

Opening Pathways for Underrepresented High School Students to Biomedical Research Careers: The Emory University RISE Program

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ABSTRACT Increasing the college graduation rates of underrepresented minority students in science disciplines is essential to attain a diverse workforce for the 21st century. The Research Internship and Science Education (RISE) program attempts to motivate and prepare students from the Atlanta Public School system, where underrepresented minority (URM) students comprise a majority of the population, for biomedical science careers by offering the opportunity to participate in an original research project. Students work in a research laboratory from the summer of their sophomore year until graduation, mentored by undergraduate and graduate students and postdoctoral fellows (postdocs). In addition, they receive instruction in college-level biology, scholastic assessment test (SAT) preparation classes, and help with the college application process. During the last 4 yr, RISE students have succeeded in the identification and characterization of a series of proteins involved in the regulation of nuclear organization and transcription. All but 1 of 39 RISE students have continued on to 4-year college undergraduate studies and 61% of those students are currently enrolled in science-related majors. These results suggest that the use of research-based experiences at the high school level may contribute to the increased recruitment of underrepresented students into science-related careers.

THE current state of science education in the United States has raised concerns about whether current policies and approaches are succeeding in preparing students for successful careers in this field (Fu *et al.* 2009; National Science Board 2010). Studies examining the performance of students in science and math show that the United States falls well behind the top performing countries (Martin *et al.* 2008). Development of strategies aimed at increasing the number of students that complete advanced degrees in science, technology, engineering, and mathematics (STEM) disciplines and engage in research careers in the sciences is critical to maintaining US global competitiveness. These educational deficiencies are being addressed using a number of approaches, including restructuring how science is taught in the classroom, placing a greater emphasis on the methods used for scientific thought and discovery, and development of critical thinking skills rather than just memorization of

large amounts of information (Gerzina *et al.* 2003; Wood and Handelsman 2004; Maciejewski 2007; Willingale-Theune *et al.* 2009).

One of the critical contributors to the state of science education in the United States is the high attrition rate among students who initially display an interest in majoring in STEM disciplines. Approximately half of these students change their career plans during their first 2 yr in college (Center for Institutional Data Exchange and Analysis 2000). The significance of the problem is accentuated when one considers the effect of this high attrition on different ethnic groups of the US population. For example, the rate of graduation in STEM majors is only 27% for underrepresented minority (URM)—African American, Hispanic, and Native American—students compared to 47% for White and Asian American students (Huang *et al.* 2000; National Science Foundation 2004). A recent study that tracked the percentage of URM students who enrolled in STEM majors in 2004 and were able to complete their degree in 4 or 5 yr presents an even bleaker picture. Results from this study indicate that White and Asian American students are able to complete their degrees in 4 yr at a rate of 24.5% and 32.4%, respectively, as compared to Black, Hispanic, and Native American students whose graduation rates are 13.2%,

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15.9% and 14%, respectively. This difference is maintained for students who earn their degrees in 5 yr, with White and Asian Americans graduating at rates of 33% and 42%, while Black, Hispanic, and Native American students have graduation rates of 18.4%, 22.1% and 18.8%, respectively (Higher Education Research Institute 2010). URM students represent 18% of bachelor and 7% of doctoral degrees in biology, chemistry, and psychology in 2004 (National Science Foundation 2004). The lack of URM graduates in STEM disciplines has resulted in only 6% of US scientists and engineers being members of underrepresented minority groups (National Science Foundation 2004). Since URM scientists and physicians are more likely to be concerned and understand issues specific to their communities, this has a distinct negative effect on communities of underrepresented minorities (Claudio 1997). Strategies to increase the number of graduates in STEM disciplines need to account for the predicted increase in the number of racial/ethnic minorities entering college by the year 2015 (Carnevale and Richard 2000). The success of future students in attaining their educational goals will be determined not only by their commitment, aspirations, test scores, and high school grades but also by their gender, race, and socioeconomic background. Therefore, to educate the next generation of STEM graduates and ensure a diverse workforce, there is a critical need to develop approaches to successfully recruit and retain all students interested in science but especially those from URM groups. These approaches will need to address not only general issues faced by all STEM majors but also issues that are unique to the performance and retention of students from underrepresented minority backgrounds.

