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Article

Encouraging Minority Undergraduates to Choose Science Careers: Career Paths Survey Results

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To explore the reasons for the dearth of minorities in Ph.D.-level biomedical research and identify opportunities to increase minority participation, we surveyed high-achieving alumni of an undergraduate biology enrichment program for underrepresented minorities. Respondents were asked to describe their career paths and to reflect on the influences that guided their career choices. We particularly probed for attitudes and experiences that influenced students to pursue a research career, as well as factors relevant to their choice between medicine (the dominant career choice) and basic science. In agreement with earlier studies, alumni strongly endorsed supplemental instruction as a mechanism for achieving excellence in basic science courses. Undergraduate research was seen as broadening by many and was transformative for half of the alumni who ultimately decided to pursue Ph.D.s in biomedical research. That group had expressed no interest in research careers at college entry and credits their undergraduate research experience with putting them on track toward a research career. A policy implication of these results is that making undergraduate research opportunities widely available to biology students (including "premed" students) in the context of a structured educational enrichment program should increase the number of minority students who choose to pursue biomedical Ph.D.s.

INTRODUCTION

Despite significant efforts over the past 30 yr by federal government agencies and private organizations, there continues to be a significant underrepresentation of minority scientists engaged in biomedical and behavioral research in the United States. Voicing frustrations attendant on the slow progress in that direction, a recent National Academy of Sciences (NAS) report (NAS, 2005) noted that a diverse research workforce broadens scientific inquiry and is better able to address population-specific health problems. Critical workforce supply problems over the last decade include severe underrepresentation of Native American, African American, and Hispanic individuals—together, these and other underrepresented minorities (URMs) accounted for only 4.2% of the doctoral-level biomedical workforce in 1997 (Lopatto, 2004; NAS, 2005).

A wide array of intervention programs has attempted to redress this disparity; most focus on individual research experiences and financial support. The implicit assumption is that "when students are provided the opportunity to engage in state-of-the-art biomedical research, with appropriate facilities, support and mentorship, their appetite will be whetted to enter a career in biomedical research" (National Institutes of Health [NIH], 2007). Although significant resources have been expended on such programs, few studies have rigorously investigated their efficacy. This dearth of research, coupled with the persistence of underrepresentation in the sciences, resulted in an NIH-funded initiative to build an empirical base of evidence upon which new interventions can be developed and existing interventions improved.

The goal of this study is to understand the manner and degree to which undergraduate experiences, especially targeted enrichment activities included in intervention programs, influence the career choices of program participants. We give particular attention to the undergraduate research experience and gauge its influence on the career choices of high-achieving URM students who started college intending to major in the life sciences and participated in an intervention program at the University of California, Davis (UCD).

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Although the overall study uses a two-stage survey-interview research design, this article uses only the survey data to describe the selection of paths to doctoral degrees in the biomedical sciences and "leakage" in the pipeline to scientific careers. We also examine values and interests associated with the consideration of scientific research careers and conclude with recommendations for the implementation of targeted intervention programs that could increase the number of URM scientists.

Underpinnings of the Present Study

Influences on Career Selection. Effective interventions promoting research careers should be based on an understanding of the characteristics and experiences that affect students' career selections. Previous research has identified three categories of factors that influence the occupational choices made by college students (Bowen *et al*., 1998; Cole and Barber, 2003; Nieli, 2004; NIH, 2007). First are the background characteristics of individual students when they enter college: these statistics include race/ethnicity, sex, socioeconomic status, high school performance, SAT scores, and occupational and educational aspirations. The next two sets of factors reflect the students' differing experiences during college. One set defines the structural characteristics of the institution attended, such as size, selectivity, location, and racial/ethnic makeup. The other set reflects individual student experiences during college and is made up of factors such as courses taken, grades, amount and quality of faculty contact, social environment, and participation in supplementary educational or advisory activities. Although all of these factors are expected to influence career choice, within a particular institutional environment, only the variables associated with students' experiences during college can be altered, and hopefully improved, through undergraduate intervention programs.

Influence of Undergraduate Research. Research participation as an undergraduate enrichment activity has long been held to increase the probability of students persisting in science majors. Because this belief is consistent with the experience of many successful scientists, programmatic interventions that include undergraduate research have multiplied over the years, but until recently there has been little systematic study of their efficacy. An early empirical study of the impact of research participation on persistence in science majors (Astin and Astin, 1992) found a consistent association between participating in a professor's research project and persistence in—or recruitment into—a science major.

More recent studies of undergraduate research experience (URE) fall into two groups. One set of investigations, largely ethnographic and descriptive in nature, focuses primarily on how undergraduate research experience increases skills and may lead to other cognitive or personal gains (Kardash, 2000; Lopatto, 2004, 2007; Seymour *et al*., 2004; Hunter *et al*., 2006). Among the gains participants report are an improvement in basic science inquiry skills, including data collection and analysis and oral presentations (Kardash, 2000; Lopatto, 2004), an increased general understanding of what scientists do and how they do it (Lopatto, 2004), and an increased sense of professional identity and confidence in being able to do the work of a scientist (Seymour *et al*., 2004; Hunter *et al*., 2006). Most of these studies describe the changes experienced by URE participants over time, but they do not include postcollege outcomes. Although some studies have identified differences between men and women in the influence of URE, few have addressed variations by participant ethnicity/race.

Another cluster of studies attempts to understand how participation in the URE influences academic and career outcomes (Nagda *et al*., 1998; Hathaway *et al*., 2002; Bauer and Bennett, 2003; Barlow and Villarejo, 2004; Russell *et al*., 2007). These researchers ask whether research experience makes a difference in academic outcomes or career choices and whether the effect of research varies by demographic group. Research designs that compare URE participants to nonparticipants and control for other variations in individual characteristics between members of these two groups find that undergraduate research targeted to URM participants in their early years of college is associated with retention in science majors to graduation (Nagda *et al*., 1998; Villarejo and Barlow, 2007).

A weakness common to many of these studies is that the direction of causality is undefined—it is not clear whether students who were interested in research careers elected to participate in URE or whether URE influenced students to pursue careers in research. A notable exception is a multistage experimental design study of a structured undergraduate research program at the University of Michigan in the early 1990s that followed matched clusters of applicants who had been randomly assigned to intervention treatment and control groups (Nagda *et al*., 1998; Hathaway *et al*., 2002). Findings suggest that URE is indeed a causal factor that increases the rates of college completion, entry into graduate-level training, and enrollment in doctoral or professional programs, particularly for members of underrepresented minority groups. Unfortunately, these studies do not disaggregate their data by academic major, so it is not possible to determine whether the effect is different for science majors compared with other areas in the liberal arts.

Importance of Supplemental Instruction. The underpreparation of many incoming URM students for college-level science courses is reflected in both SAT and high school GPA (Fullilove and Treisman, 1990; Villarejo and Barlow, 2007). Although remedial programs for minority students have not been very successful (Born *et al*., 2002), supplemental instruction targeted to difficult courses rather than at-risk students has elicited more positive outcomes (Maton *et al*., 2007; Rath *et al*., 2007; Villarejo and Barlow, 2007).

In a prior analysis, the effectiveness of this supplemental instruction was demonstrated by student persistence and performance in basic science classes: Biology Undergraduate Scholars Program (BUSP) students who entered 1994–1999 outperformed both non-BUSP URM students and the white/Asian majority in general chemistry and calculus, despite the fact that BUSP students' average combined SAT scores of 983 were >100 points lower than the white/Asian average of 1086 (Villarejo and Barlow, 2007; Table 1). Supplemental instruction in basic science classes at California State University campuses also has been shown to have a significant effect on the persistence and performance of URM students in science majors (Rath *et al*., 2007).

Table 1. Persistence and performance in foundation courses, by group

		Calculus		General chemistry	
	Total	Persistence	Mean GPA	Persistence	Mean GPA
Group	*n*	%		%	
BUSP	336	75	2.94	81	3.1
Non-BUSP URM	1267	42	2.69	43	2.56
White/Asian	5559	54	2.89	55	2.79

BUSP students outperformed both non-BUSP URM students and the white/Asian majority in general chemistry and calculus. Persistence is defined as completing the course series (i.e., all three quarters of chemistry and all three quarters of calculus). Mean GPAs are also significantly different by group (t test, $p < 0.01$).

