metric. Similar and equally dramatic changes in Dobell Numbers (faculty: student ratio) were also observed as indicated in the figure shown to the right. In the latest data available (2005/2006 academic year) Chemistry has **3946 FCE** (#8 in A&S) and a Dobell value of 32 (#15) and down from 04/05, due to arrival of multiple new faculty, when it was 35 (#12 overall). In absolute student FCEs, and in comparison to the ten science departments, Chemistry ranks 4th behind Math (7723), Psychology (5256) and Anthropology (4369) but slightly ahead of the biology departments (3919 & 3641) and well ahead of Physics (2722). In regards to gender and ethnic balance, data compiled from our survey (see below), the overall undergraduate chemistry



program is ~60% female and ~66% of our students consider themselves a “visible minority” and an additional 5% as “First Nations ancestry”.

The performance of Chemistry is even more dramatic when viewed in light of the curriculum changes that resulted in our deleting over 1,000 FCE from the first and second year programs. The fact that we have more than made up the lost ground suggests students have chosen to take chemistry courses rather than being ‘captive’ to program requirements. It is difficult to point to any one action that resulted in such success though it would be persuasive to argue it was a combination of: 1) the addition and enhanced position of teaching faculty ranks; 2) the changes to curriculum that now has organic in 1st year; 3) breadth of Chemistry’s programs and courses; and 4) Phase I renovations (12,000 sq ft) to the teaching labs (discussed in more detail below).

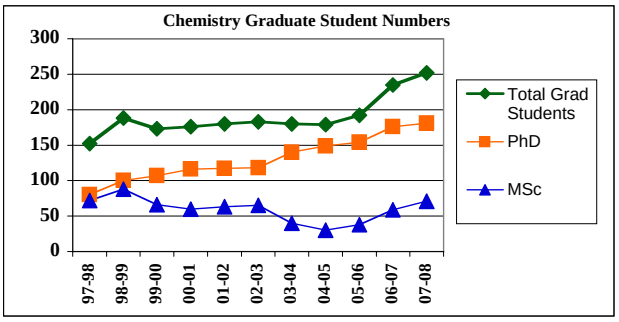
Chemistry’s Survey of Student Engagement: To accurately assess what undergraduates think of the Chemistry Department, its programs, and Phase I of the teaching lab renovations, an on-line survey was devised based on the National Survey Of Student Engagement (NSSE, http://nsse.iub.edu). NSSE is designed to obtain information from universities about student participation in programs and activities that institutions provide for their learning and personal development. Forty-eight questions were written to discover what students generally thought about how their chemistry courses compared to those offered by other departments and what they thought more specifically about their chemistry laboratory experiences. The survey was administered on-line via the BlackBoard learning management system and was distributed to 2699 students (who were selected if they had taken a minimum of one undergraduate chemistry course). 1274 students completed the survey (47%) representing an above-average response rate for this type of activity. Data was collected from students at each academic level e.g. from those having completed only one first-year course through to those graduating with a Chemistry specialist degree.



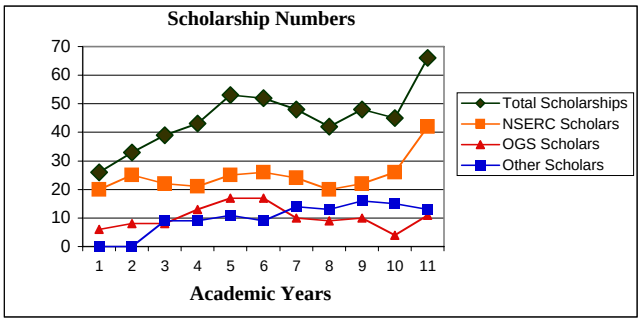
The major survey conclusions and statistics can be found in **Appendix F**. Briefly, students across the four years largely agreed they would take the courses again and were very positive about the overall lab experience. Significant differences were observed between those in 1st & 2nd vs 3rd & 4th years with the latter being more enthusiastic about overall course quality, the skills acquired in Chemistry courses helping in other UofT courses they carried, and were positive about the challenging lab reports and assignments. The CHM-SSE will be done again next spring to capture the potential impact of the second and final phase of teaching lab renovations that have transformed the physical domain where the labs are held.

Academic Programs - Graduate

At over 250 PhD and MSc students, our graduate program is now larger than at any time in departmental history. Expansion over the past three years followed a long period where external constraints contributed to our numbers hovering around 180 students from 1999 to 2004. In response to recent success in faculty hiring and significant financial contributions from the University, we planned and aggressively recruited the very best students and reached our 2010 goal three years early; the Associate Chair Graduate (Walker) and his able team deserve much of the credit for this outsized success.



By the most obvious metrics, entering GPA and number of students bringing externally competitive scholarships, the quality of the cohort has risen significantly and generally in step with rising enrolment. Additional **strong** evidence for 'quality' is reflected by the two Andre Hamer Postgraduate Prizes, which were established "*in order to recognize NSERC's most outstanding candidate in each of the Master's and Doctoral Scholarship competitions*." Amazingly, **both** the **MSc** and the **PhD Hamer** in **2007** will be awarded to two of our current Chemistry graduate students! This is the first time that any one University has one both Prizes, much less a single department.

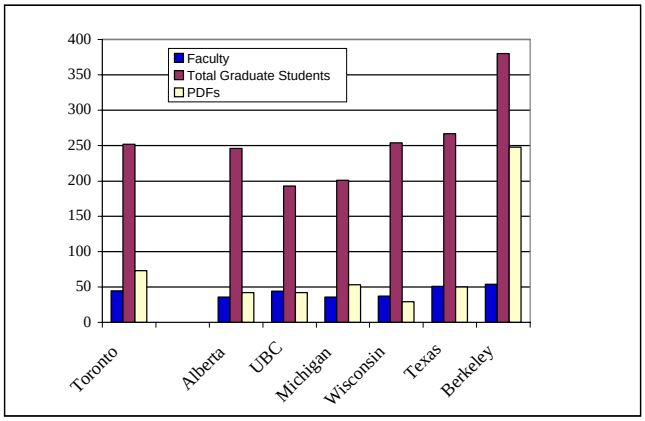


The graduate student complement is heavily weighted towards the PhD (72%) though most new students start in the MSc program and some of our students, particularly in Organic, pursue the MSc degree. The student complement is currently over weighted on the St. George campus (84%), despite the fact that research faculty FTE is only 73%, presumably due to more recent and ongoing expansion of faculty hiring and improvement of physical infrastructure. It is critical, for multiple reasons, to continue to increase graduate student enrolment at the two suburban campuses, until the ratio of students:faculty is similar; an active effort to achieve this a top priority for the Graduate Studies & Recruitment sub-committee. Gender balance is improving year to year with 45% female students in 2006-07, which compares fairly well with 36% of doctoral graduates awarded to women at chemistry programs in the U.S. (C&EN Aug 20, 2007, pp 63).