What are the reasons for the high attrition rate among potential STEM graduates? Several different issues may contribute to the problem. Crucial to a successful undergraduate experience is the availability of role models, peer support, and the development of self-efficacy (Hurtado *et al.* 2007). Albert Bandura defines the perception of self-efficacy as “judgments of personal capabilities” and argues that “people will explore, and try to manage situations within their perceived capabilities, but unless they are externally coerced, they avoid transactions with those aspects of their environment that they perceive exceeds their coping abilities” (Bandura 1997). Therefore, perception by students that succeeding in introductory science classes is beyond their coping abilities may cause these students to seek majors where they can succeed. This problem affects students from URM groups disproportionately. These students often attend schools that lack resources, such as Advanced Placement (AP) courses, afforded to students from other socioeconomic backgrounds. As a consequence, URM students are normally less prepared to experience rigorous introductory science courses. A second problem that disproportionately affects URM students is the lack of role models with whom they can identify and whose example they can follow. This lack of anticipatory socialization, the process of learning how to perform a role in a position we do not yet

possess, is the first step in the search and acceptance of an individual into an organization such as a college campus (Hurtado and Carter 1997). Research in this area of organizational communication can be interpreted in the context of student performance in college to suggest that students who know more about college life before they enter will be better able to find opportunities that fit their personalities and skill sets and, ultimately, to have a successful college experience (Arnold 1985). In support of this, a recent study of STEM majors who pursued undergraduate research experiences at the University of California Berkeley indicates that the educational background of the parents was a significant factor in their ability to succeed (Berkes 2008).

One proven approach to increasing the possibility of success of students in STEM disciplines is participation in an original research project (Boyer 1998; Lopatto 2004). Involvement in a research project in college helps students develop self-efficacy as well as the anticipatory socialization skills required to view themselves in the role of a STEM graduate. Lack of opportunities to participate in research internships during high school makes it more difficult for URM students to take advantage of research opportunities available in college that would prepare them to follow careers in STEM disciplines. The Emory University Research Internship and Science Education (RISE) program described here was designed to give high school students in the Atlanta Public School system the opportunity to become involved in an independent research project with the goal of learning the possibilities afforded by careers in STEM disciplines. To meet these goals, RISE takes a multifaceted approach, with a primary focus on a research experience coupled to foundational science education and assistance with college preparation. In addition, the RISE program attempts to influence the attitude of graduate students and postdocs toward teaching and mentoring. By closely participating in the RISE program, it is hoped that graduate students and postdocs will continue this practice in the future in their own faculty positions at research universities. Here we describe the research and educational approaches of the Emory University RISE program as well as the overall impact of RISE on the students and the academic environment in their schools.

Materials and Methods

Recruitment of students and admission to the RISE program

Candidate students for enrollment in the RISE program were initially identified by contacting high school teachers and principals at target public schools with a large URM enrollment. After a relationship was established with these schools during the first year of RISE, principals and teachers routinely submit nominations for candidates every year in the spring. Admission is based on a number of factors, including a demonstrated interest in the biological sciences,

previous participation in school science fairs, and a certain level of success in science and math courses. Letters of recommendation from science teachers and good academic performance, such as a 3.0 grade point average (GPA) or higher, are also taken into consideration. It should be noted that although RISE does use academic performance as a factor, it is not the sole driving factor for acceptance. To maximize the impact of the program, students are admitted at the end of their sophomore year and participate in the program until the summer following graduation from high school. This 2-year commitment is a critical component of the program that allows students to complete a significant research project and receive academic support to ensure their success in college. Undergraduates are selected on the basis of their interest in the research projects, their commitment to mentoring, and their ability to serve as role models for the high school students. Postdocs and graduate students are members of the Corces lab.

High school students participating in RISE are paid a nontaxable stipend of \$2500 during the summer and \$1000 per semester during the academic year. This stipend is meant to replace income the students would have received normally by working in the private sector after school or during the summer break. In addition, Emory undergraduates who conduct research and serve as mentors in the RISE program during the summer receive compensation on the basis of a standard hourly pay specified by Emory University; total compensation for the summer ranges between \$2000 and \$4000, depending on the degree of student involvement.

