
Faculty Should Consider Peer Review as a Means of Improving Students' Scientific Reasoning Skills

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The following article provides highlights of a larger body of work on the impact of peer review on undergraduate biology students' scientific reasoning, scientific writing and attitudes. Results suggest that undergraduates, even freshman can be effective peer reviewers and that peer review improves scientific writing, content knowledge, and scientific reasoning skills. Students report peer review to be a beneficial experience both within the course and in terms of helping them to develop as aspiring scientists. Science faculty are therefore encouraged to consider incorporating peer review as a regular part of instruction.

Introduction and Rationale

Despite large volumes of literature on the benefits of reformed curricula for improving student learning^{1, 2}, pedagogical revolution has been slow to occur in many higher education institutions. We suggest that this is due in part to the large time and/or resource investments required for faculty to adapt and incorporate innovative strategies. Many pedagogical innovations require unfamiliar technologies or methodologies e.g.³, and the common lack of pedagogical support for higher education faculty leaves many instructors to simply teach as they were taught^{4, 5}. Peer review is considered a productive learning experience for graduate students^{6, 7}, and we suggest that it is likely valuable and effective for improving undergraduates' scientific reasoning abilities, scientific writing, and attitudes regarding science as well.

There are several major motivations for including peer review in science classrooms. First, the ability to critique and evaluate the quality of scientific claims is an important scientific skill in and of itself, but, like other reasoning skills, it must be an explicit component of instruction and students must be given opportunities to practice and improve it as a skill. Second, understanding the role of peer review as a major accountability mechanism and source of credibility and integrity of science knowledge is critical to public confidence in science. Use of peer review in the classroom causes significant gains in undergraduates' knowledge of this critical function of peer review in the scientific community⁸. Third, using peer review allows instructors to incorporate more writing assignments without correspondingly increasing their grading load. Fourth, peer review improves content knowledge⁹, writing^{10, 11}, and, we hypothesize, scientific reasoning skills.

Peer review is not a new pedagogical technique for some science faculty and multiple online tools exist. For example, the *Calibrated Peer Review*TM system (<http://cpr.molsci.ucla.edu>) has been incorporated into over 4000 courses (including the authors') across a wide range of science disciplines¹². Other online peer review systems include Scaffolded Writing and Reviewing in the Discipline (SWORD) (<http://www.lrdc.pitt.edu/schunn/sword/index.html>) and Waypoint Outcomes which runs through Blackboard (www.subjectivemetrics.com). All these systems allow faculty to engage their students in peer review anonymously and outside of class time.

Regardless of the method of implementation, the central impact of peer review on the student can fall into one of two categories: formative feedback as a mechanism for learning, or summative grading. While both provide the benefits of engaging students in the evaluation of scientific thoughts and writing, we feel that formative feedback stimulates greater learning because students can apply new ideas gained from the experience directly and immediately. Contrary to many instructors' and students' initial concerns, previous research has shown that undergraduate peers can be valid and reliable reviewers¹³, regardless of academic strength¹⁴.

Student perceptions of Peer Review

The *Calibrated Peer Review*TM (CPR) system was used in Introductory Biology courses for majors at our institution and we measured its impact on students' writing, scientific reasoning and attitudes. Student attitudes were assessed using an anonymous online survey that was administered in several different biology classes over multiple semesters (total n = 1026 students). From the survey data, we know that an overwhelming majority of the students viewed their peer review

experience positively (Figure 1). Among other benefits, students reported that peer review improved their content knowledge, their scientific writing skills (generally as well as directly impacting the assignment at hand), and their critical thinking skills. Interestingly, a vast majority (85%, $n = 557$) agreed that even just the act of giving feedback was helpful to improving their own work because it stimulated self-assessment (see also ¹⁵). Lastly, students reported that the act of engaging in peer review provided a window into realistic scientific practice and contributed to their development as practicing scientists.