Significant attention has been focused on graduate student support. On the financial side, the base guaranteed stipend in Chemistry has risen from ~$18k 10 years ago to the current $25,913 ($19k plus tuition and fees) with the largest rise in 'take-home pay' over the past 4 years; Chemistry's stipend is the highest in the Faculty of Arts & Sciences. With the large number of scholarship

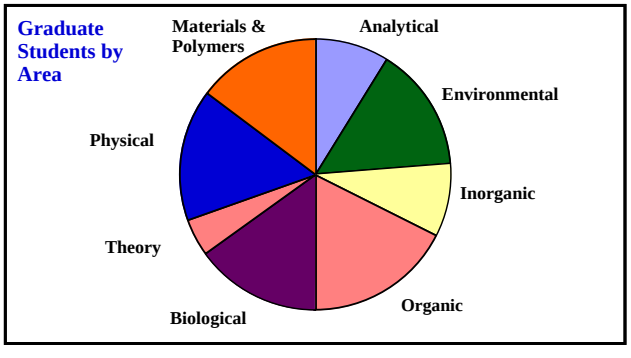
holders, most of which yield higher stipends, the actual median support for last year was $27,000. Early in 2007 Chemistry implemented an eight-week Pregnancy Leave Policy, the first in Canada and one of only a handful in North America; leave is funded jointly by the Dean, the Chair, and the respective Faculty supervisor.

Overall graduate student support comes primarily from faculty research grants via research assistantships, teaching assistantships, and internal/external scholarship support. The stipends noted above are the entire sum required to support an individual graduate student, as there are no additional overhead or benefits tacked on since they are already delivered to all Canadians. Chemistry receives over $1.6M in UofT scholarships to support graduate students, the St. George campus alone approaches $1M in expenditures for Teaching Assistants, and our students bring in another $1M in scholarships. For 250 students at the guaranteed stipend of $25k requires $6.25M of support. Ultimately individual faculty, through their grant funds, provide between $5k (external scholarship holder) and $14k (beyond funded cohort and thus ineligible for internal scholarships) for each student in their group with the average ~$10k. The relatively inexpensive per student cost contributes significantly to the overall ability of Chemistry faculty to maintain research groups and represents an advantage over Universities, particularly in the U.S., where per student costs to faculty grants can be much higher. Historically, this has balanced a grants landscape that tended to deliver far fewer research dollars per faculty member. Currently, 250 graduate students require ~$2.5M from grant support while Chemistry faculty, in the current fiscal year, have $15.7M in overall funding, of which $9.7M is operating funds.



Post-doctoral Fellowship students (PDFs), following UofT guidelines, must be within 5-years of their PhD and can reside in a particular research group for 3-years. Beyond these terms the positions are typically converted to that of Research Associates which carries ~21% overhead towards benefits; PDFs receive no 'extra' benefits and faculty are charged no overhead. The average current PDF salary is $36,000. Chemistry currently has 73 PDFs (of which 33% are female) while another 20 carry the rank of Research Associate. The number of PDFs was as high as 100 just 4 years ago, but the specifics of the UofT situation mean some of these are now Research Associates which if added in would yield 93 combined post-PhD researchers; recent grad student increases probably also influence the number to some degree. Senior Research Associates, of which Chemistry has a few, are generally viewed as long-term soft-money positions.

Programs of Graduate Study & Research: Chemistry has five Fields of study approved by the Ontario Council on Graduate Studies or OCGS. These are as follows: 1) Inorganic, Polymers and Materials; 2) Organic Chemistry & Biological Chemistry; 3) Physical Chemistry & Chemical Physics; 4) Environmental Chemistry; and 5) Analytical Chemistry. The general popularity of the various sub-disciplines is indicated in the pie chart which shows



roughly 25% for each OCGS field if one combines analytical and environmental. Although precise data are not available, the change from 10 years ago includes a large increase in Environmental and Materials & Polymers with small decreases in Physical and Inorganic.

All fields are generally similar in regards to course requirements (2 courses for MSc and 4 for PhD except for theory where 6 are required) and all require a departmental oral exam (PhD students) generally in the second year. Areas also differ in whether the breadth requirement is covered by cumulative exams (analytical, organic, biological) or research proposals and seminars (e.g. environmental, inorganic). All students have a progress committee, typically involving the supervisor and two other discipline members, which oversees course selection, adjudicates degree requirements, and provides advice and mentoring. Participation by faculty and students in the progress committee process is ensured by only allocating UTF Scholarships (the fund is $1.6M) to those students who are up to date with their annual meetings. A few subdisciplines utilize annual colloquia meetings to have students give presentations on their work. Progress meetings are scheduled shortly after and the overall process enhances collegiality and interaction beyond the individual research groups; **Appendix G** includes a copy of the *7th Annual Environmental Chemistry Colloquium* booklet. At Toronto all PhD students have a final dissertation defense, which includes an outside expert. In recent years Chemistry took the lead in popularizing an open public seminar to precede the *in camera* defense.

Normative Times & Graduation Numbers: Over the past four years we have graduated 18, 23, 25, and 27 PhD students respectively which represents between 11 and 13% of the A&S total, the most of any department, while 24% of all science PhDs are chemists. The normative time for our students, mean of 4.15 years (range 4.0 to 4.3), is well below the A&S mean of 5.7 years and is consistently the shortest in A&S (for the past four years). These data are consistent with a well-run program that addresses the direct needs of our PhD students with respect to mentoring and support. No comparative normative time data for the Top-50 U.S. research universities was available but the mean for a small data set was between 5 and 6 years. Our strongest PhD students frequently receive competitive NSERC PDF awards (3 to 6 per year) and in 2005 one of our graduates (Tetreault) was awarded a Governor Generals Gold Medal, while in 2000 (MacLachlan) and 1999 (Yang) were awarded one of four nation-wide NSERC Doctoral Prizes. During the same period we also graduated between 15 and 28 MSc students annually. From the Graduate and Professional Student Survey, Chemistry grad students were very positive about their Academic Experience with 78.3% reporting it as Excellent or Very Good (UofT overall value was 66.1%).