BUSP Intervention Program Description

All of our subjects were participants in one intervention program, the BUSP at the UCD. When BUSP was initiated in 1988, it was intended to address the disproportionate attrition of URM students from the biological sciences at UCD.[1] To counter this trend, BUSP selected a broadly targeted early intervention strategy, focused on retaining students in biology during their first 2 yr of college, to increase the pool of biology majors who might consider research careers. BUSP does not screen participants for interest in a particular career (e.g., science research or medicine) at entry as freshmen. The only academic requirements are an interest in biology and readiness to embark on the core undergraduate gateway courses (i.e., mathematics, general chemistry, and biology).

The BUSP educational enrichment program provides supplemental academic instruction in basic chemistry, calculus and biology; academic and personal advising; and practical experience and financial support through employment in research through the freshman and sophomore years (for a detailed description, see Villarejo and Barlow, 2007). Academic enrichment consists of a series of required supplemental workshops for the crucial "gatekeeper" courses in science. Before enrolling in general chemistry, BUSP students take a prechemistry course, taught in small sections of 25 students by professional instructors at the Learning Skills Center. Prechemistry is a challenging course introducing important concepts including acid/base chemistry, stoichiometry, hybridization, Lewis structures, and valence bond theory. Students are asked to solve problems and are encouraged to work in groups. The following quarter, when students proceed to general chemistry, they continue to meet twice weekly in small cochemistry workshops. Calculus instruction also is supplemented with two additional hours of instruction per week in small classes with professional instructors.

BUSP strongly encourages participants to engage in research early in their undergraduate careers. From 1988 to 1994 many started research in the freshman year, but more recently research was postponed to the sophomore or junior year. Faculty mentors were asked to provide a developmental experience for the students, introducing beginning students to the laboratory environment by starting with simple laboratory tasks, advancing to more challenging activities as the student demonstrated competence at each level. As a result, 70% of all BUSP students have chosen to participate in research for at least one term. Responses to surveys and interviews of undergraduate students indicate that the opportunity to do research was a significant inducement for students to participate in the program.

Study Design

The present study attempts to disentangle some of the intermediate steps involved in the career selection process using survey data collected from BUSP alumni who were 1 to 13 yr beyond college graduation and whose undergraduate GPA suggested the possibility of admission to graduate or professional school. The survey collected a range of data concerning career interests at college entry, ultimate career choice, and the impact of undergraduate enrichment experiences. This information was combined with institutional data to follow students' progression through their college experience, illustrated in Figure 1.

The career choice model starts at college entry with choice of college major and career interests, both of which are influenced by academic preparation and socioeconomic factors (these are also referred to as "input factors"). These starting points shape the experience of undergraduate enrichment activities, and the sum of input factors and undergraduate enrichment experiences in turn influence college major, graduation, and career goals at graduation. Undergraduate experiences in turn influence ultimate career choices.[2] Values and interests underlie the entire career selection process. We expect that undergraduate enrichment experiences influence career goals by two main routes: indirectly, through enhancing undergraduate achievement, which in turn influences college major and likelihood of graduation and admission to graduate school; and directly, through stimulating (or rerouting) student choice of a scientific career.

This article combines quantitative and qualitative analyses of survey responses to explain the career selection processes described in the model. The results are presented here in three parts. The first section looks at early events in the student's academic career: respondents' career interests at college entry and the impact of undergraduate enrichment experiences on academic success and persistence in a biology major. The second section presents an analysis of respondents' career paths—the evolution of career interests from college entry to the time of the survey—that describes the contribution of individuals' undergraduate experiences

[1] URM groups, defined using NIH categories, include African Americans, Hispanic Americans, Native Americans/Alaska Natives, and Pacific Islanders. Filipino Americans were considered underrepresented at UCD in the early years of BUSP (Student Affairs Research & Information, 2000) and account for most of BUSP's non-URM participants.

[2] The survey only measured the endpoints of this process: career goals at college entry and ultimate career goal. Career goal at college graduation was asked of the 106 respondents in the interview stage of the research project. Sixty-six percent of interview respondents said they had made their ultimate career choices before or during college.

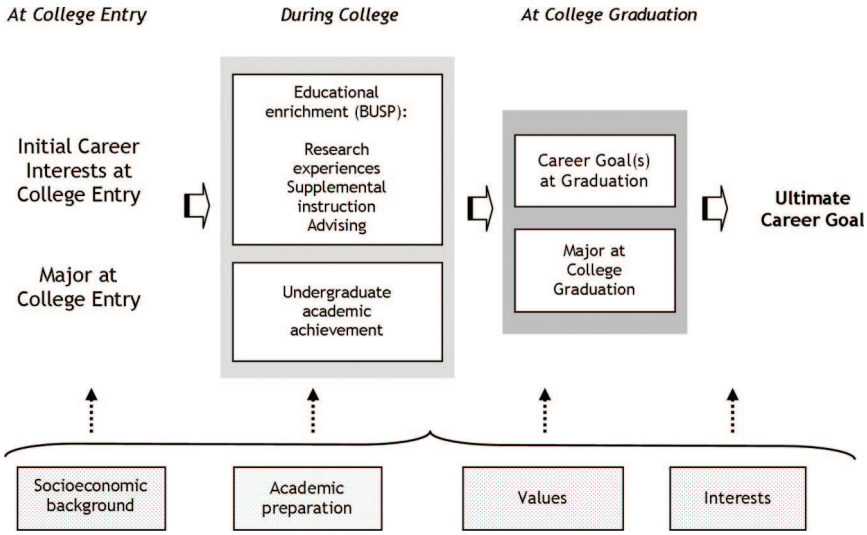

Figure 1. Influences on career choice during the undergraduate years.

and compares the experiences and attitudes of groups with different ultimate career goals. The final section explores, by ultimate career goal group, hypothetical values and interests pertaining to the choice of a Ph.D.-level scientific research career. Our goal in this study is to explicate factors associated with respondents' selection among the various biology-based professions, particularly between careers in medicine and scientific research. Because this work focuses on the influence of undergraduate enrichment experiences in informing career choices, our analyses highlight the contribution of undergraduate research to respondents' career interests.

METHODS

Sample Definition

To reveal the relationship between undergraduate experiences and the decision to pursue graduate study in the biomedical sciences required study of a group of students whose undergraduate performance would qualify them to pursue doctoral education in the biomedical sciences. BUSP database information on the postgraduate attainment of some program alumni who pursued doctoral study in biology-related fields (Ph.D., M.D., O.D., D.D.S., or D.V.M.) indicated that those who graduated with a minimum cumulative undergraduate GPA of 2.7 obtained entrance to some of these postgraduate programs. Those with GPAs at the lower end of the range sometimes found it necessary to improve their academic records by completing a master's degree, often at one of the California state universities, before seeking entry to a doctoral program. Although the majority of these students graduated from UCD with a major in biology, other majors (e.g., psychology, human development, English, history, and Chicano studies) also served as entry points to biomedical study. As a result, our sample was defined as all students who started in BUSP as freshmen, participated in the program for at least one quarter, and received any baccalaureate degree from UCD during 1992–2004 with a minimum cumulative GPA of 2.7. The total sample was 322 students.

Survey Design

Because of the large number of career influences we were interested in investigating, and the need to collect both factual and process-related information, we developed a two-stage survey/interview design for the overall study. Our main goal for the survey was to collect enough information for stand-alone data analysis for those who did not complete the interview, and also provide a springboard for additional elements covered in the interview process. The survey instrument collected the following information (see Supplemental Material, BUSP-NIH Career Path Survey instrument):

- Postgraduate education planned, completed or currently enrolled;
- Postgraduate employment;
- Career interests at college entry and career expectations;
- Assessments of the contribution of BUSP program components to academic success;
- Undergraduate research experiences and contributions to major and career choices;
- Experiences with undergraduate advising;
- Attitudes toward hypothetical qualities of biomedical Ph.D. research careers;
- Amount borrowed for undergraduate education and whether loan was paid off; and
- Parental educational attainment and occupation.