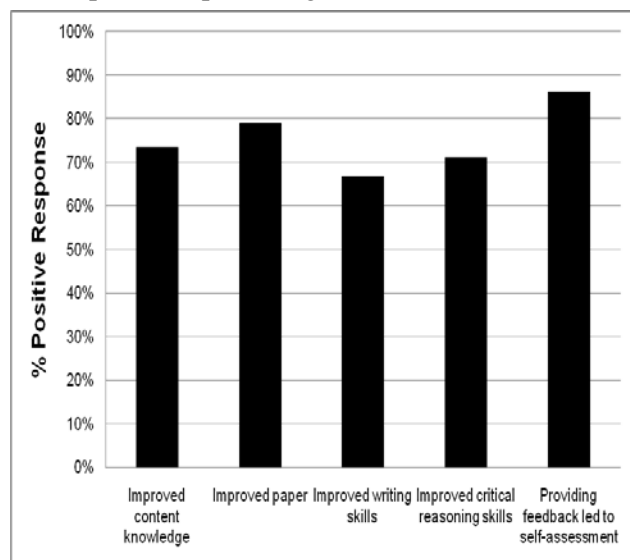


Figure 1. Student perceptions of the role and impact of peer review from surveys of three Introductory Biology courses for majors (total $n = 1026$ students, number of responses per item ranges from 440 to 998).

While many instructors are sensitive to student opinion, most are equally concerned with how much students are actually learning. Therefore, the effectiveness of the peer review experience was also measured directly using two different mechanisms of measurement: student papers and an independent objective (multiple choice) measure of scientific reasoning skill.

Effect of Peer Review on Student Scientific Writing

When we looked directly at the laboratory reports involved in the peer review process, we primarily wanted to know if peer review actually improved the papers. We found that peers were capable of providing multiple useful feedback items and when students made changes in their papers based on this peer feedback, scores on lab reports increased (Figure 2).

In our experience, two major factors contribute to the usefulness of formative peer feedback: explicit instruction about what constitutes

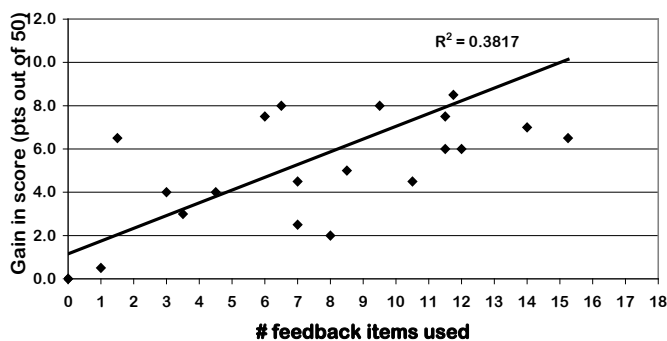


Figure 2. Effect of peer feedback on the quality of Introductory Biology lab reports. Gain is change in total score from draft to final version ($n = 22$ unique papers).

useful feedback, and student accountability to provide such feedback. A discussion of useful feedback was included in an explanation of the role of peer review in the scientific community and helped students focus on providing constructive criticism rather than making value judgements. A representative handout with feedback examples helped students to understand these criteria (Appendix 1), and help them to avoid overly positive or generic comments, neither of which is useful ^{16, 17}. Accountability can be ensured by including the review process in the grade for an assignment. One method we used was to randomly select one review per student to be quickly skimmed for useful feedback, resulting in a grade equivalent to a quiz. Therefore, with proper planning, freshman undergraduates have effectively engaged in peer review and used the resulting feedback to improve their scientific writing.

Next we were concerned with how peer review impacted students compared to those who did not engage in peer review. In order to compare performance across multiple classes, we developed the Universal Rubric for Science Writing. We subjected the Rubric to formal reliability testing using three science graduate student raters per paper across three different biology courses (total of 9 raters) and found it to be highly reliable (*generalizability coefficient* = 0.85 (Timmerman *et al* manuscript submitted)). When we compared lab reports from introductory biology courses (BIOL 101 and 102) that incorporated peer review with those from a course that did not use peer review (BIOL 301), students in the introductory biology course outperformed students in the upper level course on many of the scientific reasoning criteria (total $n = 142$ papers, ANOVA $p = 0.001$). In particular, freshman outperformed upperclassman in the areas of data selection, data presentation and use of primary literature despite the fact that students in the upper-level course had more

academic experience and a higher average institutional GPA.

Impact of Peer Review on Scientific Reasoning

For our second measure of the impact of peer review process on scientific reasoning skills we intentionally selected an assessment tool that used mostly physical science scenarios to ensure that results would not be influenced by students' prior biology course enrolment. Biology majors in five different biology courses (total $n = 581$ students), ranging from freshmen level to seniors, took the *Test of Scientific Reasoning*^{18,19}.