Graduate Student Life and New Programs: Chem Club is a highly successful graduate student organization with a business license, that provides lab coats, goggles, and lab/course notes to undergraduate chemistry students. This volunteer activity annually raises significant funds that are plowed into enhancing student life for the tri-campus graduate program in Chemistry. Activities are varied and extensive including trips to hockey games, ski trips, guest seminar speakers, welcome events for new students, and recent funding of undergrad and graduate scholarships (each @ $50k). Chem Club makes a positive contribution to department life while providing valuable business experience to the annual Chem Club executive committee.

In recent years Chemistry has created a number of programs designed to improve the quality of mentoring beyond the domain of research. One example is the *Chemistry Teaching Fellows Program* targeted at providing a high-level mentoring project for senior graduate students and PDFs. The three specific goals are: 1) enhance the quality of our undergrad program; 2) enhance the competitiveness of our PhD students in the academic job market; and 3) provide faculty with

a venue for a 'Chem Ed' activity. Typically three to six CTFPs are chosen per year, with selection based on the quality of a written proposal, and are paid the TA rate for ~50 hrs of activity. Projects involve the Fellow working closely with a faculty member on pedagogical project that might involve developing an innovative set of lectures, design of novel tutorial material, or the creation of a new laboratory exercise. Since 2002 a total of twenty-two students have successfully completed the CTFP program. Also in 2002 the department created Croft Teaching Assistant Awards to recognize and celebrate excellence in the demonstrator and tutor ranks of our TAs. Named after the first Professor of Chemistry at UofT, the Croft TA Awards are nomination driven and highly competitive.

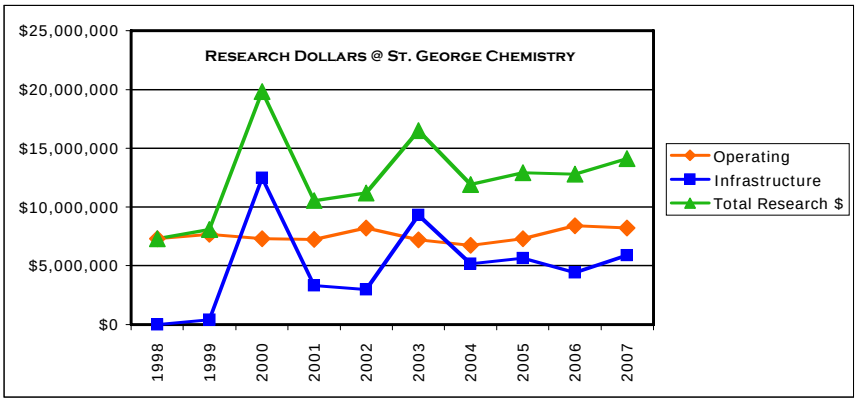
Under the leadership of Prof. Cynthia Goh the department supported a non-credit course in *Scientific Entrepreneurship 101* that originated in Chemistry four years ago and is now jointly offered with MaRS (with enrolment of ~500). Created in response to strong demand by graduate students for mentoring beyond the domain of teaching and research, the inaugural year had an enrolment of over 90 students attend the semester long course covering topics on IP and patent law, financial management, fund raising and grant writing, hiring and human resource management, writing business plans and others. The second term, with a smaller number of students (~40), was more focused on the mechanics of actually transferring a technology from the lab to the marketplace. To date, at least three companies have been started by students who took these courses. The popularity of this course has led to the exploration of developing a professional masters program in scientific entrepreneurship that we hope to propose in the near future.

Research & Scholarship

Areas of Scholarship: Research interests have changed dramatically over the past 30 years. While in the 70's the Department's strength was primarily in physical chemistry and chemical physics (our Nobel Prize was in that field) currently we now have substantial strength across and within the breadth of modern chemistry including organic synthesis and medicinal chemistry, biological (organic and inorganic) chemistry, inorganic, materials & polymers, environmental, analytical, and experimental and theoretical physical chemistry. Although listed as part of one area of chemistry, many to most faculty supervise students in multiple-areas and collaborate broadly in the department and without. The organic group is now very strong with two young synthetic organic chemists (Dong & Taylor) recently joining three mid-career staff resulting in an age distribution that positions this group for substantial impact for decades to come. Similarly, Environmental is well-populated with junior (Simpson & Murphy) and four mid-career faculty. The Biological and experimental Physical Chemistry groups are well-balanced with both young recent hires in biological (Nitz, Gunning, Kanelis) and physical (MacMillen), and multiple mid-career, including a recent hire (Walker) and multiple senior members. The Analytical group, which for decades had a strength of two, has recently added two young faculty (Wheeler & Jockusch). Inorganic recently added a young hire (Song) who joined a more senior group (Ozin, Morris), including the recent addition of Stephan, of faculty. The addition of Segal as an assistant professor in Theory adds some age balance to a strong group that has one mid-career position and four senior faculty who are post-60. Similarly, Materials & Polymers is currently searching for a junior professor to join the relatively senior group (Kumacheva, Georges, Winnik).

Many individual faculty have cross-appointments in other departments (e.g. Physics, Chemical Engineering & Applied Chemistry) while Miller has a joint appointment between Chemistry and Physics and Shoichet has a 10% appointment in Chemistry and the balance in Chem-Eng. Although formally in Chemistry, Prof. Wheeler's appointment was the result of a joint hire with Medicine's Centre for Cellular and Biomedical Research (CCBR) where he maintains a second laboratory. Additionally, Chemistry is heavily invested in a number of centres and institutes including the Institute for Optical Sciences or IOS (Miller and Goh are Director and Associate Director respectively), the Centre for Quantum Information and Quantum Control or CQIQC (proposed and funding garnered by Lidar), the Centre for Global Change Science or CGCS (Abbatt is a Co-Director), and the Centre for the Environment; the department provided critical leverage funding to IOS and CQIQC in their inaugural operations.

Research Funding: The department participates heavily in research and scholarship. Research grants success has grown overall from 10 years ago when the total funds received was $6.5M (St. George) to the current $15.6M total attracted by the tri-campus research faculty. The total number compares fairly well with our cohort U.S. universities where the top 30 Chemistry departments had an average of $18.2M (latest data available from 2004; C&EN Dec 18, 2006, pp 49; range $13 to $29M) and particularly so given the relatively low or nonexistent (NSERC) overhead rates. In a typical year, Chemistry faculty were assessed ~$800k of overhead of which 25% was directed to the faculty member and 25% to Chemistry to support indirect costs of research.