The questions probing the hypothetical qualities of Ph.D.-level biomedical research careers were modeled on Cole and Barber's survey regarding the occupational choices of high-achieving minority students (2003). They devised a set of hypothetical attributes that might make a career as a college professor attractive or unattractive (p. 276). Although we retained many of the specific questions, some were not appropriate to biomedical research careers and were modified accordingly. We also added some questions regarding the influence of family ties and the role of childbearing on the choice of a research career.

Survey Mechanics

The survey instrument was pretested for comprehension and length on staff and recent BUSP graduates before it was launched using Survey Monkey in October 2005. Invitations to participate in the survey were extended to the 282 program alumni falling within the sampling frame for whom we were able to obtain some contact information. Multiple tracking strategies were necessary to find this highly mobile population. About one-third of the targeted alumni maintained voluntary, intermittent contact with BUSP staff, providing us with e-mail or street addresses. The UCD Alumni Association provided street addresses for 297 of the 322 alumni on our list, although many addresses were not current and others were the

parents' home address. The National Student Clearinghouse (NSC) was used as a source of postgraduate enrollment information and e-mail addresses for currently enrolled students. Although NSC data provided new information on some subsequent enrollments, a large number of enrollments were missed, most at nonmember schools (e.g., University of California, San Francisco [UCSF], Massachusetts Institute of Technology, and Stanford). This was a serious omission as many of our most successful students go on to UCSF and Stanford.

Snowball tracking (asking contacted alumni for information on their classmates) was minimally useful, yielding general information on whereabouts rather than concrete contact information. Some individuals were tracked using Google to find published accounts of activities. Commercial tracking services were used as a last resort.

The means of invitation to participate in the survey thus varied by the type of contact information available for a particular respondent (e-mail or surface mail). Survey invitations were sent at least three times to nonrespondents who seemed to have valid addresses, following the method pioneered by Dillman (2000).

Data Handling and Analysis

After data collection was complete, closed-ended data were downloaded in tab-delimited format, imported into Excel (Microsoft, Redmond, WA), and then brought into SPSS version 16 (SPSS, Chicago, IL). University administrative data, including high school GPA, SAT scores, race/ethnicity, sex, college cumulative GPA, college major, and year and term of graduation were merged with the survey data for analysis. Data were scrubbed and recoded.

Respondents (n = 201) were asked to "check all that apply" in response to the survey question "the career(s) you were interested in when you entered college" (initial career goal), but were asked to check only one for "the career you expect to end up in" (ultimate career goal). Some respondents checked more than one career goal for their ultimate career goal. In these instances, the most likely career choice was coded from consulting responses to other survey questions. For example, a person who selected both "physician" and "human services" and was currently enrolled in medical school was coded as a physician. Those who selected the "undecided" response category or three or more unrelated fields were coded as undecided. As a result, separate variables were constructed to describe the dynamic nature of maintenance, development, and loss of career interests in biomedical research and medicine. After recoding the closed-ended data, we used chi-square analyses to detect significant group differences for nominal-level data. We also tested for significant group differences using independent-samples *t* tests, and in instances where variances differed significantly across groups, nonparametric estimates were used.

In the section on hypothetical attributes that would make a career as a Ph.D.-level biomedical researcher appealing or unappealing (see Tables 7 and 8), tests for independence between hypothetical attitudes and ultimate career goal (UCG) group were run using only the larger UCG groups to reduce the incidence of empty cells and increase the reliability of chi-square statistics. Where chi-square tests indicated a statistical association between UCG and hypothetical attitudes toward a career in biomedical research, z-tests for differences among proportions, adjusted for multiple comparisons using the Bonferroni method, flagged significant group differences (Bland and Altman, 1995).

The survey contained several open-ended questions that allowed respondents to describe their experiences with advising and research and the consequences of these experiences on their career choice. These narratives were examined using a combination of several accepted qualitative analysis techniques. Grounded theory and the constant-comparative method were used to locate issues and themes offered directly by the respondents (Glaser and Strauss, 1967). Hypothetical constructs drawn from key prior studies helped to frame and organize relevant themes (Bowen *et al*., 1998; Cole and Barber, 2003; Nieli, 2004). Qualitative analysis using similar strategies has been used in recent studies in this area (Kardash, 2000; Seymour *et al*., 2004; Hunter *et al*., 2006; Maton *et al*., 2007).

Several steps were followed to ensure the validity of the coding scheme and the reliability of the qualitative analysis. The initial code categories were developed by two analysts who read through the entire set of open-ended responses. The analysts then created a draft of relevant code categories, which was verified by two additional analysts who were not involved in the initial review. New categories were added, removed, and combined as needed. Coding reliability was assessed by three analysts independently coding 15% of the responses (n = 30) and comparing results. Differences in coding were discussed until agreement was reached. The code outline and definitions were revised continually during this phase, and a codebook with definitions was developed and maintained to track the coding scheme as it evolved. This review phase lasted until agreement was reached on at least 95% of codes per response. For the final coding phase, the remaining responses were divided among three analysts who coded independently based on the definitions created above. Qualitative analysis software (*Atlas.ti*) was used to manage the large amount of open-ended response data. The overall length of responses ranged from four to 511 words, with an average length of 108 words.

RESULTS

Characteristics of Respondents versus Nonrespondents

Table 2 compares the characteristics of survey respondents and nonrespondents. Of the 322 alumni in the sample, 68% were female. This percentage reflects the overall enrollment in BUSP throughout the past 20 yr: the ratio of women to men has been approximately 2:1 each year. That, in turn, reflects the gender proportions of minority students entering UCD intending to study biology, not any bias in application or acceptance into the program. Although females were slightly more likely to respond to the survey than males (Table 2), the difference is not statistically significant. There was also no significant difference in the proportion of racial or ethnic groups among respondents and nonrespondents.

Respondents differed from nonrespondents by college GPA: the mean GPA of respondents was 3.2, whereas nonrespondents averaged 3.0 ($p < 0.001$). Respondents were also more likely to have graduated in a biology major ($p < 0.01$). This selection in favor of biology graduates with higher GPAs probably reflects higher program affinity by those who successfully remained in science, and it does not significantly affect the validity of our results given the emphasis of this study on tracking the influence of factors on those who remain in science careers.

Career Interests at College Entry

To investigate the relationship between input factors, undergraduate enrichment experiences, and the ultimate career choices of BUSP alumni, we first discuss the careers respondents were considering at college entry. Respondents were asked to select from a list of possible career fields, checking as many initial career interests (ICIs) as necessary. The 24 fields listed in the survey were grouped into the eight categories shown in Table 3, and fall into three broad areas: scientific research careers, clinical careers, and other areas. Scientific research careers and clinical careers together represent the biomedical professions.

Table 2. Characteristics of respondents and nonrespondents

	Total sample, %	Respondents, %	Nonrespondents, %
Total, *n*	322	201	120
Female	68	71	63
African American/African	17	18	14
Native American	4	4	3
Asian American/Pacific Islander	8	7	11
Filipino/a	15	18	10
Latino/a	18	17	21
Mexican American/Chicano/a	37	35	39
White	.3	1	0
Other	1	2	.8
Graduated 1992–1996	21	17	26
Graduated 1997–2001	46	47	43
Graduated 2002–2004	34	36	31
Graduated w/biology major ($p < 0.01$)	66	72	56
Mean UCD GPA ($p < 0.001$)	3.1	3.2	3.0

Percentages of respondents and nonrespondents reflect the overall enrollment in BUSP throughout the last 20 yr. There was no significant difference in the proportion of racial or ethnic groups among respondents and nonrespondents. This analysis represents completed surveys only; one survey was partially completed and excluded from the analysis.

Most BUSP alumni were considering multiple career options when they entered college: the mean number of career interests at college entry was three.[3] Only about one-third of all survey respondents were initially focused on a single career.

The top career choice at college entry was physician (n = 138). The small number of aspiring veterinarians (n = 14) was combined with physicians to create the category "medical doctor" and was selected by approximately 75% of respondents as a possible career at college entry. We elected to combine the aspiring veterinarians with physicians rather than with allied health doctorates for several reasons. First, some students selected both physician and veterinarian as possible career choices at college entry. Second, there were strong similarities in the decision-making processes used by the two groups. The majority of physicians and veterinarians identified their future careers early in life (before entering college), were highly focused on achieving that goal, and expressed strong altruistic values. In contrast, most of the allied health doctorates made their decision during college, based largely on practical considerations, and they were considering many other career options when they entered college.