As expected, students' scores improved significantly as they gained academic experience (as measured by number of credit hours) with freshman scores averaging 4.89 (on a 12 point scale), seniors 6.07 and sophomores and juniors falling in between (ANOVA $p = 0.011$). When scores were categorized based on the number of peer review experiences in which a student had engaged however, freshman who had engaged in 2 peer review experiences scored significantly higher (average score = 6.82, $n = 61$) than students who did not engage in any peer review experiences (ave. = 5.22, $n = 260$) with students who engaged in a single peer review experience scoring intermediately (ANOVA $p = 0.000$).

Conclusions and Recommendations

Based on these results, we recommend that science faculty incorporate peer review into their courses. Peer review has been previously demonstrated to benefit graduate students⁸ and these results suggest that it benefits even freshman in large introductory courses. Peer review allows faculty to incorporate or increase student writing in their course (with all its associated benefits) without incurring significant costs in terms of time and effort. It improves scientific reasoning and writing because it provides three to four times the practice at writing and evaluating as well as increases formative feedback while decreasing instructor load. Additionally, students report it to be a worthwhile and productive experience and perceive it to be an important component of their development as future scientists. Based on our experiences of using peer review effectively, we provide the following recommendations to help other faculty incorporate peer review (Table 1).

Table 1. Summary of Recommendations for Implementing Peer Review.

- **Be explicit** in discussing with students the role of peer review in the scientific community as well as its benefits in the classroom.
- **Share research results** with students demonstrating that peers are effective reviewers and that peers can provide useful feedback that improves paper quality if incorporated (e.g. Figure 2).
- Design assignments to **encourage students to provide high quality written feedback**.
 - Explicitly define and discuss the characteristics of useful feedback (Appendix 1) and
 - Use accountability measures which reward students who make honest efforts at providing useful feedback.
- Design assignments to **align assignment criteria, peer review criteria and instructional goals**. Ideally, instructional goals span multiple courses and expectations for student performance are consistently aligned and developed throughout those educational experiences.
- **Make your expectations explicit** and explain the criteria for a writing assignment to students (e.g. Appendix 2). Better yet, use a rubric as a means of defining assignment criteria to students. Descriptions of what constitutes different levels of performance deepens student understanding of the intent of criteria and helps them to provide better feedback to peers as well as better understand the learning goals.

Acknowledgements

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Appendix 1: Student Handout

How to provide useful feedback

Useful feedback is:

- **specific and concrete,**
- **focuses on the quality** of the author's argument (e.g. are conclusions logical and supported by the evidence/data?) **rather than on the mechanics** of writing, (e.g. spelling or grammar),
- **identifies hidden or implicit assumptions or consequences** of author's ideas.
- tells the writer **why** you think they did or did not meet the criteria.
- In sum, useful feedback is likely to result in meaningful revisions or new content being added to the paper.

You will be prompted by the peer review website to provide feedback for three papers written by your peers. The criteria are the same as those in the assignment handout. Your TA will randomly select one of your reviews and grade the quality of the feedback you provide. Useful items earn 1 pt and partially useful items earn 0.5 pts. Non-useful feedback earn 0 points. A review may earn up to 10 points. You may write as many feedback items as you would like, but you must provide at least one piece of feedback in response to each prompt. Reviewing other students' papers may also give you insight into strengths and weaknesses in your own paper. The benefits you will receive from this exercise are directly correlated with the effort you put into it. Below are some examples of what constitutes useful feedback.

Examples:

Feedback item	Useful?	How to improve the feedback
1. Your paper is GREAT! How did you come up with your idea?	NO	Provides no information to the writer on how to improve the paper.
2. At the end of paragraph 2, you say you think this was a sex-linked cross. Is this your hypothesis? What traits do you think the parents had? Why do you think this is the best explanation?	Yes	Feedback has detail on where and why the reviewer was lost. If the writer answers the reviewer's questions, the paper will have a clearer statement of the hypothesis, consider alternative explanations and make a logical connection between hypotheses, data and conclusions.
3. Your argument makes no sense. What is your evidence?	Partially	Asking for evidence is useful, but reviewer does not indicate which part of the paper is confusing them or what exactly they don't understand.
4. Your argument depends on weight being an inherited trait. What evidence do you have to support this assumption?	Yes	The reviewer has identified an assumption made by the writer and pointed out how the validity or invalidity of this assumption could impact the writer's conclusion.
5. Which of your hypotheses is best supported by the data?	Partially	The reviewer is specific in indicating that the writer did something well (posed multiple explanations) but provides only a vague indication that the writer needs to discuss the data more without indicating how or where they felt the writer's conclusions were lacking.

