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Promoting Research and Minority Participation via Undergraduate Research in the Mathematical Sciences. MTBI/SUMS-Arizona State University

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Mathematical Theoretical Biology Institute (MTBI) and the Institute for Strengthening Understanding of Mathematics and Science (SUMS)

The *primary goal* of the Mathematical Theoretical Biology Institute[1] and the Institute for Strengthening Understanding of Mathematics and Science[2] (MTBI/SUMS) is to increase the number of US Residents or Citizens, particularly members of US underrepresented minority groups, who complete a Ph.D. in the mathematical sciences. The cornerstone of this effort is MTBI/SUMS' summer REU program. MTBI and SUMS have instituted a series of carefully refined mentorship and apprenticeship programs, from the high school[3] to the postdoctoral level, that promote mathematical learning and, in the process, help diversify participation in the mathematical sciences.

Traditionally, MTBI/SUMS has provided research mentorship training for students who want to work at the interface of applied mathematics and theoretical and computational biology[4]. The REU summer program, which has been held for the past eleven years, in conjunction with Cornell University (1996 – 2003), Los Alamos National Laboratory (2003 – 2005), and Arizona State University (2004-Present)[5] focuses on the applications of mathematics to problems at the interface of the natural and social sciences. MTBI/SUMS programs are aimed at increasing

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[1]http://mtbi.asu.edu

[2]http://www.asu.edu/mshp/index.htm and winner of a 2003 *Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring.*

[3]SUMS through its Mathematical Sciences Honors Science Program has mentored 2098 high school students who have begun to participate in MTBI/SUMS' summer REU undergraduate program early in their college studies.

[4]Research mentorship is provided during the summers or throughout the year (at the host institution) with the support of MTBI/SUMS Sloan Pipeline Program.

[5]MTBI/SUMS efforts have been supported through grants by the National Security Agency, the National Science Foundation, the Sloan Foundation, Los Alamos National Laboratory, and the offices of the provosts of Cornell University and Arizona State University.

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the participation of students from diverse educational, cultural, racial and socioeconomic backgrounds in areas where the mathematical sciences play a fundamental role. A large percentage of summer selected participants come, by design, from colleges and universities with limited research opportunities. Not surprisingly, these institutions often tend to serve large numbers of individuals from US underrepresented minority groups.

MTBI/SUMS summer research programs are run like NSF-sponsored workshops[6]. New students take three and half weeks of intense training in dynamical systems (broadly understood to include stochastic processes) by modeling in the biological and social sciences while becoming familiar with tools like MATLAB[7], MATHEMATICA[8], XPP-AUTO[9], other computational packages, and LaTeX[10]. At the end of the initial training period participants form groups of $3-4$ students around a project of their own choice. In other words, students set each the research agenda each summer. This philosophy accounts for the diversity of research manuscripts that have been produced[11] over the past decade. Each group gets assigned a faculty advisor and is provided with appropriate graduate student support. Between 20% and 33% of the undergraduates participate in two summers and graduate student participants (14) have participated at least two times with some participating as many as seven times. MTBI/SUMS summer workshop produces an average of 10 technical reports per year. The research productivity of each summer group of young investigators has instigated or re-invigorated the research efforts of a class of participants that includes students, faculty and postdoctoral students.

MTBI/SUMS Sloan Pipeline Program (MTBI/SUMS-SLPP) is at the heart of MTBI/SUMS mentorship activities at the graduate level. MTBI/SUMS alumni[12] who are enrolled at MTBI/SUMS home institution[13] receive partial support towards the completion of their graduate studies (leading towards the Ph.D.'s) in the forms of fellowships, research assistantships and MTBI/SUMS research assistantships. The area of Ph.D. study has been dictated exclusively by the students' interests and objectives. Recent alumni (Cornell) have received their Ph.D.'s in numerical

[6]Our efforts have been carried out with the active collaboration of the Santa Fe Institute (NM) and the Center for Statistical Genetics and Genome Science Training Program at the University of Michigan.