Scientific research was the second most common ICI: 96, or almost half of the entire respondent pool, reported an interest in scientific research. Seventy percent (n = 68) of those expressing an interest in research had a dual interest in medical doctor and scientific research. Altogether, 90% of BUSP alumni respondents had an interest in careers as a medical doctor and/or in scientific research when they entered college. The remaining 10% were interested in allied health careers, such as pharmacy, dentistry, and nursing, and a variety of other careers.

[3] Respondents were asked to check all "the field(s) you were interested in when you entered college" without indicating rank order or preference. This was a limitation of the data collection software we used for the study, which did not have the capacity to simultaneously rank-order two columns of multiple-response items. However, this issue was partially resolved in the follow-up interview (n =106) by asking respondents with multiple ICIs about their primary career interest.

Role of Enrichment Experiences in Supporting Undergraduate Achievement

Survey respondents were asked to think back to their BUSP experiences and rate the importance of three different program components to their academic success: supplemental instruction, advising, and undergraduate research. ("To the

Table 3. Career goal categories

Career category	Definition
Scientific research career	
Biomedical Ph.D.	Biomedical researchers at the Ph.D. level, including professors
Biomedical technician	Biomedical researcher, not doctoral level
Clinical career	
Medical doctor	M.D., D.O. (osteopathy), D.V.M. (veterinary medicine)
Allied health doctorates	D.D.S. (dentistry), PharmD (pharmacy), O.D. (optometry), Doctor of Nursing
Other allied health workers	Nurses, nurse practitioners, physical therapists, public health professionals
Other careers	
Other Ph.D.s	Ph.D. researchers in other areas
Other	All other careers, not doctoral level, including K–12 teaching
Undecided	Selected "undecided" and/or three or more unrelated fields

The 24 career choices listed in the survey were grouped into eight categories, falling into three broad areas: scientific research careers, clinical careers, and other careers.

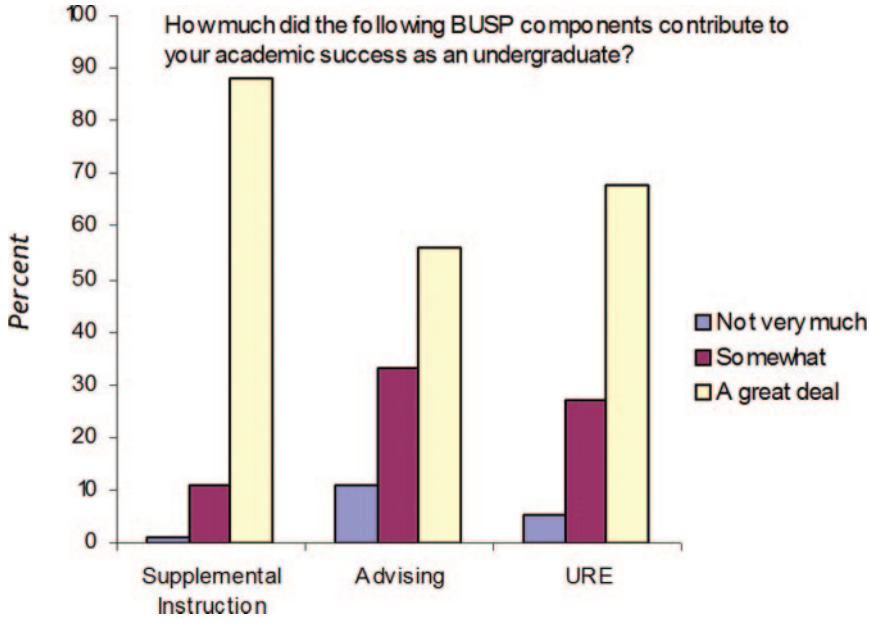

Figure 2. Contribution of BUSP components to academic success.

best of your recollection, how much did each of the following BUSP components contribute to your academic success as an undergraduate student?).

Supplemental Instruction. A first step toward the achievement of students' career goals is the successful completion of college academic course work. Supplemental instruction in mathematics and chemistry received the strongest endorsement, with nearly 90% of respondents attributing "a great deal" of value to that intervention, underscoring the importance to the student of getting off to a strong academic start in college (Figure 2). Alumni perceptions were matched by the actual record of BUSP student accomplishment in foundation courses, as shown in Table 1 (Villarejo and Barlow, 2007).

Advising. Alumni were asked in closed-ended questions whether anyone associated with the university provided advice or encouragement during their undergraduate years and, if so, to identify the roles of those individuals. Ninety-six percent of respondents indicated that they received advice or encouragement from multiple sources during their undergraduate careers (Table 4). Interaction with a BUSP adviser was the most frequently cited (80%), but faculty contact was next, with research directors and other professors each providing advice and encouragement to 49% of respondents. Students who participated in research had access to a richer array of advising experiences than other program alumni, interacting with research directors, graduate students, postdocs and lab technicians. As a result, those who participated in UREs reported an average of three sources of advice or encouragement, compared with two for nonresearchers ($p < 0.001$).

These results were extended through an open-ended query to describe how "that person (or people) advised or encouraged you." Thirty-eight percent of alumni explained that they received emotional support, including confidence-building and dealing with stress (often related to being part of a minority group on campus); 35% received academic advice on course selection, scheduling, and choice of major; 34% cited career counseling; and 11% received academic support in terms of tutoring or study techniques.

Undergraduate Research Experiences. The majority of survey respondents (85%) participated in URE, some in multiple settings (Table 5). The majority commenced their URE during the first or second undergraduate year, with only a handful (n = 12) beginning research after the second year of college. Although fewer females did research than males (82% vs. 90% of males), the difference was not statistically significant. However, males were more likely to report that research influenced their career choice (77% of males vs. 61% of females), and that difference was significant ($p < 0.05$).

When asked "how much did (undergraduate research) contribute to your academic success as an undergraduate student?" 67% of URE participants reported that undergraduate research contributed a great deal to their academic success. Eighty-eight percent of respondents gave their URE an overall rating that was positive—either "very positive" or "somewhat positive." However, respondents who elected to follow different career paths had different levels of enthusiasm when looking back at their undergraduate research experience. Table 5 shows that those who ultimately chose doctoral-level research were nearly overwhelming in their evaluation of their research as a "very positive" experience ($p < 0.01$). Only ~60% of physicians and other allied health doctorates were as positive about their experience, compared with 50% or fewer of those in other career categories.

Respondents were also largely positive about the value of URE to increase their understanding of science concepts being taught in the classroom, with ~40% crediting the research experience with helping a great deal and 40% stating that it helped somewhat. In addition to specific science knowledge and skills, open-ended comments confirmed our finding that the research environment granted access to additional sources

Table 4. Sources of advice or encouragement for research participants

Source	n	%
BUSP adviser	156	80
Research director	96	49
Professor (nonresearch)	96	49
Non-BUSP staff advisor	79	41
Graduate student	55	28
Teaching assistant	38	20
Laboratory technician	32	16
Postdoctoral fellow	24	12
Someone else	13	7

BUSP participants received advice from a number of different sources. Students who participated in research reported an average of three sources of advice, compared with two for nonresearchers ($p = 0.005$).

of advice and encouragement, and also provided a "sense of belonging" to URE participants (Hurtado and Carter, 1997). Responses to an open-ended question asking "How did your undergraduate research experience influence your career choice?" supported these perceptions of the positive nature of the research experience, particularly for the biomedical researchers at the doctoral level. Seventy-five percent (n = 15) of biomedical Ph.D. aspirants noted that their URE influenced them to stay in science, and 60% (n = 12) felt that the experience motivated them specifically toward a career in research. One remarked that he had initially intended to pursue a medical degree but found research "more rewarding." In contrast, 16% (n = 27) of respondents who participated in research felt that research was simply not a good fit, citing a need for more personal interaction or a preference for a different work environment. A small number (n = 4) credited the URE with solidifying their decision to leave science for other fields.