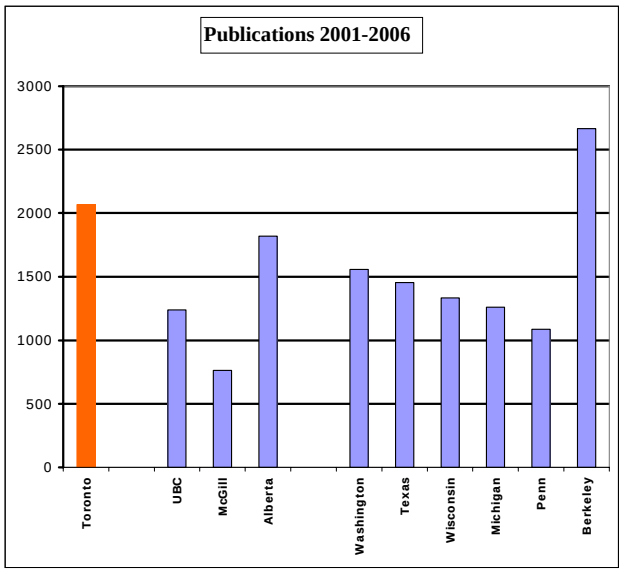
Most years indicate operating funds exceeded those of equipment and infrastructure with the exception of the two years when Chemistry received a large infusion of funds for the new building (2000) and a major equipment and infrastructure grant ($10M) was awarded in the area of materials chemistry (Winnik). In the current year the major source of operating funds comes from the Federal Grants Councils at NSERC and the Canadian Institutes of Health Research (CIHR) (total $5.2M) and other government sources ($1.8M), the not-for-profit sector ($0.75M) and industrial funds ($0.5M). Grant activity through the Canadian Institutes of Health Research (CIHR) is growing rapidly (nonexistent a few years ago) but overall remains low at $0.25M; the department has a recent NIH grant (~$0.5M 2007). The not-for-profit sector has increased ~50% over the past five years, while "other government" funding has remained steady, and industry funds are only half what they were 5 years ago. The most significant change, over the past 10 years, is the substantial investment made by the federal and provincial governments in our research infrastructure. The Canada Foundation for Innovation (federal) and the Ontario Research and Development Challenge Fund, recently renamed Ontario Research Fund (ORF), together provide 80% of the costs of major initiatives and the infrastructure portion of new faculty startup packages; Chemistry has averaged ~$5M per year, for the past four years, from these sources.

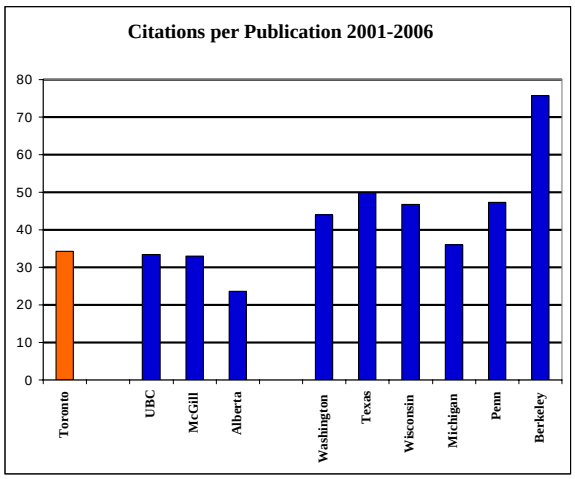
Success of regular research faculty, in the Canadian context, can be gauged from their success in NSERC Discovery (operating) Grants Program. The average NSERC Discovery grant in 2007 is $86,039 which is 1.75x the national average for GSCs 24 and 26. "*This is particularly noteworthy in view of the relative youth of so many of the Department's complement*" is quoted from the Chair's report of 10 years ago. Then the average grant was only 1.5x the national average and when median age was even 9 years higher than it is today (54 vs 45). This is an important point since NSERC does not fund project costs but rather provides funds to support research programs. The level of funding generally correlates well with excellence of the individual and his/her age in the system. A young investigator or a senior hire new to the country, however talented, will tend to receive smaller Discovery grants than an older researcher. Support for the truly talented researchers tends to rise faster and more steeply than the average. Despite the lean budget climate at NSERC this year (funds available at 92% of last year) five of seven faculty members renewed received increases with some substantial (>25%). The NSERC Discovery program remains the most significant source of 'operating' funds that Chemistry faculty have to support their research programs. It is appropriate to note that these grants are highly efficient since the grant typically runs for 5 years and requires 5 pages of text for the proposal with no reporting requirements over the life of the grant. They remain the foundation faculty use to effectively leverage the balance of support acquired.

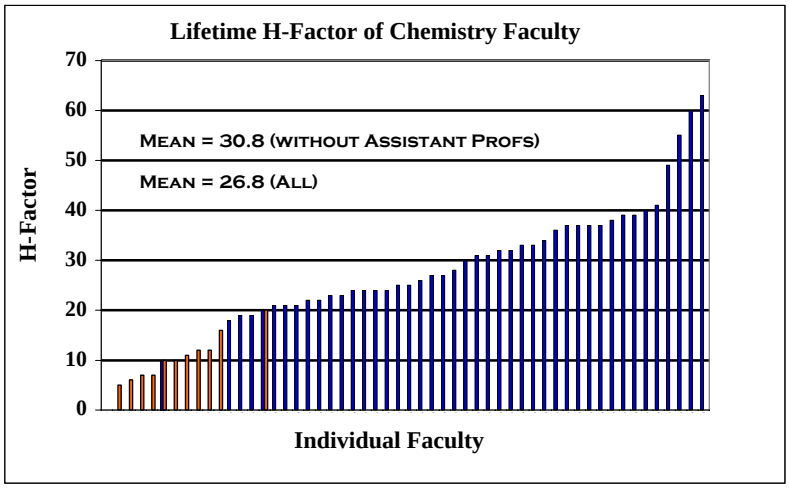
Chemistry faculty participate significantly in other NSERC programs including Strategic Grants program, the University/Industry partnership programs, I2I (Idea to Innovation), and currently has one Industrial Chair. Combined these programs represent ~$2M of the total from NSERC. NSERC's research tools (instrumentation) competition yielded $894k this year with 9 of 15 applicants successful.

An area of substantial concern is that operating funds have generally risen (28% over past 10 years) in line with inflation. Specific steps to address this must be taken with the most obvious being continuation of the increased activity in CIHR, finding out why industrial funding has fallen, and exploring what the department itself can do staff-wise to promote greater grants activity. Overall though the funding climate is more positive in Canada than at any other time in the last 10 years with substantial and varied opportunities available – Chemistry faculty are generally quite optimistic about the funding scene. This does not appear to necessarily be the case elsewhere as noted by the recent (Sept 21, 2007) Chronicle of Higher Education front page headline: "***The Real Science Crisis: Bleak Prospects for Young Researchers***." The ensuing article reports that the average first-time NIH recipient is 43 years old while the current average NSF grant is $142k (Chronicle Sept 7, 2007 p A30).