Mentoring structure

The success of RISE relies heavily on a multitiered mentorship structure in which every lab member participates. Postdoctoral fellows and graduate and undergraduate students are directly involved in mentoring RISE students in all aspects of their projects. In particular, undergraduates work closely with high school students helping to oversee their research while also being directly involved in their own research projects, different from those of the high school students, and for which they can earn college credit. Although an effort is made to have URM undergraduate students who can better serve as role models, it is not always possible to find sufficient URM undergraduates willing to participate.

Emory undergraduates also contribute to several important mentoring activities other than the laboratory research projects. Summer classes on introductory college-level biology and SAT preparation courses are taught by Emory undergraduates. In addition, Emory undergraduates have established the Educating Minorities and Exploring Resources to Grow and Excel-RISE Mentor Program (EMERGE-RISE). Undergraduates who participate in the EMERGE-RISE program are different from those who participate in the laboratory mentoring of high school students. Upon joining the program, each RISE student is paired with an EMERGE-RISE mentor who helps the student with the college application

process. This includes choosing the appropriate school, filling out applications, learning strategies for success as a college freshman, and the opportunity to shadow Emory undergraduates on campus to gain insights into college life. Students meet with EMERGE-RISE mentors as a group once a month and maintain contact with their specific mentor on a weekly basis. EMERGE-RISE mentors do not receive financial compensation or college credit.

Educational experiences of RISE students

During the three summers in the program, RISE students receive instruction in college-level biology and SAT preparation classes. The biology course is designed to fill the educational gap created by the lack of rigorous AP science courses at their high schools and to help them understand and appreciate their research projects. Students are not graded for their class performance and they are not eligible to receive college credit. The course is taught by RISE undergraduate mentors and is designed to be interactive and problem based to develop independent learning and critical thinking skills. SAT preparation classes, also taught by RISE undergraduate mentors, combine content-based tutoring with test-taking skills. In addition to this formal instruction, students also participate in a seminar series in which speakers from the local biomedical community give presentations on their career paths and accomplishments. These presentations offer RISE students the opportunity to personally interact with accomplished members of the scientific and medical community and evaluate their interest in various career paths.

Choice of a research topic for the RISE program

The most critical issue during the initial process in the establishment of the RISE program was the identification of a research topic that is technically feasible for high school students, offers the potential for advanced study, and can be tailored to allow each participant her/his own independent project. To meet these goals, we set up a research program based on work currently being pursued in the lab. Our major area of research centers on the relationship between nuclear organization and transcription using the model organism *Drosophila melanogaster*. The three-dimensional organization of the chromatin fiber in the nucleus is important for the spatial and temporal regulation of transcription during development. Our laboratory studies the role of insulators in chromatin organization and gene expression (Geyer *et al.* 1988; Bushey *et al.* 2008). Previous studies have shown that *Drosophila* insulator proteins are present at hundreds of sites throughout the genome that colocalize to distinct foci predominantly around the nuclear periphery in diploid cells (Ramos *et al.* 2006; Gerasimova *et al.* 2007). A number of proteins have been identified that interact with insulator DNA but additional components may be required to explain all the properties of these sequences (Pai *et al.* 2004; Capelson and Corces 2005; Lei and Corces 2006; Bushey *et al.* 2009). The research project carried out by students

Table 1 Number of GFP protein trap lines screened and further characterized

Localization of protein trap lines			
Total lines screened	GFP positive	Nuclear GFP	
606	486	141	
Nuclear trap lines			
Total	Unmapped allele	Uncharacterized gene (CG)	Characterized gene
141	26	32	83
Nuclear trap lines used for further studies			
Total	Unmapped allele	Uncharacterized gene (CG)	Characterized gene
76	15	26	35

in the RISE program seeks to find novel protein components of insulator complexes as well as other proteins that may have unique roles in nuclear organization. The approach is to screen a collection of GFP-tagged protein-trap *Drosophila* alleles to identify those with interesting nuclear localization patterns (Morin *et al.* 2001; Kelso *et al.* 2004; Buszczak *et al.* 2007). Once a protein is identified, further analysis is carried out to elucidate its role in chromatin organization and nuclear biology. Students begin at a common starting point that only requires understanding basic concepts in genetics and cell biology. As they progress through the program, RISE students become familiar with sophisticated technical and intellectual aspects of their projects and they have been able to obtain significant results as described briefly in the following section.