Persistence in Biology Majors. Completion of an undergraduate biology major is key to entrance into a biology career. Within our sample, 72% persisted in biology majors to graduation, a high rate compared with the campus average of ~40% (Villarejo and Barlow, 2007). Both persistence to graduation in a biology major and college grades were strongly associated with high school achievement measures, as has been found in previous studies (Barlow and Villarejo, 2004; Villarejo and Barlow, 2007). Graduates in biology had statistically higher high school GPAs and math SAT scores than graduates who left biology (each $p < 0.01$), even within our sample chosen for the potential for admission to graduate and professional degree programs. All three high school achievement measures (math and verbal SAT scores and GPA) were positively associated with cumulative GPA at college graduation ($p < 0.001$) and college graduation in a biology major with a GPA ≥ 3.0 ($p < 0.01$).

Socioeconomic status had limited direct influence on the undergraduate achievement and persistence of this select

Table 5. Participant evaluation of the influence of undergraduate research experience

	Biomedical Ph.D.s	Medical doctors	Allied health doctorates	Other allied health workers	Biomedical technician	Other fields	Other doctorates	Undecided	Total
					% (n)				
Participated in research	100 (24)	96 (63)	64 (9)	62 (13)	93 (13)	76 (32)	82 (9)	89 (8)	85 (171)
Which of the following phrases best describes your undergraduate research experience(s)?									
Very positive ($p < 0.01$)	96	58	66	31	46	44	56	38	57
Somewhat positive	4	34	22	31	31	44	44	38	31
Neutral	0	5	0	39	8	13	0	25	9
Somewhat negative	0	2	11	0	15	0	0	0	2
Very negative	0	2	0	0	0	0	0	0	1
Did your research experience(s) influence your MAJOR choice in any way? Yes	63	40	33	15	31	34	56	63	41
Did your research experience(s) influence your CAREER choice in any way? Yes	83	66	38	69	62	59	56	88	66
How much did your research experience(s) help you understand concepts from your science coursework?									
A great deal	58	39	63	23	31	39	22	25	40
Somewhat	33	41	25	54	31	39	33	50	39
Not very much	8	18	13	15	39	13	44	25	19
Not at all	0	2	0	8	8	10	0	0	3

Respondents were highly positive about how much the URE contributed to their academic success and helped to increase their understanding of classroom concepts. Because of the small number and distribution of responses across the answer categories, chi-square analysis was performed using a dichotomous coding of "very positive" versus all other response categories.

group of college graduates. Those with >$10,000 in debt (our proxy for economic disadvantage) graduated with statistically lower cumulative GPAs than those with less debt (3.1 vs. 3.3; $p < 0.01$). Similarly, only 39% of those with the higher debt level graduated with a biology degree and a GPA ≥3.0, compared with 58% of those with more modest debt loads ($p < 0.05$).

Socioeconomic measures indirectly influenced college outcomes through their impact on the precursor of college success: academic preparation. Minority race/ethnicity, college indebtedness >$10,000, and being the first generation to graduate from college were each statistically associated with lower math SAT scores and lower high school GPAs (each $p < 0.01$ or less). Last, females entered college with higher verbal SAT scores than their male counterparts ($p < 0.05$), although this advantage did not translate into a significant difference at college graduation with regard to graduation major or cumulative GPA.

Career Path Analysis

The BUSP-NIH Career Paths Survey allowed us to describe the trajectories that students followed as their career interests developed during college and beyond. These data allowed us to determine to what extent our working model of the career development process (Figure 1) helped us to understand their ultimate career choices.

Ultimate Career Goals

Overall, 70% of alumni respondents expected to follow a career in the biomedical professions (n = 139). Of these, roughly three-quarters (n = 101) selected a clinical profession, with 66 electing a career as a medical doctor. Only one of every five respondents reported choosing a science research career (n = 38); two-thirds of these researchers were at the doctoral level (n = 24; Table 6). In the following sections, we map the evolution of respondents' career goals and address the question of why such a modest proportion of high-achieving alumni chose research careers.

Relation of Career Goals to Major Field of Study

Predictably, the choice of an ultimate career goal within the biomedical sciences is closely associated with the completion of a biology major ($p < 0.001$; Table 6). All biomedical Ph.D.s graduated with biology majors, as did nearly all biomedical technicians. There is also a very strong relationship between choice of doctoral-level clinical fields and graduation in biology majors: All of the allied health doctors and 88% of the medical doctors also graduated with a biology major (Table 6).

Many of those who ultimately moved away from biology-based careers into other fields (including those who moved into nonbiology Ph.D.s), made their choice during their college years and changed their majors to other fields. One-third of the "other field" category (n = 15) chose to be educators, the majority of whom teach either primary grades or secondary school science.

Paths to Biomedical Research Careers

Biomedical Ph.D.s. Our survey data allowed us to explore the development, maintenance, or loss of interest in scientific research careers. About half of the alumni planning to go on to biomedical Ph.D.s discovered their interest in science research after entering college. Of the 24 individuals who ultimately selected biomedical Ph.D. as their career goal, only 13 had considered research as a possible career choice at college entry (Figure 3), and only five among that group had identified research as their primary or only career interest at that time.

The group of alumni pursuing biomedical Ph.D.s was very strong academically: They had the highest levels of achievement in high school and also had the highest average college GPA of any group of alumni respondents (Table 6). All biomedical Ph.D.s participated in research during their undergraduate careers, and 96% described their URE as "very positive" (Table 5). Eighty-three percent reported that their URE had influenced their career choice: A majority reported that the experience was an impetus to stay in science, pursue a research career, and/or go on to graduate school.

The URE was particularly influential for the biomedical Ph.D.s because it allowed the members of this group to discover how much they enjoyed conducting research, which was a major motivation to attend graduate school. In some cases, the research experience helped students select or

Table 6. Graduation outcomes and ultimate career goals

	Biomedical Ph.D.	Medical doctor	Allied health doctorate	Other allied health worker	Biomedical technician	Other field	Other Ph.D.s	Undecided	Total (n)	Total %
Graduated in a biology major ($p = 0.001$) (%)	100	88	100	67	93	43	9	33	145	72
Graduated in a biology major/GPA ≥3.0 ($p = 0.01$) (%)	79	64	86	38	57	21	9	33	102	51
Cumulative UCD GPA ($p = 0.01$)	3.36	3.28	3.30	3.04	3.09	3.07	3.22	3.24	3.20	
Total (*n*)	*24*	*66*	*14*	*21*	*14*	*42*	*11*	*9*	*201*	100%

The choice of a biomedical career is strongly associated with completing a biology major. All biomedical Ph.D.s and allied health doctors and most of the biomedical technicians graduated with biology majors. The relatively lower GPA of the biomedical technicians and those in the other field could have been a limiting factor for applying to graduate school.