Appendix 2: **Criteria used in the Universal Rubric for Science Writing.** Contact the authors for more information or for a full version of the rubric including descriptions of performance levels (novice to proficient) for each criterion. A scoring guide including examples of student work at each performance level for each criterion is also available upon request.

Introduction	Context Demonstrates a clear understanding of the big picture; Why is this question important/ interesting in the field of biology?
	Accuracy and relevance Content knowledge is accurate, relevant and provides appropriate background for reader including defining critical terms.
Hypotheses	Testable and consider alternatives Hypotheses are clearly stated, testable and consider plausible alternative explanations
	Scientific merit Hypotheses have scientific merit.
Methods	Controls and replication Appropriate controls (including appropriate replication) are present and explained.
	Experimental design Experimental design is likely to produce salient and fruitful results (actually tests the hypotheses posed.)
Results	Data selection Data chosen are comprehensive, accurate and relevant.
	Data presentation Data are summarized in a logical format. Table or graph types are appropriate. Data are properly labeled including units. Graph axes are appropriately labeled and scaled and captions are informative and complete.
	Statistical analysis Statistical analysis is appropriate for hypotheses tested and appears correctly performed and interpreted with relevant values reported and explained.
Discussion	Conclusions based on data selected Conclusion is clearly and logically drawn from data provided. A logical chain of reasoning from hypothesis to data to conclusions is clearly and persuasively explained. Conflicting data, if present, are adequately addressed.
	Alternative explanations Alternative explanations (hypotheses) are considered and clearly eliminated by data in a persuasive discussion.
	Limitations of design Limitations of the data and/or experimental design and corresponding implications for data interpretation and conclusions are discussed.
	Implications of research Paper gives a clear indication of the implications and direction of the research in the future.
Use of Primary Literature	<p>Primary Literature Writer provides a relevant and reasonably complete discussion of how this research project relates to others' work in the field (scientific context provided) using primary literature. Primary literature is defined as:</p> <ul style="list-style-type: none"> • peer reviewed • reports original data • authors are the people who collected the data. • Journal produced by a non-commercial scientific association
Writing Quality	Writing Quality Grammar, word usage and organization facilitate the reader's understanding of the paper.

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Improving Diversity in PhD Programs in the Biological Sciences at USC

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During the 1990s, approximately 19% of the undergraduate Biology majors at the University of South Carolina were African American. However, African Americans represented only 2-3% of the students pursuing PhD degrees in the biological or biomedical sciences. To correct this imbalance, USC initiated an effort to increase minority participation through focused recruiting and to increase funding opportunities for minority graduate students. A guiding principle has been that success breeds success.

Undergraduate Research

Undergraduate research is a critical component of science education because research is the primary enterprise of science. Unfortunately, many students complete high school thinking that science consists of learning new terms and memorizing irrelevant facts. When students participate in scientific research, they learn the true meaning of science. In addition, the laboratory environment is much like a family business where everyone helps each other to make the business successful. Therefore, it provides a nurturing support system that helps students from strong educational backgrounds thrive. However, for first generation college students, inclusion in a laboratory research group can be a lifeline. College can be intimidating if you do not know how the system works and you are out on your own for the first time. If you work in a laboratory, there is a place where you belong, a place where people care about you and show you how to be successful. It is a place where good work is rewarded with praise, and students discover the true nature of science. Thus, for many students participation in a laboratory research group can be a critical component that is important for academic success.

Hughes undergraduate research program

The Hughes undergraduate research program was initiated in 1993 with a grant from the Hughes Foundation to the USC Department of Biological Sciences to provide research opportunities for biology undergraduates. The program was so successful that when the grant ended, the university administration committed funds to make the program permanent. Since that time the program has been replicated in several other departments at USC, and the university has made undergraduate research a university-wide priority. In fact, USC has established an office of undergraduate research to promote undergraduate research participation throughout

USC. To enhance the prestige of undergraduate research, the Office of Undergraduate Research hosts Discovery Day where undergraduates present their research and compete for cash prizes. In addition, undergraduate students are encouraged to submit proposals for prestigious, university-funded Magellan grants to fund their research projects.