[7]MATLAB is a product of MathWorks (http://www.mathworks.com/).

[8]It is a product of WOLFRAM RESEARCH (http://www.wolfram.com/).

[9]http://www.math.pitt.edu/ bard/xpp/xpp.html

[10]http://www.latex-project.org/

[11]MTBI/SUMS alumni are prolific writers. *Am I too fat? Bulimia as an epidemic* has appeared in the Journal of Mathematical Psychology ($47(2003)515-526$); and the article *Effects of education, vaccination and treatment on HIV transmission in homosexuals with genetic heterogeneity* has appeared in the Journal Mathematical Biosciences ($187(2004)111-133$). These are but two examples of what our students produce.

[12]The term MTBI/SUMS alumni has been used throughout to identify primarily those who participated in one or more summer research experiences. However, MTBI/SUMS does not focus *exclusively* on summer research experiences. In fact, it has had a large number of support programs that involve sponsored research at the interface of the mathematical and natural and social sciences as well as the administration of various human resource programs including RTGs, Sloan Fellowships, Mentorship Programs and Additional Educational and Training Programs K-20 and beyond.

[13]Cornell University (1996−) and Arizona State University (2004+)

analysis, mathematics of finance, statistics, computational biology, mathematical physiology, mathematical epidemiology, biometry and dynamical systems. At Cornell University, sixteen MTBI/SUMS alumni were awarded Sloan Fellowships while six MTBI/SUMS alumni were supported via a RTG[14] grant (pre-IGERT) in computational biology. MTBI/SUMS has worked hard to establish similar forms of support at ASU. *Nine* Sloan fellowships have been awarded to underrepresented US minorities who are enrolled in the mathematics department at ASU[15]. Professor Carlos Castillo-Chavez[16], MTBI/SUMS Director (MTBI-founder) has led MTBI since 1996 and SUMS since 2004.

Success Stories

In the years 2001 and 2002, prior to MTBI/SUMS producing Ph.D. graduates, the U.S. awarded an average of 10 Ph.D.s to Latinos[17]. MTBI/SUMS efforts have significantly increased the national rate of production of U.S. Ph.D.'s. In 2005, MTBI/SUMS alumni received 10 Ph.D.s in the mathematical sciences, 7 of which were awarded to members of underrepresented[18] US minority groups. This is almost *a fourth* of the national total output for that year. Of those, 6 were Latino, *one third* for that year (6 out of 18). Of the 10 total MTBI/SUMS alumni Ph.D. graduates in 2005, 7 took on prestigious postdoctoral positions and one became an Assistant Professor at the University of Puerto Rico, Mayaguez campus. Looking at female graduates, MTBI helped produce *one third* (5 out of 15) of the total female underrepresented minority groups for 2005. Four of those five were Latinas, over half of the national production (4 out of 7). In 2006 10 MTBI/SUMS alumni received their Ph.D. including 7 from US underrepresented minority groups and their record of success is similar to those who completed their degrees in 2005.
MTBI/SUMS has mentored and supported 277[19] undergraduate students, and 31 graduate students, of which 14 had participated previously in MTBI/SUMS as undergraduate students throughout eleven summers[20].

Since 1996, MTBI/SUMS alumni[21] have co-authored 111 technical reports during the summers[22]. Revised reports are continuously being published in refereed

[14]I was either the PI or co-PI of an NSF RTG grant at the interface of mathematics and biology for over a decade.

[15]The rate of growth in its minority graduate student population would have not been possible without the support programs instigated by the Hispanic Research Center led by Gary Keller and the openness of the mathematics faculty that has embraced MTBI efforts to increase and maintain diversity.

[16]Winner of the 1997 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring.

[17]The data for national Ph.D. graduates was obtained from the AMS notices http://www.ams.org/notices/200602/05firstreport.pdf.44444444

[18]US Residents who are Latino (the overwhelming majority are Mexican Americans or Chicanos and Puerto Ricans but there are some whose heritage is from Peru or El Salvador) or African-American or Native Americans.