Research experiences of RISE students

Students start in the program during the summer of their sophomore year in high school by screening a collection of GFP protein-trap strains for interesting patterns of nuclear distribution of GFP fluorescence. The ultimate goal of this screen is to identify new proteins involved in nuclear organization. Once a strain with the appropriate characteristics is identified, progression in the characterization of specific proteins requires additional understanding of concepts in bioinformatics, molecular biology, and biochemistry. The initial discovery of a novel protein with a particular distribution pattern quickly becomes the student's personal independent work, developing a sense of ownership that is essential for continued involvement. The development of project ownership at an early stage along with the understanding of the novelty of the discoveries is central to fueling student motivation and the success of the program.

Student evaluation of the RISE program

Yearly evaluations of RISE are carried out to determine the strengths and weaknesses of the program as well as its impact on the participating high school students. Two evaluation formats have been used to assess student opinions. The first focuses on written feedback and gives students the option of choosing statements with which they agree or disagree. Twenty-one students responded to surveys in this format over the first two and half years of the program. Students who participated in the program over this time period completed this specific survey format each year. Although these questionnaires provided us with some information, they proved

ineffectual for a number of reasons. First, the evaluations were difficult to quantify, complicating the understanding of the status of various programmatic activities. In addition, the format limited the number of questions that students could answer in a reasonable amount of time. For these reasons, we designed a second survey that attempts to be more comprehensive by addressing the same topics using a five-point Likert scale (Canaday *et al.* 1978; Mendelson *et al.* 1978). Twenty-one survey responses from different students were collected using this format over the past 2 years. This format has proved to be more quantifiable, allowed us to ask more detailed questions without imposing undue effort on the students, and allowed us to pose more clear and direct questions. These responses were thus used for further analysis of the program; however, responses to the initial survey format followed closely the opinions conveyed using the Likert scale.

Results

Progress of the research carried out by RISE students

To date, students have screened 606 protein trap fly lines (Table 1). Of these, only 78 lines have been kept for further analysis. Lines are discarded if there is no detectable GFP (120 lines), the GFP fluorescence is not nuclear (345 lines), or if it is nuclear but either in a pattern not of interest or it corresponds to a well-characterized protein (65 lines). Of the remaining 78 lines, some represent multiple protein trap alleles for the same protein and thus the number of potential proteins available for study is <10% of the initial lines screened. Therefore, this approach has provided sufficient candidate lines for further exploration. The proteins characterized to date include CG11138, an ubiquitin E3 ligase present in the nuclear lamina; Df31, a nuclear nonchromosomal protein that appears to demarcate chromosome territories in the nucleus; Stwl, a previously identified protein shown to play a role in *Drosophila* germ line cell differentiation although work by RISE students suggests a more widespread role in transcription; and dNlp, a protein involved in chromosome condensation.

Evaluation of the RISE program

Details from the student surveys using the Likert scale are presented in supporting information, Table S1 and discussed below. Although the results of the initial survey are not

presented in the table, the trends of the answers are very similar. For example, 86% of students indicated in the initial surveys that they wished to pursue a career in science or medicine (data not shown), which is very similar to the percentage of students who scored a 4 or higher on the Likert scale to separate statements indicating they wished to pursue a career in science (77%) or a career in medicine (86%) (Table S1). In addition, 90% of respondents to the initial surveys indicated they were more likely to pursue a career in science after participating in RISE and 76% answered with a 4 or greater to the statement, “I am now convinced a career in science or medicine is right for me” while <5% scored a 2 or lower on this question (Table S1). When students were asked whether they had intended to pursue a career in science, medicine, or health prior to RISE, 90% responded with a ≥ 4 while $\sim 20\%$ gave the statement “I was considering a career in science, but I was not sure” a score of ≥ 4 . This indicates that most students have a prior interest in a career in science and/or medicine but there is still a significant degree of uncertainty in their preferred path (Table S1). After participation in RISE, 81% indicated they felt better prepared and motivated to pursue a career in science and 71% felt the same toward a career in medicine. In contrast, <5% indicated they did not wish to pursue a career in these fields, indicating that much of the uncertainty felt at the beginning of the program has been resolved (Table S1). In addition, 71% felt RISE helped them to better prepare to excel both in their current schoolwork as well as in college; 80% felt RISE challenged how they process information. All respondents felt RISE enhanced their general science knowledge and 85% said they improved their critical thinking skills (Table S1). Thus, on the basis of current survey results, RISE students feel positively affected by participation in the program.