Research & Scholarship Productivity: Overall research productivity by chemistry faculty members, as evidenced by publications in top journals, is strong relative to both Canadian and U.S. comparators though significantly less than Berkeley (see Figures). Total publications and citations have been ~350 and ~13,000 respectively for each of the last two years which compares well with that of 10 years ago at 242 publications and 7125 citations. As noted earlier, the department at present is modestly larger but also substantially younger than ten years ago, thus this progress bodes well going forward for continued and significant improvements in overall impact. Chemistry has two faculty (Winnik & Ozin), one staff member (Coombs), one cross-appointment (Kay) and two adjuncts (Bidleman and Muir) active in the department in both teaching and supervising multiple graduate students, who all appear on the ISI Most Highly Cited List of researchers. Over the past 10 years, Chemistry has **124 papers** that have appeared in the **Top 1%** of **Highly Cited Papers** from the *Essential Science Indicators* database (Thomson Scientific). The figure below shows the H-Factor for all Chemistry faculty except those who have started in the last year; assistant professors appear in orange while Associate Professors and above are in blue. The department maintains an active and frequently updated profile of 'journal covers' on its web page with two recent notable SCIENCE covers highlighting the work of Miller and colleagues.

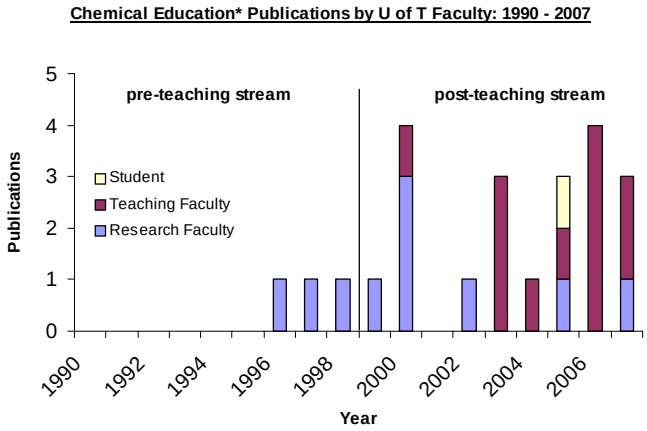




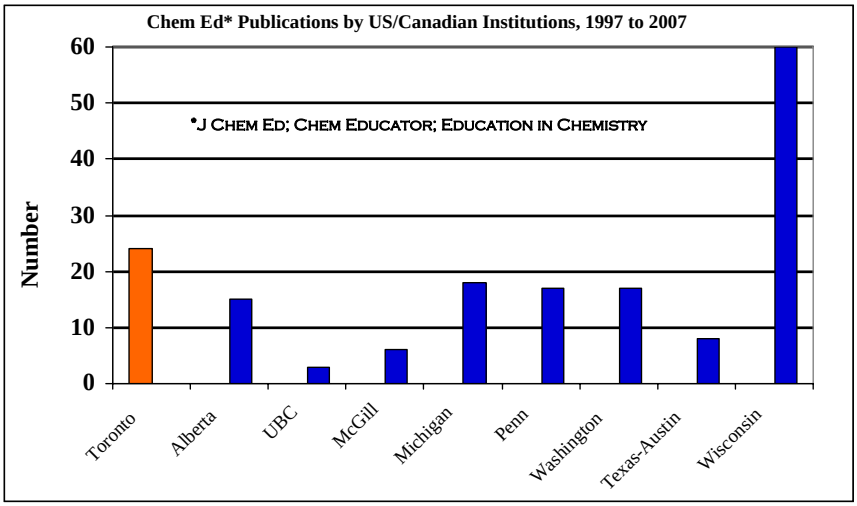


Intellectual Property: Chemistry is the most innovative department at UofT as evidenced by the number of ***Invention Disclosures*** with 601 total filings or 19% of all IDs filed at the University. Individually, Chemistry personnel make up 13 of the top 30 spots with Ozin number one overall. Patent activity has been rising dramatically with ~200 (granted and in progress) since 1995. Licensing and overall IP income to the department has grown to the point it demands attention and planning in order to maximize the overall benefit to our research infrastructure. There are currently four companies 'incubating' in chemistry through rental of lab space and use of departmental facilities. Each has a research connection with one or more faculty members in the department and three of these have hired a significant number of our recent graduates. The intensity of IP activity has resulted in a cost-share proposal by UofT to place a 'business development officer' directly in the department.

Teaching Faculty & Chemical Education: The rise in activity in the peer-review chemical education literature, since the change to the lecturer ranks, has been substantial and profound in impact; prior to 1995 there was only one UofT Chemistry publication in J Chem Ed. Activity is reasonably balanced between teaching and research faculty and overall productivity exceeds that of top cohort Universities save Wisconsin. Of special note was the cover of JCE in December 2005 that profiled an experiment in Zamble's bio-analytical course.



*publications in *Journal of Chemical Education*, *The Chemical Educator* & *Education in Chemistry*



Infrastructure ~ The Good Ship Chemistry

Ten years ago the Chair's Report commented on our "*historical*" building "*with its great age evident both externally…and internally, in the outmoded and ill-vented research laboratories… our modern building over-ready for a post-modern facelift and an organ transplant or two, as well.*" Major surgery and renewal have since yielded a completely new or newly renovated suite of research and teaching laboratories, departmental facilities, and common areas that, beyond the hallways, are entirely unrecognizable from the building that in 1997 was 'Old Lash Miller'. These capital improvements, requiring a significant investment of departmental staff time and the bulk of our discretionary funds, have fundamentally improved our ability to teach, learn, and discover. Our physical infrastructure improvements have been key to leveraging the substantial success enjoyed in growing the undergrad program, in recruiting new and exceptional faculty and staff, and in growing our graduate student cohort.

Research Facilities: The new Davenport Wing encompasses two floors (60,000 sq ft) of organic, inorganic, biological, and materials research labs, attendant faculty and group room offices, and the A.D. Allen Chemistry Library. Two lab configurations were developed to focus either on synthesis (7 large fume hoods each) or biological (3 fume hoods) with additional rooms interspersed for instrumentation, cold rooms, stills, etc. The majority of faculty requiring significant fume hood capacity moved to the Davenport Wing (117 additional fume hoods), when it opened. The old Lash Miller Labs, spread over 7 floors (65,000 sq ft) have almost completely been renovated to support research in polymers, physical, environmental, materials, analytical, and theory. These research labs, typically individuated projects, were rebuilt to the plans and specifications as required by the research of the faculty member. Group rooms, individual or shared by groups of faculty or whole sub-disciplines, are spread across the building (Lash Miller & Davenport) in order to get students out of the lab for eating and to enhance collaboration. The few old remaining labs will be renovated for new hires as they arrive or when necessary to respond to further expansion of existing faculty.