NSF Research Experiences for Undergraduates (REU)

Funding for an REU program in the biological sciences has been provided by the National Science Foundation since 1999. This program provides support to bring 12 undergraduates to USC from schools throughout the US for a nine-week intensive research experience. More than 100 students apply for this program each year, and approximately one third of the participants are minority students. The existence of the REU program also helps leverage funding for additional students since faculty can request support for undergraduate research stipends on their research grants and add students to the REU program. To date, five REU participants have returned to USC for their graduate work after completing their undergraduate degrees.

Research Access for Graduate Success (RAGS)

With funding from the National Institutes of Health (NIH), the USC Department of Biological Sciences initiated the RAGS program to provide funding for interested minority students to join research laboratories during their freshman or sophomore years. Traditionally, undergraduates have waited until they have completed their sophomore level core courses before joining a research laboratory. The RAGS program encourages early research participation so that the students can reap the benefits of belonging to a laboratory research group as soon as possible. To date, each of the RAGS students has been able to give up off campus employment as a

result of RAGS program participation. Thus, time that was previously spent in the retail sector is now being used to enhance their education and allowed them to make better use of their study time. RAGS students meet as a group twice per month to share their research experiences, learn strategies for doing well in their courses, read scientific papers, and receive help with applications to graduate school. They are required to write a research proposal early in their program and then write a research thesis during their senior year. The current RAGS students have reported that both their self-confidence and their grades have improved since joining the RAGS program.

Strategies to increase minority enrollment in PhD programs in the biological sciences

PREP, a bridge program to graduate research

Many minority students come from disadvantaged backgrounds. As a result, they find that they are always trying to catch up to their better prepared peers. Even after they finish their undergraduate education, many talented minority students are not adequately prepared for graduate school. The NIH-funded USC Post-baccalaureate Research Education Program (PREP) is designed to serve as a bridge program to address this problem. Students chosen for the PREP have completed their undergraduate degrees, but they are not ready for the rigors of graduate school, and often, they do not have the credentials needed for graduate school acceptance. As part of PREP, scholars are employed as full time research technicians in a mentor's laboratory and have the opportunity to take one class each semester. Each student has a unique program tailored to his or her needs. The courses they take are chosen to fill holes in a particular student's background and to provide them with the opportunity to demonstrate that they can succeed in graduate level courses. If a PREP scholar does well in both her graduate courses and her research project, and is recommended by her mentor and the PREP program directors, she is guaranteed acceptance into one of the USC biomedical science graduate programs. Our experience is that most PREP scholars get involved with a research project and continue to work on it for their dissertation research after entering a doctoral graduate program. To date, nine minority students have transitioned from PREP to PhD programs at USC (figure1).

Support for minority PhD students

A second strategy for increasing minority participation in PhD programs has been to obtain additional sources of financial support. Minority students tend to have lower scores on standardized tests such as the GRE, and consequently, they have trouble competing for acceptance into PhD programs. However, research has shown that GRE scores are poor predictors of academic success. Therefore, the availability of funds to support minority graduate students provides an incentive for PhD programs to accept otherwise qualified minority students, in addition to the other students who are admitted to the program. As a result, the percentage of minority students in the PhD program increases without impacting the students who would normally have been accepted to the program. This increased minority participation, in turn, attracts additional qualified minority students so that the pool of applicants improves as well. Our follow up data show that once accepted into the PhD program, minority students with good credentials, but poor GRE scores, perform as well or better in their courses than the graduate students with higher GRE scores.

One important source of support for minority graduate students has been an Initiative for Minority Student Development grant from the National Institutes of Health. This grant provides funds that allow minority students who have not participated in PREP to come to campus during the summer prior to the start of their doctoral graduate program. This early start enables the student to get started on a research project in a mentor's laboratory and get settled in Columbia prior to the start of the fall semester. In addition, they are awarded a research assistantship so that they do not have any teaching responsibilities during their first semester. This combination of an early start and reduced responsibilities reduces the stress of their first semester in graduate school and helps ensure that the student will be successful. The Sloan Foundation also provides funds to help minority students successfully complete their doctoral programs, and the students are encouraged to apply for scholarships from other funding sources as well. To date, all minority students accepted into doctoral programs in the biological sciences have had sufficient support to enable them to complete their PhD degrees.