Impact of the RISE program on the students and their schools

The RISE program has had important effects on both the students and their schools. Thirty-nine high school students have participated in the RISE program to date, 10 Emory undergraduates have worked directly with the high school students in the laboratory, and 12 have served as college mentors. In addition to the progress students have made in their research, the RISE program has achieved other important goals.

A condition for participation in RISE is that high schools establish a science fair for all the students. This type of program was already in place for some of the schools involved with RISE. However, two of the schools whose students participate in RISE had never had a science fair prior to their involvement but they now hold this fair every year. As a consequence, RISE has had a positive impact on science education not limited to the participating students, but also to the science learning environment in the participating high schools. For the past 3 years, RISE students have successfully competed in regional, state, and international science

fairs and the accomplishments of the students have improved every consecutive year. In 2008, one student received “Golden Key” honors, indicating she had earned the highest level of points available in the competition at the Atlanta Public Schools (APS) regional fair. This accomplishment allowed the student the opportunity to participate in the Georgia State Science Fair competition, the first time a student from her high school had done so. In 2009, the same student received “Golden Key” honors again at the Atlanta Public Schools regional fair and went on to win third place at the Georgia Science Fair competition level within her division. A second student was both a first-place winner and a “Golden Key” winner at the APS regional fair in 2009, earning attendance to the Intel International Science and Engineering Fair Competition (ISEF) in Reno, NV. This student also went on to compete at the Georgia Science Fair and won a second-place ribbon within her division. In 2010, 12 RISE students competed in two different regional science fairs. A RISE student from each competition presented one of the top two projects, earning trips to the ISEF Science Fair held in San Jose, CA. Six additional students won “Golden Key” honors at the regional competitions and two won “Silver Key” honors, giving all a chance to compete at the Georgia State Science Fair. RISE students received first-, second-, third-, and fourth-place honors in this competition within their divisions.

In considering these accomplishments, it is important to note that other participants in the Georgia State Science Fair are students attending public high schools in suburban areas or private schools, where the resources and quality of the education are well above those experienced by APS students. The outside recognition accompanying these awards has had several important consequences at various levels. First, it has given the students the confidence that they can be successful in biomedical research. In this process of anticipatory socialization they can now envision themselves in the role of successful undergraduate college majors in a science discipline. Second, their success has taught other students at their schools the importance of academic achievement. Third, it has shown other APS high schools a possible pathway for success. As a consequence, RISE has had an impact that is not limited to its direct participants but also extends to other students in the same school and other schools in the district.

RISE students have received other awards in recognition for their accomplishments. Out of 20 students from the Atlanta Public School system who received Gates Millennium fellowships in 2009, 4 were participants in the RISE program. There have been seven Gates Millennium scholarships awarded to RISE students, which is of particular significance since these awards are specifically geared toward students wishing to pursue careers in science and medicine. RISE students have been awarded scholarships from various colleges and universities as well as sources such as Coca-Cola and Best Buy. More importantly, all but one RISE student have continued their education at colleges and universities including Xavier, Tuskegee, Spelman, Morehouse,

Stanford, Duke, Emory, Cornell, Georgia Tech, Georgia State, and Davidson.

A semiquantitative analysis of the effect of RISE on student outcomes

The evaluation of the results of the RISE program requires sharing of data by the participating schools to compare the performance of RISE students to that of their peers. This is not always possible, as some schools are hesitant to share this information. Of the four Atlanta area public schools participating in RISE that were contacted, only one was willing to share a limited amount of data. As a consequence, our analysis is limited to comparing 15 RISE students from this specific school to their fellow classmates. On the basis of senior class average scores submitted by the school administration, RISE students perform significantly higher than their peers on the SAT exam (P value = 0.0013). The average SAT score for graduating seniors from this specific school is 1255 out of 2400 possible points, whereas the average score for RISE students is 1452. While it is true that this analysis does not allow us to include all RISE students, comparison of SAT scores among RISE students indicates that there is no significant difference between the average SAT score of these 15 RISE students vs. other RISE students (P value = 0.67). This indicates that the group of 15 students is an accurate representation of the general population of RISE students. In addition, the average SAT score for the contributing school is not statistically different from the 2010 average SAT scores for other schools participating in the program (P value = 0.42) (Cardoza 2010; College Board 2010).