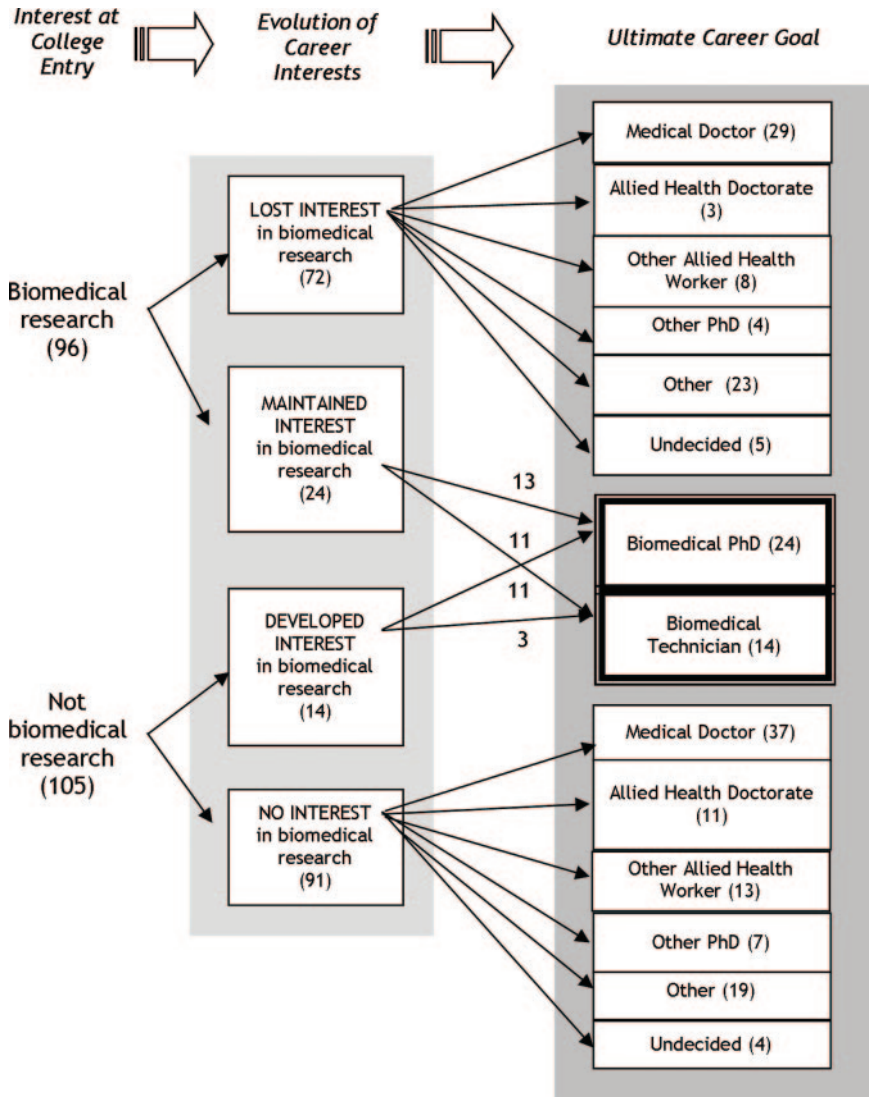

Figure 3. Evolution of interest in biomedical research during the undergraduate years.

solidify interest in a specific field within science, which they subsequently pursued in graduate-level training.

Nearly half of the alumni who ultimately decided to pursue biomedical Ph.D.s had started their college careers with a different, singular goal: to be a medical doctor. Some of these students may have initially chosen to do research simply as a strategy to increase their competitiveness for medical school. However, for others, the URE revealed career options they had not considered previously; subsequently, these individuals changed their career trajectories. The transformation of this group from aspiring medical doctors to researchers makes the strongest case for exposing a broad range of undergraduates to science research.

Biomedical Technicians. Of the 14 respondents who opted for research careers as biomedical technicians, 11 had been interested in research careers at college entry, and three discovered that career interest later (Figure 3). The technicians were similar to the Ph.D.s in having high rates of persistence in biology majors (93%) and research participation (93%). They differ from the Ph.D.s in two main respects. First, they had a lower average college GPA (3.09 vs. 3.36; $p < 0.05$). Second, only 57% of technicians graduated with a GPA $\geq$3.0, compared with 79% of the Ph.D.s, so fewer would have been highly qualified candidates for graduate school. Also, in contrast to many of their Ph.D.-bound colleagues who report that their intellectual curiosity was piqued through the URE, nondoctoral-level biomedical researchers tended to value the research experience for the practical skills they gained and for its resume-building attributes.

Paths Away from Biomedical Research

An additional 72 individuals who had indicated an interest in research as at least one possible career choice among several at college entry had decided against that path by the time they were surveyed as alumni. Medicine had attracted 29 respondents, 11 changed to allied health fields, four selected other doctoral fields, 23 switched to a host of other

fields, and five were undecided (Figure 3). Twenty-six of the 29 who elected medical doctor careers had dual interests in research and medicine at college entry. Some are planning to continue this dual interest through involvement in clinical research or academic medicine. For many, the URE helped them to decide that a research career was not a good fit for their personality, talents, or values. Many cited a need for more interpersonal interaction or a desire to help others in a more direct manner. Although the URE showed many of these individuals that research was not an attractive career for them, the majority felt that their research experience was positive, helping them to understand how research fits within the world of science careers, and promoting the development of valuable technical and analytical skills.

Paths to Clinical Careers

Medical Doctors. Figure 3 shows that the most popular career option considered by these high-achieving BUSP alumni when they entered college was medical doctor (n = 152). Among the 134 aspiring physicians, 69% were female, essentially equal to the proportion of women in our sample. Women were somewhat overrepresented among aspiring veterinarians at 84%. However, by the time our alumni had identified their ultimate career goals, the percentage of females was 63% for both physicians and veterinarians.

Of the 66 survey respondents expecting to become medical doctors, 89% had entered college with that goal, and two-thirds of that group reported that medical doctor was their sole or primary interest at college entry. The early commitment to medicine reflects a high level of precollege awareness of this career and is in marked contrast to the pattern for biomedical Ph.D.s, only about half of whom had even identified the field as a possibility at college entry.

Medical doctors reflected on the perceived rewards of their chosen career, and the fact that practicing medicine was somehow consistent with their value system, frequently expressed as a desire to help people or animals. Physicians mentioned that their volunteer experiences in primary care clinics further underscored their pre-existing commitments to medicine by providing an opportunity to experience patient care firsthand. Five aspiring medical doctors noted the financial and social rewards associated with being a medical doctor, but these rewards were secondary to stronger motivating factors such as the desire to help people and a strong interest in science.

BUSP experiences facilitated the career choices of this group. The medical doctors had a high research participation rate (96%), and two-thirds reported that URE influenced their career choice (Table 5). Among the 40 medical doctors who expanded on the influences of the URE to their career choice in open-ended responses, 24 reported that URE influenced them toward science and research, and 11 reported that the experience pushed them away from future research involvement. Four of the latter group specifically articulated a desire for more interpersonal interaction. Six medical doctors whose research experiences revealed a poor fit with their personalities and/or interests expressed the view that the experience itself gave them a newfound appreciation for science or the work of researchers or that it put their classroom science into perspective. Medical doctors who credited their URE as moving them toward research nearly always referenced some sort of health-related or clinical research. For some members of this group, the URE connected a passion for medicine with research and sparked an interest in academic medicine. Last, a large number of the medical doctors reported that their direct experience with BUSP advisors and mentors provided the tools and encouragement necessary to succeed in their undergraduate courses, without which they would never have been able to embark on their chosen career path in the first place.

Allied Health Doctorates. This UCG category is mostly composed of pharmacists and dentists. All members of this group were female and highly qualified for graduate study in biology: Each graduated with a major in biology and the group GPA averaged 3.30. Eighty-six percent attained or exceeded the general 3.0 threshold GPA for admission to graduate or professional school, the highest of any UCG group (Table 6). These respondents could easily have gained admission to Ph.D. or M.D. programs, yet other factors led them to choose other careers. Many were strongly influenced by family members, peers, counselors, and mentors to pursue their particular career. Practical and lifestyle considerations such as job availability and location, salary, perceived compatibility with parenting demands, and desire for recreational time also were driving factors.

Although they were all biology majors, only 64% (n = 9) of allied health doctorates participated in a URE, compared with nearly universal participation by the biomedical Ph.D.s and medical doctors. Among those who did research, only 38% said that the URE influenced their career choice in any way, the lowest level of URE influence on career choice of any group. In most cases, the URE encouraged the participant to stay in science, albeit in a clinical area, or fostered an appreciation for research studies.

Other Allied Health Workers. Alumni who opted to pursue other allied health professions such as nursing were most like medical doctors in their motivation to serve others; this is not surprising given that two-thirds of this group had been interested in careers as medical doctors at college entry. However, their average GPA of only 3.04, and the associated fact that only 38% graduated with a biology degree and a GPA $\geq$3.0 indicates that many would not have been competitive candidates for medical school admission (Table 6). In other cases, respondents with competitive GPAs made an active choice to follow another path in the health care field rather than becoming a physician. Family concerns were foremost in this area, likely because of the 95% female sex composition of the group.

Other allied health workers had the lowest level of research participation of any group, only 62%. When asked to explain "Why did you choose not to participate in research?" nonparticipants explained that they lacked interest in laboratory work or wanted to spend more time in clinical internships. Many who did participate in a URE found that research was just not a good fit for them, even though they may have gained an increased appreciation for research or learned useful skills applicable in other contexts.