Results

In recent years, the research environment in the biological sciences at USC has been transformed. Enrollment in PhD programs in the biological sciences has increased by 30% and minority students now comprise more than one fourth of the total. This six-fold increase in minority enrollment in the PhD programs combined with a similar increase in minority undergraduate research has resulted in an environment where students from all ethnic groups feel included and supported. Since substantial numbers of foreign-born students and faculty participate as well, the atmosphere is truly multicultural and transcends differences resulting from ethnicity or culture. This success at improving diversity has led to a larger and more diverse applicant pool which will continue to improve the quality and diversity of students in the biological sciences at USC. Success breeds success.



Figure 1. The Ely Research group: a picture of diversity. From left to right, Jinxian Liu, Vida Mingo, Kurt Ash, Margo Saunders-Mack, Bert Ely, Melissa Eldridge, Amerline Occean, Julius Hamilton, and Jeremy Dietrick

Ultrasound in Second Year Pathology Medical Education

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Ultrasound machines are becoming smaller and more portable which improves diagnostics at the level of the physical examination alone in certain organ systems. As the technology becomes less expensive and more compact, these machines will be available for use in doctors' offices. Training medical students in this technology from their first year of medical education will better prepare them for the future and presumably improve their diagnostic capabilities. In partnership with General Electric Healthcare, this is currently being performed at the University of South Carolina, one of only two sites chosen nationally for a vertical curriculum training during medical school. In a vertical curriculum setting, ultrasound images and movies coupled with a full presentation of case histories, gross specimen, and microscopic analysis will be incorporated to aid pathology teaching. This vertical curriculum will also encourage medical students to embrace advances in ultrasound technology that will potentially benefit their future practice. It is essential to integrate training in small compact technologies that will improve diagnostic capabilities into all aspects of medical school so that students are fully prepared for future advances. Pathology can play an all encompassing role.

Results and Discussion

Diagnostic ultrasound is an essential part of practice in multiple medical sub-specialties such as cardiovascular medicine, obstetrics/gynecology, emergency medicine, urology, vascular medicine, and surgery. Ultrasound technology was first used in medical practice in the late 1940's and early 1950's and has advanced greatly. With further technological progress, these instruments have become smaller and more portable. Some even predict that as the ultrasound equipment becomes more compact, it will be the new stethoscope of the future.

The General Electric Healthcare LOGIQ e ultrasound system is a portable laptop-sized device that uses a patented CrossXBeam technology to generate sharper border definition and a coded harmonics for higher frequency. It has B steering technology, a 17 inch LCD screen when paired with a portable docking station, and weighs approximately 10 pounds. There are multiple transducers available for use with the device. The transducers are interchangeable and have a wide range of ultrasound frequencies suited for various clinical applications. The array of available transducers allows ultrasound imaging of virtually all organ systems. The LOGIQ e also has advanced features like color doppler flow, power doppler, and pulsed wave doppler that allow for study of cardiovascular system dynamics. In addition, the system is capable of making measurements and calculations in various applications like cardiac, vascular, obstetrical and general ultrasound. Images can be printed on a Sony digital printer or saved to the machine's hard drive or a memory stick. The system has pre-set features for imaging specific organ systems as well as manual

controls to modify scanning parameters such as gain, frequency, depth and focus.

Training medical students for future trends in medicine is essential. Multiple reports have shown that medical students are able to acquire and interpret ultrasound images after a short period of training (Fernandez-Frackelton, 2007; Arger, 2005; and Yoo, 2004). Medical students have also become proficient in such areas as cardiovascular, gynecologic and emergency medical procedures as well as pressure ulcer development (Decara, 2005; Wittich, 2002; Fernandez-Frackelton, 2001; and Quintavalle, 2006). For example, medical students with eighteen hours of hand held ultrasound device training, out performed board-certified cardiologists using standard physical examination by almost 60% in diagnosing lesions producing diastolic murmurs (Kobal, 2005). Their diagnostic accuracy was also superior in recognizing left ventricular dysfunction, enlargement, and hypertrophy.