Teaching Labs: Our old Chemistry teaching labs were ill-suited for modern lab instruction, grossly inefficient with respect to space, represented significant health and safety challenges, and were decidedly uninspiring as a learning and teaching environment. The new labs (36,000 sq ft), with Phase I completed in 2003 and Phase II just now finished, have completely transformed learning in chemistry and the overall student experience. Labs were designed to enhance instruction in all areas of chemistry (organic, inorganic, physical, materials, analytical, and environmental) while responding nimbly to large first and second year courses as well as more advanced third and fourth year specialized courses. For instance courses requiring synthesis were designed around learning pods housing 16 students each, where students work in their own fume hood outfitted with all the necessary services including a closed loop chilled water system and house vacuum. Each pod has an instruction zone, which significantly enhances the ability of TAs to deliver chalk talks on a digitized white board or run tutorials via the LCD projection screen. The first lab renovated via Phase I was designed to be nimble and can handle a course with 128 students or 8 courses of 16 students each

or any combination in between. The newly renovated space allows two lab courses per day for a total of 256 students in space that prior to renovation only allowed instruction of 90 students ~ an astounding increase in efficiency that required no increase in staff resources. The success of the renovations resulted in our expanding the tenancy for access to include the Faculties of Pharmacy and Applied Science and Engineering who now have a significant presence in utilizing the labs. Next year we expect to host a biology course from the Transitional Year Program. The $10M required for the two Phases was raised entirely from internal sources with the bulk of funds coming from the Dean, Provost, the two partner Faculties, and Chemistry. Success in this endeavour was driven by the clearly demonstrated enhancement to student learning and engagement; **Appendix H** contains copies of the successful *Academic Initiative Fund* and *Student Experience Fund* proposals written to raise a portion ($3M) of the funds required.

Departmental Library, Facilities and Shops: Chemistry has major space and staff allocated to library, instrument facilities and technical support shops. All are run by directors or managers who are responsible for the technical and administrative operations and who have been granted significant financial independence to optimize function and service. Primary users or clients are in Chemistry, from all three campuses, though the facilities and shops enjoy significant use by others at the University and by local industry. Students are trained for hands-on use of all our instruments. The library resides prominently in the Davenport wing, houses the Department's substantial holdings of books and journals while maintaining support to the substantial on-line resources available (>34,000 journals, Beilstein, Web of Science, Sci-Finder, etc) and providing valuable study space to chemistry students.

The instrument facilities include the recently renovated Advanced Instrumentation for Molecular Structure (AIMS) facility (3,500 sq ft) that contains seven mass spectrometry systems while a separate group has a stable of ICP-MS systems in the facility. This facility has changed dramatically from ten years ago when it basically had one sector instrument that even at the time was fairly old. Our plan was to renovate space to be ready to realize opportunities, to acquire additional systems, as they arose. Our NMR facility, currently spread over multiple rooms, is planned in the near future to occupy newly renovated space next to AIMS. The NMR lab has seven magnets (500 MHz is the largest), with both liquids and solids capabilities, which are currently so heavily utilized the facility is at the limit of capacity with significant need for additional high-field systems. Our X-ray diffraction facility has capability for both single crystal and powder samples with two new systems expected over the next year. Analest is a multi-user lab that houses the full suite of chromatographic (GC/IC/LC) and spectroscopic (ICP, MS, AAS, FT-IR, UV-Vis) instrumentation to support analytical needs in research and teaching with a particular emphasis on environmental measurements. The relatively new Centre for Nanostructure Imaging (CNI) houses an SEM, STEM, and laser confocal microscope in a newly constructed basement laboratory. Combined, these facilities have just six base supported staff which is woefully inadequate to realize the full potential of these facilities.

Chemistry maintains a first-rate machine shop (5 machinists), glass-blowing shop (2 glass blowers), and electronic and computing shop (4 staff). The machine shop is currently crowded with the plan to expand when the new NMR facility is completed. Chemical services and Stores personnel (4 staff) handle the demand for maintaining our chemistry stores, the preparation of chemical solutions to support teaching, waste handling, shipping and receiving, and overall chemical health and safety in the building. The department also recently built a ***cell culture facility*** that is maintained by the biological chemistry groups.

Future Capital and Renovations Projects: We are currently finalizing the move of our computer clusters from the sixth floor to the basement where we can provide adequate space, cooling, and facilitate basic maintenance. This will free up space for the planned Emeritus Suite of offices that will reside on the Sixth floor with a commanding view looking south. Analogously, completion of that project will address a shortage of space for faculty and graduate student offices. This Fall we will demolish an old basement teaching lab where we plan, pending financing, on building the new NMR facility. A security project for the Chemistry building has been planned and priced multiple times but deferred due to budgetary pressures. It is ever apparent that this project is necessary to be completed and relatively soon. We will also be renovating space for the Polymer Chemistry position we are currently searching and the labs of Miller on our second floor require attention. Midterm, Chemistry needs to reassess its overall space needs in light of recent hires, cessation of mandatory retirement, and massive expansion in graduate student numbers. One option worth exploring would be to construct a Chemistry Student Centre on top of the lecture wing in order to house some of the administrative offices of the department, which now reside in potential research lab space. This would address space and design limitations of the current student admin offices and yield student and seminar room space that is woefully lacking in Chemistry at present.

Infrastructure at UTSc: UTSC is home to the Environmental NMR Centre, which houses two state of the art NMR spectrometers with capabilities to study liquids, HR-MAS, solids, imaging, fully hyphenated LC-SPE-NMR/MS, and a globally unique capability to study samples *in situ*. As well, there is a newly established, state-of-the-art instrument facility (a smaller version of ANALEST), primarily for undergraduate teaching, but also available for research purposes. A new Science Building is scheduled to open in the summer of 2008 which will house faculty research laboratories in interdisciplinary clusters based on common research interests.

Infrastructure at UTM: Chemistry at UTM is integrated into the cluster of chemistry/bio-physics/life sciences that overall is well-endowed with core analytical (GC-MS, LC/MS/MS, and other chromatographic and spectroscopic instrumentation) and bioanalytical facilities (e.g. microarray printing/readers, DNA sequencers/synthesizers, surface plasmon resonance, RT-PCR, cell culture and animal facilities, etc), and a well-endowed NMR facility (5 magnets including 400, 500, and 600 MHz); significant specialized equipment resides in individual research groups and is available through collaborations. The current Science building provides good quality research space for Chemistry faculty and research, though with recent hires space is nearing or is already at capacity.