Paths Away from Biomedical Science

Other Ph.D.s. The 11 members of the group who chose a doctoral level career outside the biomedical sciences reacted

positively to the idea of continuing in research, but re-evaluated their particular field of interest during college or later. All members of this group who participated in UREs described their experience as positive. In the words of one respondent: "I learned to appreciate the process of doing science rather than just reading, attending classes and taking exams. I just decided I wanted to do science in a different field. I'm in a Ph.D. program still intending to stay on a research/teaching university …" Instructors or mentors in college were frequently the source of inspiration for members of this group.

Other Careers. This heterogeneous group has at its core 15 pre-college educators. These educators were highly focused on working directly with people and helping others, particularly children, to learn. The realization that teaching is something they can do well seemed to be a key discovery for many—several began college with the intention of a career in medicine and shifted their interest along the way. Importantly, the research experience was not the catalyst for this discovery, despite the fact that approximately half of the K–12 educators in this sample graduated in biology majors and some are now teaching biology in secondary school. Instead, teachers reported that it was actual teaching or tutoring experience during undergraduate years that sparked their interest in teaching. The science educators within this group reported that the URE informs their current teaching practices as they explain scientific concepts and/or processes to their students.

Hypothetical Attitudes toward a Career as a Biomedical Ph.D.

Respondent values and interests underlie the entire career decision-making process as depicted in the model in Figure 1. Although a substantial number expressed an initial interest in research, or tried it out through URE only a small number settled on Ph.D.-level research as their chosen career. To elicit more information about respondent attitudes and motivations that might shape the decision to pursue doctoral-level careers in biomedical research, we developed a set of hypothetical attributes that might make such a career appealing or unappealing (Cole and Barber, 2003). Respondents were asked to select from a list those attributes that would make a career as a Ph.D. scientific researcher appealing or unappealing, whether or not they had ever considered a career as a Ph.D. scientific researcher.

The attributes with greatest appeal to our alumni arose from interest in science and satisfaction derived from doing research (63% each) and desire to serve the community and mentor minority undergraduates (66 and 62%, respectively; Table 7). Secondary factors were the opportunity to teach undergraduates and have graduate education paid for (48 and 46%). Only 30% of respondents were attracted by the salaries of researchers and 27% by the respect accorded to scientists. There were strong similarities across UCG groups in their ranking of the appeal of these positive attributes, with a few exceptions. Although medical doctors largely agreed with biomedical Ph.D.s and biomedical technicians that "science is really interesting to me" (76, 88, and 86%, respectively), medical doctors were somewhat less attracted by the idea of doing research than biomedical Ph.D.s (only 61% would get satisfaction from doing research, compared with 92% of the biomedical Ph.D.s ($p < 0.05$). Only 29% of alumni pursuing allied health doctorates agreed that it would be satisfying to do research.

The primary factors that make a scientific career unappealing to the alumni group as a whole are practical considerations: They ranked the perceived difficulty of getting a good job, with good pay, in a reasonable amount of time as the three most important factors that make a research career unappealing (43, 37, and 42% respectively; Table 8). Difficulties balancing family concerns—the desire to accommodate childbearing and rearing and to stay in physical proximity to an extended family—were perceived as negative attributes of science research careers by 33 and 28% of respondents, respectively.

There were large differences across UCG groups in their ranking of these negative attributes, in sharp contrast to their similar responses to attributes that would make a scientific career appealing. For example, 73% of allied health doctorates responded that "Getting a Ph.D. takes too long," far more than any other UCG category. That perception is not unreasonable. The average time in professional school for the allied health doctorates in our study was only 4.3 yr, compared with 7.2 yr for the biomedical Ph.D.s. The biomedical Ph.D.s themselves do not seem to find this daunting; only 17% expressed concern about the length of graduate study. In contrast, 64% of biomedical technicians agreed with the statement that getting a Ph.D. takes too long ($p < 0.05$).

The biomedical Ph.D.s seemed to be acutely aware of other negative attributes of their chosen career. Seventy-one percent agreed that other jobs offer greater financial rewards and 58% were concerned with the difficulty in getting a decent job. Apparently, these very real concerns were outweighed by their interest in science and love of research.

A focus on childrearing was also unevenly distributed among the UCG groups and was strongly associated with the sex composition of the UCG group. Fifty percent of allied health doctorates and 57% of other allied health workers responded that "Other careers could better accommodate my plans for raising a family," compared with only 25% of biomedical Ph.D.s ($p < 0.05$). Because the sex composition of the allied health group was almost entirely female, it suggests that the duration of postgraduate education and a desire to enter family-friendly careers were particularly acute concerns for women planning their workforce entry. However, there were no statistically significant sex differences among the group of respondents as a whole on this attribute: Overall, this component was considered an unappealing attribute of scientific careers by 36% of males and 32% of females.

Other factors rendering a scientific career appealing or unappealing did differ by sex. Females were more likely to view the opportunity to mentor minority students as appealing (68 vs. 49%; $p < 0.05$), whereas males were more likely to find a scientific career appealing because of the intrinsic attraction of science ("science is really interesting to me"): 73% of males and 58% of females cited the appeal of this attribute ($p < 0.05$).

These attributes were also valued differently by members of different demographic groups. First-generation college

Table 7. Hypothetical attributes that would make a scientific research career APPEALING

Which of the following statements would make a career as a Ph.D. scientific researcher APPEALING to you—whether or not you have ever considered it as a career? (Select all that apply)	Biomedical Ph.D.s	Medical doctors	Allied health doctorates	Other allied health workers	Biomedical technicians	Other field	Other doctorates	Undecided	Total
					%				
• The scientific knowledge I create will help members of my community	63	76	57	57	79	55	64	67	66
• Science is really interesting to me ($p = 0.015$)	88	76	50	62	86	36	55	22	63
• I would have the opportunity to mentor minority students	58	61	71	62	50	74	46	67	63
• I would get satisfaction from doing research	92	61	29	52	79	55	82	44	62
• I would have the opportunity to teach undergraduates	58	50	50	57	36	38	64	22	48
• They pay for your education in graduate school	58	41	36	57	57	41	36	67	46
• Ph.D. scientific researchers can make a decent living	33	38	21	14	29	31	27	22	30
• Other people respect the work of Ph.D. scientific researchers ($p = 0.063$)	42	18	14	24	43	26	55	22	27
Total, *n*	24	66	14	21	14	42	11	9	201

The most appealing attributes of research careers arise out of an interest in science and a sense of satisfaction from doing research. There are similarities across career groups in their ranking of the appeal of these positive attributes, with the exception of medical doctors who are less attracted to doing research than biomedical Ph.D.s. Allied health doctors were the least interested in research.

graduates were more concerned with some of the negative practical considerations than respondents who had at least one parent with a 4-yr degree. First-generation graduates were more likely to think that scientific researchers do not make a decent living (37% vs. 24%; $p < 0.05$) and were concerned about being too much in debt to consider a Ph.D. (26 vs. 13%; $p < 0.05$). First-generation students who graduated with $10,000 or more debt were more than twice as likely as those with less debt to report being too much in debt to get a Ph.D. (36 vs. 16%; $p < 0.05$).

DISCUSSION AND CONCLUSIONS

The Career Path Survey of high-achieving alumni of the BUSP has provided useful insight into the attitudes and experiences that may influence minority undergraduate students in their choice of career and has enhanced our understanding of how a targeted support program can expand the pool of students positioned to pursue careers in biology-based professions.

Early recruitment and enrichment strategies, including supplementary instruction, undergraduate research opportunities, creation of a supportive peer community, and interaction with faculty and other mentors, have been shown to increase the proportion of underrepresented minorities who complete college with science majors (Barlow and Villarejo, 2004; Nagda *et al*., 1998). Graduation with a science major is an important step to a biology-based doctoral degree and is all but required for careers in biomedical research. Our alumni selected supplemental instruction as the most important component of BUSP enrichment activities in promoting academic success. This provides subjective confirmation to earlier analyses showing that supplemental instruction is associated with significantly higher grades in the target courses (Rath *et al*., 2007; Villarejo and Barlow, 2007). The key role played by supplemental instruction in supporting academic success deserves more attention in the design of intervention programs to increase the proportion of underrepresented students who are prepared to pursue science careers.