Presently, cadaver based courses and virtual patient (Tabas, 2005) training allow standardization of ultrasound teaching and learning (Tabas, 2005; Heer, 2004; and Maciellan-Tobert, 1998) and are beneficial to undergraduate and graduate physicians. Therefore, it is necessary to expose future doctors to ultrasound technology, training and images during medical school. Currently, incorporation of ultrasound images and training on compact, laptop devices has been initiated at the University of South Carolina School of Medicine. The medical school is a prime place to begin because of the advanced information technology capabilities and infrastructural support for the development of future ultrasound application. The medical school is also incorporating ultrasound in a vertical curriculum or integrated ultrasound curriculum (iUSC) that involves

training, courses and application from the first year to graduation (Hoppmann, 2006).

Continuous exposure to ultrasound images in a pathology course for medical students has not been previously initiated or emphasized. Our interests include incorporating ultrasound images with gross and microscopic pictures into a second-year pathology course to broaden students' knowledge of cases encountered in different organ systems. For instance, chronic cholecystitis with cholelithiasis (Figure 1) is taught with the ultrasound image to get the clinical diagnostic picture coupled with the pathology. We propose using ultrasound images first in small group teaching whereby students can review the history, physical exam findings, laboratory data, and ultrasound images for individual cases. After studying the ultrasound images, the gross and microscopic changes can be presented as part of the case. This comprehensive overview will not only allow the student to associate the images with the pathological changes but also may help in future understanding of disease processes.

At the University of South Carolina School of Medicine second year students are becoming technologically advanced in their diagnostic capabilities while learning pathology. As our image bank expands, we will incorporate ultrasound images in systemic pathology lectures, particularly involving those of the cardiovascular and male/female genitourinary systems. Single images as well as time lapse ultrasound video will be used to understand flow conditions. This will benefit the understanding of the gross pathology as well as the pathophysiology of disease.

With the ultrasound curriculum added to pathology lectures, students may acquire a more comprehensive overview of disease processes that will better prepare them for the cases they will be encounter routinely during their clinical careers. We expect this will aid the students' ability to understand pathology concepts and further improve their understanding of the pathology seen in the ultrasound images. Early exposure to the ultrasound images, correlated with the gross and pathological changes, may lead to better recall of disease processes. Conversely, improved understanding of tissue densities in different pathological processes may improve understanding of the ultrasound image. Use of ultrasound images in pathology teaching in an integrated curriculum is an innovative approach that will prepare medical students for predictable future trends and enhance their diagnostic capabilities as physicians.

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Appendix

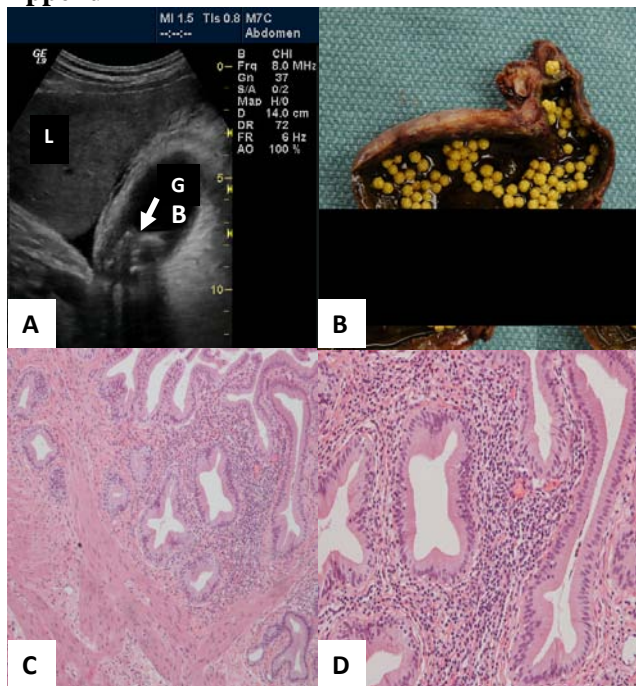


Figure 1. Abdominal ultrasound of the right upper quadrant (A) showing the liver (L) and gallbladder (G). A thickened gall bladder wall with gallstones in the infundibular region of the gallbladder (arrow) results in shadowing on the ultrasound image. Cholecystectomy specimen showing thick wall, erythematous mucosa, and cholesterol stones (B). Low power microscopic section of the gallbladder (C) demonstrates a thickened muscular wall with an inflammatory infiltrate within the lamina propria. Under higher power (D) the inflammatory infiltrate consists primarily of lymphocytes making the diagnosis of chronic cholecystitis with cholelithiasis.