[19]This figure includes students from the summer of 2006 who completed their work on July 30, 2006.

[20]It has also mentored dozens of students throughout the regular academic year at either Cornell University and Arizona State University.

[21]MTBI/SUMS alumni refers to those who have participated in its summer research programs or who are mentored throughout the year by MTBI/SUMS

[22]This number already includes the reports of the summer of 2006.

journals. The references at the end of this manuscript list *ten recent representative refereed publications*, the result of the collaborative work between MTBI alumni, staff and visitors over the past 10 years.

MTBI/SUMS alumni[23] have, or currently are attending universities across the United States, Colombia, Argentina, Britain and Mexico. MTBI/SUMS sequential summer programs have helped establish large communities of underrepresented U.S. minorities at Cornell University[24] (totaling twenty-four[25], eighteen[26] of which are members of underrepresented US minority groups), at the University of Iowa[27] (totaling seventeen[28], fourteen of which are members of underrepresented US minority groups) and Arizona State University (totaling thirty-four[29], twenty-four of which are members of underrepresented US minority groups[30]).

MTBI/SUMS has sent 130 students from *underrepresented minority groups* to graduate school over its *first ten years*[31] and a total of 169 students overall. Furthermore, 52% have been females, including 65 from minority groups.

MTBI/SUMS Alumni have established a community of minority scholars at ASU and in the process, their presence has facilitated the recruitment of increasing number of minorities to its graduate programs. We currently have *at least* 29 US

[23]That is, individuals who participated in MTBI/SUMS summer programs as graduate or undergraduate students or who received mentorship support from the MTBI/SUMS Sloan Pipeline Program.

[24]Most of the minority students in the mathematical sciences since 1996 have come from the pool of MTBI/SUMS alumni. Four of them completed their Ph.D. in 2005 (a fifth transferred to Florida and also completed her Ph.D. in 2005); two more in the summer of 2006; and two more are expected to graduate by December of 2006. The success rate (obtained their Ph.D.) at Cornell University when it comes down to MTBI/SUMS alumni (the only data that we have) is over 80%.

[25]That is, 24 MTBI/SUMS alumni have enrolled in a mathematical sciences program at Cornell University. Students have enrolled in the departments of biological statistics and computational biology, statistics, the center for applied mathematics and the department of theoretical and applied mechanics.

[26]Three US minorities received a MS degree prior to or on 2000 and left. Seven US Minorities have completed their Ph.D.s with two more expected by December of 2006. Five more will receive their degrees over the next two years and one will transfer to the Ph.D. program in Arizona State University.

[27]The Mathematics Department at the University of Iowa has created a model in which most if not all the members of the mathematics faculty participate. It recruits heavily in Puerto Rico, Historically Black Colleges and MTBI/SUMS. The Mathematics Department at the University of Iowa received a 2004 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring.

[28]That is, 17 MTBI/SUMS alumni (who participated in its summer program) have enrolled in a mathematical sciences program at the University of Iowa, most in the mathematics department.

[29]34 MTBI/SUMS alumni have enrolled at ASU. Thirty-two of them have enrolled in the mathematical sciences (mathematics and statistics) and two in the sciences. This group includes 28 permanent residents or US citizens and six international students. Currently, there are 32 enrolled as two received a masters degree and left.

[30]July 1st 2006-data.