Undergraduate science research influences career exploration and career choice for a broad range of students. In our study, many students reported that research experience increased commitment to science in general, created awareness of areas of science that were previously unknown, and enhanced understanding and appreciation of the research process. It also helped students explore different options for working in the sciences. But, can the URE result in an actual change in career trajectory?

A major study of summer research programs for rising seniors at four elite liberal arts colleges suggests that URE does not alter career path. In that case, and in most others cited in that study's thoughtful review of the literature, the research experience served to "clarify, confirm and refine" career choices, but no evidence could be found to support the claim that it actually redirected students into a research career path (Seymour *et al*., 2004). The undergraduates stud-

Table 8. Hypothetical attributes that would make a scientific research career UNAPPEALING

Which of the following statements would make a career as a Ph.D. scientific researcher UNAPPEALING to you—whether or not you have ever considered it as a career? (Select all that apply)	Biomedical Ph.D.s	Medical doctors	Allied health doctorates	Other allied health workers	Biomedical technicians	Other field	Other doctorates	Undecided	Total
					%				
• It is hard to get a decent job as a Ph.D. scientific researcher	58	46	29	52	50	36	18	33	43
• Getting a Ph.D. takes too long ($p < 0.001$)	16	33	72	52	64	48	27	67	42
• Other jobs offer greater financial rewards ($p = 0.009$)	71	31	57	29	50	31	18	11	37
• Other careers could better accommodate my plans for raising a family ($p = 0.020$)	25	21	50	57	36	33	36	44	33
• I might have to move away from my family to find a job	17	29	27	33	36	33	58	33	28
• Other careers contribute more to the public good	13	24	0	33	14	31	27	22	23
• I am too much in debt to consider getting a Ph.D.	8	17	22	19	36	24	18	22	20
• Other careers have more prestige	8	8	14	5	14	2	0	0	7
Total, *n*	24	66	14	21	14	42	11	9	201

Practical considerations are the primary factors that make a scientific career unappealing to the group as a whole. The perceived difficulty of getting a good job with good pay in a reasonable amount of time are the three most important factors that make a research career unappealing.

ied by Seymour *et al*. (2004) were largely white, ~60% male, middle class, and perhaps most importantly only 1 yr from college graduation when they participated in undergraduate research.

In contrast, our results demonstrate that for a small subset of respondents (n = 11), the URE was indeed transformative. These alumni entered college as premedical students, but were swayed by the URE to change career path and pursue a biomedical Ph.D. rather than attend medical school. However, there are important differences between the population studied by Seymour *et al*. (2004) and ours. Our population consists largely of underrepresented minority students, two-thirds female, attending a public university, half of whom are the first generation to complete a 4-yr college degree. Few of our students had selected science research as a singular focus at college entry. Subsequent interviews indicated that many were simply unaware of research career options at that time. Because of their membership in BUSP, they had the opportunity to begin research early in their undergraduate years and to do research both in the summer and during the academic year.

There are two other studies that also present evidence to substantiate the claim that URE can successfully recruit students into science research careers: Both are evaluations of programs targeting students of color from undergraduate institutions without substantial research resources "who are the least likely to have prior graduate school knowledge or aspirations" and invite them to participate in a summer research experience at a large research university (Alexander *et al*., 1998; Foertsch *et al*., 2000). In those two studies, as in ours, some students credit the URE with awakening interest in entirely new career possibilities. Also, a recent large survey showed that URE had the greatest effects on Hispanics and the least on non-Hispanic whites, although the differences across groups were small (Russell, 2006). However, this last study did not consider the precollege educational backgrounds of the students or their parents. From our results, we would expect that the impact of URE would be greatest on first-generation minority college students. The results presented here support the idea expounded by Seymour *et al*. (2004) that those who are least likely to have prior graduate school knowledge or aspirations, whether due to cultural or class backgrounds, are indeed the ones most likely to be inspired by a URE.

Those who opted for biomedical science at the nondoctoral level were also motivated by their URE to pursue science research. However, their comments reflected a more instrumental attitude toward scientific research: a job that pays the bills. Some open-ended comments of technicians indicate that high college debt was a significant deterrent to pursuing the Ph.D.

Respondent sex is significantly associated with career choices of BUSP alumni. Women make up slightly more than half of the biomedical Ph.D.s but are heavily overrepresented in the allied health fields. Female dominance among nondoctoral allied health workers is not unexpected, because this group is primarily composed of nurses and nurse practitioners, traditionally female professions. It is

more surprising that 100% of the dentists and pharmacists in the allied health doctorates group are female. The practical concerns expressed by the allied health doctors, many of whom were academically well qualified for biomedical research careers, may be related to the female deficit found at the highest levels of biomedical research (Huang, 2000). This group found careers as Ph.D.-level biomedical researchers unattractive for a number of reasons, including poor financial rewards and possible lack of proximity to their families.

The most frequent career aspiration at college entry was the desire to become a physician, a profession that is highly visible and respected in the community. A medical career is widely perceived as a visible symbol of "giving back to the community," and altruism seems to be a powerful motivation for pursuing that choice. Students, particularly from families in which the parents had not completed college, also referred to the strong desire of their parents to have their children pursue a career as a physician or another medical professional (e.g., dentist, pharmacist) because of the prestige and financial security attached to these careers.

Partly because of the widespread appeal of medicine as an initial career choice and the competitive nature of admission to medical school, one common career path for individuals in this study was the path away from medicine. Experiences during and after college introduced some students to the attractions of new intellectual and career interests, and tested the academic mettle of still other would-be physicians and made them reassess whether they would be able to gain entry to this highly competitive field.

It is too simple, however, to view the ultimate career choices of highly qualified science undergraduates as the result of a competition to see who will succeed in getting into medical school. Individuals are attracted to and repelled from different career choices within science for very specific reasons. Respondents who chose to become biomedical Ph.D.s were motivated by interest in science (which they share with those who choose to become medical doctors and biomedical technicians) and by an affinity for the activity of doing scientific research (which they share with biomedical technicians).

One novel finding of this study that deserves attention is that many individuals who chose careers as biomedical Ph.D.s had serious misgivings about the practical disadvantages of their career choice, in terms of balancing work and family and the financial insecurity they see as endemic to a career as a science researcher. Although they persevered despite these concerns, the same characteristics repelled others. Future studies should explore the personal characteristics that allow some individuals to pursue research careers despite the obvious drawbacks.

Study Limitations

There are some obvious limitations in the design of this study. The first is the relatively small size of the respondent pool, which made it difficult to disaggregate the data and assess possible differences across groups that included very small numbers of respondents. Thus, we could make only limited comparisons between groups with different ultimate career goals, or between alumni at different points in their career development. Next, there are significant problems associated with retrospective studies, including issues of recall and reinterpretation. We asked alumni to remember detailed information from as many as 17 yr before the survey. Follow-up interviews with approximately half of the survey respondents provided some checks of reliability on initial and ultimate career goal measures.

The survey software used to deploy the Web survey also restricted the data we could collect. For example, it was not possible to rank-order career interests at college entry or ultimate career goals, nor was it feasible to collect information about advising experiences associated with each person who provided advice or support. Finally, the self-administered questionnaire is more prone to errors of interpretation than a well-designed and administered interview. We have used a two-stage survey-interview design to limit the extent of such errors, holding the more complex, process-oriented questions for the interview phase. This article reports only on the survey results.

Policy Implications

Our findings on career paths have clear implications for the design of intervention programs to promote doctoral-level biomedical research careers. Academic enrichment early in the college years supports students in attaining the level of academic excellence required for graduate or professional school success. Because many students discovered their interest in scientific research as a result of their UREs, intervention programs should be as inclusive as possible and give students the opportunity to "try on" the research role at a relatively early point in their undergraduate years. In particular, admission to the intervention program should not be restricted to those who already have an avowed interest in research careers. It should be noted that our suggested strategy for widening the pipeline is in tension with current patterns in undergraduate research participation. Most programs require that students wait until their junior or senior year to participate in URE, and access to URE opportunities is often targeted to high-achieving students as part of a competitive application process favoring those who have already selected the research route. Selection of a broader group of student participants and granting opportunities for research experience earlier in the undergraduate career are more likely to have the desired result of increasing the number of well-qualified minority research scientists.

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