Organizational Structure

Chemistry is a department that both broadly and in detail works well while the description of its denizens as the ***Chemistry Family*** resonates broadly across the cohort of students, staff, and faculty.

Chemistry is by intent relatively lean in overall governance structure, numbers of committees, and particularly careful with the time commitment it asks of its faculty, staff, and students for committee work. The Chair relies heavily on advice from the Departmental Advisory Committee and weekly discussions with the two Associate Chairs of Graduate and Undergraduate programs; all three Chairs consult widely and frequently within and without the department. The Departmental Advisory Committee, made up of research faculty from all three campuses and teaching faculty from the St. George program, provides overall guidance and

feedback about issues related to departmental operations, tri-campus graduate program, and overall strategic planning. The Full Professors of this committee serve as the department's promotion committee. The Chair meets regularly with a large group of graduate students, who form the graduate student advisory committee, selected from the various campuses and sub-disciplines and often with undergraduate students from the Chemistry Students Union. The Chair holds full faculty meetings intermittently throughout the year and whenever a faculty search committee has completed its work. Special *ad hoc* committees, such as the space committee, are constituted to address or advise on the assigned task and the committee then is generally dissolved.

The two Associate Chairs have significant responsibility and oversight in their roles while each heads up an active committee focused on graduate and undergraduate issues respectively. These committees typically meet monthly and are tasked with oversight of the educational programs of the department; committee membership is determined by the Associate Chairs through consultation. The Undergrad Committee primarily focuses on the St. George program in chemistry though remains cognizant of programmatic needs and enhancements at UTM and UTSc. The Grad Studies Committee is fully grounded in the tri-campus nature of our graduate program in chemistry. Young faculty members are frequently tasked with the Graduate Studies Committee as this is where admission and recruitment of new graduate students as well as allocation of scholarships is done.

The more specific and task oriented committees include the Colloquium, Awards, Appeals, High School and Community Liaison, and Library Committees typically meet at most once or twice a year with significant work often carried out by individuals outside of meetings. An example would be the Colloquium Committee, where we also seek Assistant Professors to serve as it is an effective means for them to become better known in the international chemistry community through the hosting of visiting stars; **Appendix I** contains the Colloquium schedule for the last 2 years. Our highly effective awards committee meets twice a year to recommend nominations while the main office staff, led by Ashcroft Moore, works diligently with the nominee to develop the package.

The department is very frugal with the committee work it asks of its faculty members. At most the standing and *ad hoc* committees, other than search committees, combined would require no more than 20 to 25 hours per year from any particular faculty member. The intent is to use faculty and staff time, for committee work, only when necessary in order to preserve time for, and the support of, the higher order functions of research and teaching scholarship.

The Health and Safety Committee meets at least quarterly and whenever else necessary to address issues as they arise. Ken Greaves, the Chemical Stores Manager, and his team are largely responsible for the superb safety and training record of the Department.

Day to day operations of Chemistry are effectively managed by three individuals who occupy the position of Technical and Administrative Officer (Dr. Mike Dymarski), the finance officer (Maggie Cameron), and the Chair's assistant (Penny Ashcroft Moore). Their commitment, creativity, ability to inspire others, and passion to their work and department overall are key to many of our successes. The undergraduate and graduate programs have stellar program assistants in Armando Marquez and Anna Liza Villavelez respectively. As noted above, the full breadth of departmental 'self-funded' units have good managers and effective and committed staff. Chemistry, rather uniquely, invests significant Chair, staff, and faculty time in planning

and managing all aspects of capital projects of construction and renovation. This has helped ensure the many dozens of projects come in on or under for both time and budget. Overall lines of reporting are indicated in **Appendix J**.

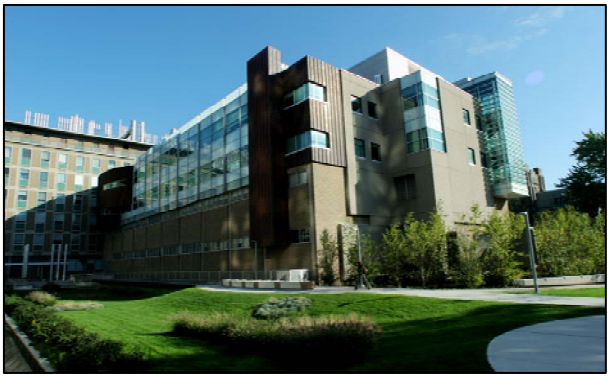
Budget: The annual base-budget in Chemistry is ~$8M (essentially faculty and staff salaries) with another ~$1M in revenue roughly matched with expenses (self-funded units including stores). The relatively modest sums available at UofT arise from the lean financial value available from government and tuition (~$11k per student) which compares poorly with a cohort AAU value of >$16k per student from these sources. Chemistry generates additional funds through endowment, annual giving, space rental, licensing income, salary savings from faculty on full-year sabbatical and a portion of the salary of faculty who have left, and research overhead on non-NSERC/CIHR grants and contracts. Our graduate program operations have benefited significantly from the recent infusion of funds tied to graduate expansion (~$700k in total this fiscal year). With diligence, care, planning and leverage in all cases, the department strives to ensure the highest possible impact of its resources on its research and teaching mission.

However, Chemistry is severely challenged in overall indirect costs of making the most of our operation. Specifically, the department lacks sufficient staffing, both administrative and technical, to support research and teaching faculty in reaching their full potential. It also lacks the financial means to provide the desperately needed investment in our instrument facilities and shops. Exacerbating these two issues are two distinct areas where expenses are not currently matched with appropriate University revenues. The first is the budget required to run our undergraduate teaching program, which annually requires more than $200k from Chemistry above and beyond what we receive (base transfer from A&S, OTOTA, DACCA summer support, Pharmacy) to fund operations. These are funds that Chemistry must 'generate' annually through its operations and are thus not available for investment elsewhere. In effect, the better Chemistry does in enhancing the student experience, and thus attracting more students to its courses and programs, the less dollars per student it has from central sources and consequently the more it has to generate from operations.