[31]This number does not include the admission to graduate school of members of the summer of 2006 MTBI class. However, we are to a good start. Eight MTBI/SUMS alumni from the 2006 class will be attending graduate school in the Fall of 2006 or the Spring of 2007.

minorities[32] in the mathematics department at ASU including 24 US Latinos and 5 African-Americans. ASU[33] will enroll three MTBI/SUMS alumni[34] (US underrepresented minorities) to its mathematics graduate program in the spring of 2007[35]. ASU graduate mathematics program will continue to host the largest US minority student population (32) in the nation[36]. Finally, it is worth noticing that ASU campuses have hired *three MTBI alumni to its mathematics and statistics faculty, all from underrepresented minority groups and two in tenure-track appointments.*

Philosophy and Goals

MTBI/SUMS believes that this community of minority scholars is *vital* to increasing the number of underrepresented minorities in the sciences. It is not enough that MTBI/SUMS creates an increase in the population of minority scholars. This change must become self-generated. In order for MTBI to have a lasting impact outside the scope of its own individual focus programs, MTBI/SUMS alumni must begin to make their own changes, their own waves, and their own recruitment initiatives. In terminology that our own program alumni would be instantly familiar with, we want to create an *epidemic* of minorities in the sciences. Now that MTBI/SUMS alumni are beginning to take faculty positions and in fact, there is some evidence of secondary recruitment[37].

MTBI/SUMS philosophy adheres to the principles of the *New American University*[38] that is, MTBI/SUMS is an institute that, like its home institution, ASU[39], wants to be judged by the quality of the research and academic accomplishments of its students and alumni rather than by the academic pedigree or prior access to *selective* educational settings of its participants. MTBI/SUMS wants to be an institute whose alumni, while pursuing their scholarly and scientific interests, "also consider the public good."[40] MTBI/SUMS wants to be an institute whose students,

[32]Twenty-seven minority students in the mathematics department, most of them have been recruited by MTBI/SUMS. All are members of its Sloan Pipeline Program and hence are considered MTBI/SUMS members.

[33]The premier graduate program in the mathematical sciences is Richard Tapia's at Rice University. Richard who received a 1996 Presidential Award for Excellence in Science, Mathematics, and Engineering Mentoring has been the primary mentor of US minority Ph.D.'s over the past two decades. Additional strong efforts led in part by Raymond Johnson, have been carried out at the University of Maryland. In December of 2000 alone, three African-American women received their Ph.D. in applied mathematics from the University of Maryland.

[34]This group includes four US-underrepresented minorities, a US female student and a female international student.

[35]We expect that these three students will accept ASU support offers. Their admission will bring the number of US underrepresented minorities within the mathematics department at ASU to 30 and the number of MTBI/SUMS alumni who have enrolled at ASU will have reached 37.

[36]The mathematics department at the university of Iowa has had an average number of 23 US minority students over the past few years (David Manderscheid, chair mathematics department, personal communication), has graduated $2-3$ US minorities per year over at least the past two years and may currently have 26 minority graduate students.

[37]The establishment of the *Applied Mathematical Sciences Institute, http://www.amssi.org/* by MTBI alumni Erika Camacho and MTBI graduate mentor and former summer Director Steve Wirkus are indicative of things to come.

[38]http://www.asu.edu/president/newamericanuniversity/arizona/

[39]Here, we are paraphrasing ASU's mission but in the context of the work that is being carried out at MTBI/SUMS.

[40]http://www.asu.edu/president/newamericanuniversity/arizona/

alumni, faculty, and staff "transcend the concept of community service to accept responsibility for the economic, social, cultural, and environmental vitality of the communities they serve."[41]

Acknowledgments

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[41] http://www.asu.edu/president/newamericanuniversity/arizona/

[42] Malden Nesheim, Don Randel, Biddy Martin, Frank Rhodes, David Call, Hunter R Rawlings III and W. Kent Fuchs.

[43] Michael Crow, Milton Glick, David Young, Maria Allison, Marjorie Zatz, Jon Fink, Andrew Webber, Peter Crouch, Elizabeth Capaldi and Marjorie Zatz who have done everything possible to help the goals and the vision of MTBI/SUMS.

[44] Albert McHenry, Gary Keller, Antonio García and Michael Sullivan are the kind of university citizens that every university dreams to have.

[45] The encouragement and confidence given to MTBI by Barbara Deuink, Lloyd Douglas, Ted Greenwood, Jim Schatz and Michelle Wagner have played a critical role.

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