In addition to SAT scores, RISE students from the contributing school maintain a higher grade point average and continue on to 4-year colleges in greater numbers when compared to their peers. RISE students have an average GPA of 91 out of 100, while their peers' average GPA is 78 (P value = 4.17×10^{-9}). Lastly, although the percentage of graduates that went on to a 2- or 4-year college is comparable between RISE and non-RISE students, with both at ~93%, all 93% of RISE students enrolled in a 4-year college in pursuit of a bachelor's degree, whereas only 75% of non-RISE students continued on to a 4-year college. Thus, it appears that RISE students outperform their peers academically and on college entrance exams but it is not clear whether RISE is the direct cause for these outcomes. Indeed, it is likely that RISE participation is not the sole driving factor. As students were chosen for the program partially on the basis of a minimum level of academic achievement, it is reasonable to assume they should perform higher than school averages. The degree to which participation in RISE may have enhanced these differences is difficult to gauge. Increasing SAT scores or GPAs, however, was not the most important goal of RISE. RISE sought primarily to better prepare URM students for success in STEM disciplines and motivate them to engage in research. How RISE impacted these goals is a more pertinent measure of the program's success.

Did RISE, in fact, help prepare students for STEM majors, as the program set out to do? Since RISE has only been in place for 4 years, the majority of students are still pursuing their undergraduate degrees. We therefore lack statistically significant data to evaluate the effect of RISE on graduation rates of students with degrees in STEM disciplines. However, we do have information on the number of students currently pursuing undergraduate degrees in the sciences or intending to do so, although we lack similar information for their peer group. At present, 46% or 18/39 RISE students are pursuing degrees in STEM disciplines. The majority of these students are biology/premed (72.2%), while the remaining are pursuing degrees in physics or biomedical engineering. Outside of the traditional STEM disciplines, a further 15.4% of RISE students (6/39) are pursuing science/medical-related careers with majors in nursing, veterinary science, forensic science, and psychology. This brings the total number of RISE students currently pursuing degrees in the sciences to an impressive 61%. Further, 61% or 11/18 students who entered college as STEM majors have completed at least their freshman year and still remain STEM majors. Although we do not have the ideal control group to determine the significance of these numbers, we can use studies that tracked STEM graduation rates for students entering college in 2004. From this study, only 18.4% of African Americans that entered college as STEM majors graduated with STEM degrees within 5 years (Higher Education Research Institute 2010). Since 87% of RISE students are African American, and 46% of all RISE students are still pursuing college degrees in STEM disciplines, we can expect that the number of RISE STEM majors will be significantly higher than the national average. In fact, at a rate of 46%, RISE students are in a path to graduate in STEM majors at the same rate as non-URM students nationwide. Similarly, the retention rate of RISE students in STEM majors after the freshman year (61%) is well above the national average for non-URM students (Higher Education Research Institute 2010).

In addition to pursuing STEM degrees, 28% of RISE STEM majors (5/18) have continued to engage in scientific research as undergraduates. Data tracking the number of URM students engaging in undergraduate research are not currently available. However, a 2008 study conducted at the University of California Berkeley found that only 7% of African American STEM majors engaged in undergraduate research (Berkes 2008). On the basis of this information, it appears that RISE students participate in undergraduate research in STEM disciplines more frequently than the typical African American STEM undergraduate major. A study from the Teagle Foundation that compiled data from 209 four-year colleges and polled over 60,000 seniors shows that only 19% of all students, including non-URM, in all educational disciplines participate in undergraduate research (Teagle Working Group On The Teacher Scholar 2007). When one considers all RISE students currently in college, and not just those in STEM majors, eight (20.5%) RISE students continue to participate in scientific research,

a number comparable to the overall national average for all students.