The second area of severe underfunding is in the indirect costs of research. The UofT has historically been quite enlightened and supportive in passing along 50% of total 'overhead' to the department with half going directly to the PI. Since overhead rates are historically low in Canada, and most sources of funds carry no direct overhead the amount per year Chemistry realizes into its base is a relatively paltry ~$200k on average (this fiscal year the value is $140k); this is substantially and dramatically less than our comparator chemistry departments in the U.S. The dominant source of operating funds in Chemistry is from NSERC which a few years ago started providing 'indirect costs' to the University at a rate of ~20%. To date none of these funds have been provided to Chemistry though the historical 'overhead' allocation to the department would have been ~$500k per year (50% allocation of overhead on $5M at 20%). It will be important in going forward to address the dearth of overhead revenue to match the very real overhead expenses incurred by Chemistry in maintaining its research. Current discussions with the Faculty of A&S envision providing 'incremental' increases in Federal Granting Council 'overhead' directly to the department. It will be important to implement a policy that has **all** incremental gains generated by Chemistry faculty be delivered to the department; the base year reasonably should be the 2006-2007 fiscal year. Although small, these incremental funds will make a difference in the support of research and the clear incentive for increased activity will pay multiple benefits.

Advancement, Alumni and Community Relations

In the mid-1990s Moskovits, Chair at the time and driven by a severe space and resource shortage and strong support of A&S and the University, and Chemistry became very active in advancement. A strategic effort, grounded in the entrepreneurial culture of the department and assisted by good council from Chemistry Friends and A&S staff, focused on endowed chairs, student scholarships, and the need for additional research space. Over the past ten-years this effort has raised $18.8M in funds to support these and related activities. The largest and most critically important was the ***Davenport gift*** of ~$10M for a new building and funds to renovate the existing Lash Miller complex. This directly leveraged another ~$15M in government infrastructure funds. The Davenport family further endowed $3M towards support of the resulting infrastructure. A second large gift of $1.5M leveraged a further $800k to complete the Chemistry Garden. These gifts have further leveraged the $10M renovation of our undergraduate teaching labs and a few million more for individual faculty labs, our lobby, and our new mass spectrometry lab. Separate gifts have funded endowed chairs (Roel & Dorothy Buck Chair in Chemical Physics; Astra Zeneca Chair in Organic Synthesis) and multiple graduate student scholarships have taken advantage of matching opportunities (5 GSEFs, 8 OGSSTs, 15 or so OSOTFs). Recent giving typically yields a few hundred thousand annually. Chemistry's Staff Fundraiser for many years was a position the department itself funded but recently has gone unfilled given recent budget and staffing constraints; these activities are now largely handled by the Chair's assistant.



Significant effort is made to celebrate the graduation of our undergraduate and graduate students and to keep in touch as they build their careers. The primary means of keeping our alumni informed about ongoing activities in Chemistry is via Distillations, an annual publication; the most recent copy can be found in **Appendix K**. More recently we have embarked on an effort to highlight the careers of alumni via our web page, the lobby screen, and Distillations. All these and related activities are designed and led in-house by Chemistry staff.

For many years Chemistry has been a significant contributor to the Canadian Chemistry and Physics Olympiad program through organization of the Ontario program involving tutorials and the annual provincial competition. Over the past two years, Skonieczny, a Senior Lecturer in the department, served as the National Director and worked to overhaul the management and financial side of the Olympia organization. During these two years the Canadian chemistry team earned 6 medals (2 gold, 2 silver, 2 bronze), the best performance since the inception of the program in 1985. We have a High School & Community Liaison committee that works with Toronto area high schools to host student groups, provide guest speakers, and access to surplus equipment. Individually, many faculty provide outreach to the larger community, only one example of which includes Miller who is an active board member of Scientist in Schools and the force behind Science in the City slated for May 2008. Recently, the Chemistry Team comprised of 30 faculty, staff, and students, participated in UofT Service Day by working on a Habitat for Humanity project.

Self-Study Consultation & Data: The Self-Study differs from past versions of a Chair's Report through the charge to involve faculty, students, and staff and overall should "*result from a reflective, analytical, self-critical, and evaluative process that assesses the appropriateness of all areas of activity in the unit*" with the "*goal to summarize the scope and quality of the teaching programs and scholarly activity of the unit and identify real or potential problems and opportunities*." It was agreed, through discussion with Vice-Dean David Klausner, the self-study would cover a period of 10 years to reflect time elapsed since the last formal review in 1992/93. Consultation was sought early and often from various domains in Chemistry through meeting with faculty, the department advisory committee, staff, and students. Formal and detailed input was provided by the Associate Chairs of Graduate (Walker) and Undergraduate (Dicks) and during weekly meetings with Chemistry's technical and administrative manager (Dymarski) and financial officer (Cameron). The survey of undergraduate students (1274 respondents) followed a hosted lunch where students provided feedback to an overall 'status-report' of chemistry programs delivered by the Chair. The Chair also met and discussed the self-study with the graduate student advisory committee on multiple occasions. Informal input was available through the myriad of consultations the Chair has with students, staff, and faculty that are ongoing around general operation of the department. The Self-Study was primarily authored by the Chair, with sections contributed by Prof. Adrian Brook and Dr. Andy Dicks, and important input provided by Profs Walker, Krull, Donaldson, and Abbatt. A draft version of the report was disseminated to the chemmail listserve, which reaches all chemistry faculty, staff and students (741 recipients), for comment and feedback which was incorporated wherever possible.

The raw data used in this report was obtained from multiple sources which included: 1) the registrar (Loney & Altmeyer) for A&S provided program enrolments, numbers of graduating students, FCE counts, Dobell Numbers; 2) all data on research funding was from the 'research cube' as provided by the Manager, Research Information Analysis (Sigouin) in the VP-Research office; 3) donations data was provided by the A&S Office of Advancement (Jamison); 4) citation information was generated by Chemistry's Librarian (Meindl) using ISI Web of Science; 5) 10-year data on graduate student enrolment and awards was provided by the graduate office in chemistry (Villavelez); 6) invention disclosure and patent data was provided by the Director of Intellectual Property and Contracts (MacInnis); 7) NSERC data was available from the annual reports provided by GSC 24 and 26; 8) the chemistry-survey of student engagement was run out of Chemistry's undergraduate office (Marquez) with the assistance of the Associate Vice-Provost Students (Chambers) and Associate Chair of Chemistry (Dicks); 9) the data on faculty and staff awards, and other related information, was from internal Chemistry records; and 10) comparative data from cohort Universities, on staffing and graduate student/PDF numbers, was largely obtained directly from the departments themselves. Data from *Chemical and Engineering News* and the *Chronicle of Higher Education* are cited in the text. The responsibility for, and accuracy of, the use of the raw data resides entirely with the Chair.

Scott Mabury, Chair