These results suggest that, although the numbers are not sufficiently large to draw a statistically significant conclusion, RISE appears to have a positive impact in preparing students for success in college, inspiring them to pursue science-related majors and motivating them to continue to engage in research.

Discussion

The Emory University RISE program was established with the goal of addressing a critical problem in the US educational system, *i.e.*, the shortage of underrepresented minority students in science and engineering careers. Many factors contribute to this problem during high school, including a shortage of advanced science courses, lack of role models that can serve as motivating examples for a science career, and absence of opportunities to experience the excitement of scientific discovery. Once in college, success in science majors is influenced by rigorous introductory science classes. This problem affects all college students and is not specific to URM students, but it has a disproportionate effect on this group of students who tend to come from socioeconomic backgrounds that lack the opportunity to experience an enriched high school education. This may be a critical factor contributing to the shortage of URMs in STEM careers. The lack of a high school education rich in Advanced Placement courses, career advice, opportunities for internships, and role models leaves many URM students unprepared for the rigors of gatekeeper courses and at a clear disadvantage in comparison to their classmates in college.

The Emory University RISE program was established to analyze the effect of various interventional measures on the factors responsible for the low representation of URMs in STEM careers. At the core of RISE is a 2-year-long research experience in which each student develops an original research project. This project serves as the basis for learning foundational concepts in genetics, cell biology, molecular biology, biochemistry, and bioinformatics. This research experience is designed to allow students ownership of the project and to experience first-hand the possibilities associated with a career in biomedical research, *i.e.*, undergo the process of anticipatory socialization described by Hurtado and colleagues as essential for a successful college experience in STEM majors (Hurtado and Carter 1997). In addition to the research project, RISE students participate in several activities that are important to achieve the stated goals. Attendance to a summer-long college-level introductory biology class is important to overcome the deficiencies of a high school education that lacks AP courses taught at a truly advanced placement level. Participation in an SAT preparatory class permits students to achieve scores that allow them to attend college at institutions where they can continue to be involved in research. The mentoring program, with participation of undergraduate and graduate stu-

dents as mentors, gives RISE students role models and a perspective on college life. These experiences are intended to partially bridge the large gap between the quality of the education experienced by most URM students and their potential classmates in college.

The protein-trap screen used by RISE as the basis for the research experience provides an ideal vehicle to develop student interest and motivation, since it requires minimal initial technical training and allows students to be productive and obtain results from their first day in the laboratory. The observation of easily obtained samples under the microscope helps pique student interest and builds their confidence in their own ability to carry out a research project. Initial difficulties in finding GFP protein-trap lines with potential for further study becomes a positive experience, as students become driven to find a fly line containing nuclear GFP. In addition, although not all fly lines show nuclear distribution of GFP, many still have very unique and interesting localization patterns that offer an opportunity to discuss the potential role of the tagged protein in various aspects of cell function. Importantly, the research is designed to increase in complexity, both technically and conceptually, as students progress through the program. These characteristics of the research project are critical in ensuring student motivation and persistence.

The organization of the research projects carried out by RISE students was originally predicated on the assumption that each student would be responsible for the characterization of a gene identified during the screen of the protein-trap collection. Nevertheless, it quickly became clear that this approach is unfeasible and that there are enough interesting questions about a few proteins for each student to have an independent project. As the students started characterizing the various protein-trap lines, the complexity of the experiments made it difficult to maintain so many independent projects. Although having each student begin by screening protein-trap lines provided a great entry into the science, requiring each student to screen lines until they found something of interest became, at times, a long process that inhibited students from progressing to the next stage. Therefore, we adopted an approach in which RISE students are grouped into teams and each team focuses on the characterization of a specific protein (for an example of the current teams, see <http://www.biology.emory.edu/research/Corces/RISE/science.html>). Each team is organized in a multitiered mentoring structure in which more experienced high school students mentor newcomers, undergraduates mentor all high school students, and graduate students and postdoctoral fellows mentor the whole team. It is important to note that graduate students and postdoctoral fellows only serve as mentors for the research teams. The research topics explored by RISE students are not part of their own projects and they are not responsible for generating data but rather for answering questions, explaining concepts, and facilitating technically difficult experiments. New students still become involved in the protein-trap screen when they start in the RISE program

during the summer after their sophomore year in high school but at the same time they are exposed to the next level of science by helping their team. This approach allows the program to be more focused, which helps to advance the research at a much faster pace. In addition, by working in teams students are better equipped to support each other. Using the team approach has had some unexpected benefits. For example, understanding how their own work relates to that of fellow RISE members and how results from one student can impact the work of another provides a unique learning tool that helps students see connections and understand the big picture rather than just their own specific experiments.

The success of the scientific aspects of the RISE program is unquestionable. RISE students have identified and are characterizing with a high degree of technical sophistication proteins involved in chromatin organization and transcriptional regulation. Although students begin at a very elementary level, their progress is quite remarkable. Students move from basic genetic experiments to Western analysis, protein immunoprecipitation studies, RNA interference both in flies and in cell culture, and immunofluorescence microscopy in a short period of time. At each new level of technical complexity students need some initial guidance and further mentoring to fully understand the concepts, but students quickly master the new information and are able to carry out the new experiments and analyze the data with help from their mentors to plan the next step.

A critical component of the success of the RISE program has been a strong partnership with the local high schools. One of the first obstacles RISE had to overcome was student recruitment during the initial year of the program. The recruitment process has been successful since then because of the development of close contacts with teachers and school administrators in Atlanta Public Schools. Recruitment of students for RISE also benefits from the restructuring process undergone by the Atlanta Public Schools during the past 6 years (Maciejewski 2007). The purpose of this process is to provide small school environments where students can receive an education geared toward their interests. We were thus fortunate to work with schools targeting students interested in health, medical sciences, and research. This pool of students provides RISE with motivated candidates while RISE is able to support APS in its goal of giving students a unique educational experience. Other forms of support from the schools include allowing students early dismissal to spend more time on their research projects as well as help with science fairs. In exchange, RISE has had a significant impact on APS schools. RISE provides students additional reasons to strive for academic excellence while in high school and the dedication and success of RISE students serves as an inspiration to their classmates.

The RISE program provides students with a stipend to lessen the need to work after school. Although some may question the need for a stipend and may feel it can detract from the focus of the program, most RISE students are expected to contribute to their household income. Therefore,

their participation in RISE may not be possible without this stipend. It is unlikely that this stipend is the driving force for participation in RISE, since students could earn a much higher income by spending the same number of hours at a normal job.

One of the original goals of the RISE program was to develop student qualifications to the point that they could be accepted to the Emory undergraduate program. Students could then continue their participation in RISE and serve as mentors for new high school students while continuing their research and receiving help to overcome the competitive environment of weed-out courses in biology, chemistry, and physics. This is an unfulfilled goal of the program. Instead, RISE has enrolled Emory undergraduates to participate in RISE and serve as mentors and role models to the high school students. Interestingly, participation in RISE has had an important effect on these students. As members of the program, Emory undergraduates participate in the research projects and advance their scientific knowledge. More importantly, undergraduates have the opportunity of developing as leaders of the team with which they work. Some of the undergraduate students in the program have an interest in science education and RISE has given them the opportunity to explore this interest by teaching in the summer introductory biology and SAT preparation classes.

The RISE program has been in existence for only a few years. Although at this point we lack sufficient statistically significant data to draw strong conclusions, preliminary evidence suggests that the program succeeds in preparing and motivating high school students for college science majors and continued involvement in biomedical research. In addition, it makes graduate students and postdocs aware of the importance of teaching and mentoring for their own professional development and for the future fulfillment of their career goals. Perhaps the adoption of a similar model at a national scale, supported by government or private funding agencies, could begin to address the critical issue of increasing the number of members of underrepresented minority groups in science research careers while conveying the importance of teaching and mentoring to current graduate students and postdocs.

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Opening Pathways for Underrepresented High School Students to Biomedical Research Careers: The Emory University RISE Program

Margaret C. Rohrbaugh and Victor G. Corces

Table S1

Summary of RISE Program Student Evaluation

Table S1 is available for download at <http://www.genetics.org/content/suppl/2011/09/16/genetics.111.132126.DC1> as an Excel file.