The Potential For Nutrigenomics in Prevention of Metabolic Syndrome

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The relationship between diet and health has been recognized for millennia, but precisely “how” diet interacts with human physiology to elicit health or disease is only now beginning to be understood. The sequencing of the human genome as well as the development of new and innovative technologies in systems biology has allowed scientists to ask more probing questions into the relationship between diet and health at the most fundamental levels of biology. From this the “science of nutrigenomics” has emerged and it is now clear that certain dietary nutrients have the ability to interact with the human genome regulating gene function in positive and negative ways. Most importantly, the identification of specific nutrient chemicals that regulate genes is rapidly unfolding and the use of naturally occurring nutrient chemicals as pharmacological agents is becoming a reality. The net result is the development of new and innovative nutritional products for wellness and disease prevention.

Introduction

Dietary components provide the nutrient resources and energy needed for growth and repair of tissue throughout our lives. In adults, energy balance or homeostasis occurs when energy intake equals energy expenditure. Maintenance of this balance is required for a stable body weight. A chronic positive energy balance results in excess fat and obesity, which is linked to a constellation of health maladies, and is referred to as “metabolic syndrome”. This syndrome is associated with an increased risk of chronic diseases, including diabetes, cardiovascular disease, and stroke. Two hallmarks of metabolic syndrome are insulin resistance and increased markers of chronic inflammation.

Metabolic syndrome is characterized by a group of metabolic risk factors in a single person¹. They include:

- Central obesity (excessive fat tissue in and around the abdomen)
- Atherogenic dyslipidemia (blood fat disorders — mainly high triglycerides and low HDL cholesterol — that foster plaque buildups in artery walls)
- Insulin resistance or glucose intolerance (the body can't properly use insulin or blood sugar)
- Prothrombotic state (e.g., high fibrinogen or plasminogen activator inhibitor in the blood)
- Raised blood pressure (130/85 mmHg or higher)
- Proinflammatory state (e.g., elevated high-sensitivity C-reactive protein in the blood)

The underlying causes of this syndrome are overweight/obesity, physical inactivity and genetic factors. People with the metabolic syndrome are at increased risk of coronary heart disease, other diseases related to plaque buildups in artery walls

(e.g., stroke and peripheral vascular disease) and type 2 diabetes.

South Carolina has the dubious distinction of having one of the highest metabolic disease prevalence rates in the country². The occurrence of diseases related to this syndrome has resulted in a significant health-care burden and has prompted scientists from Clemson University, The University of SC and The Medical University of SC to join forces to seek solutions. In this regard an effort is now underway to form the SC Center of Economic Excellence in Molecular Nutrition where faculty from each university will collaborate to combine their individual strengths in plant breeding, nutrition, genomics, and gene regulation and function to develop prevention strategies. Motivation for this Center comes from long-held beliefs that chronic disease syndrome may one day be prevented through a better understanding and the mechanism through which specific nutrients are able to affect gene expression for human health.

Molecular Nutrition and Wellness

Molecular nutrition examines the interactions between nutrients and intracellular and extracellular molecules and is beginning to unravel the way nutrients affect cellular processes. This emerging field has been identified as one of the most exciting new frontiers in biomedical technology with the potential to dramatically improve human health and wellness worldwide³.

A component of molecular nutrition, nutrigenomics, or nutritional genomics, is a multidisciplinary science that combines information from genetics, nutrition, physiology, pathology, and molecular biology. The diet - nutrient interactions which occur in different individuals is complex and scientists are focusing on the polymorphisms which affect these interactions to help alleviate health disparities.

Dietary chemicals have been shown to alter gene expression in a number of ways⁴. For example, they may:

- act as ligands for transcription factor receptors
- be metabolized by primary or secondary metabolic pathways thereby altering concentrations of substrates or intermediates or
- alter signal transduction pathways

genes not believed to be associated with nutrient utilization. While more complex than yeast, the constellation of genes that make up the human genome respond in a similar fashion to dietary inputs⁵.

The science of nutrigenomics is multifaceted, but primarily looks at the molecular relationships between dietary intake and the response of genes, with the aim of extrapolating how gene expression affects human health^{3,4}. Nutrigenomics focuses on of the molecular relationships between dietary intake the effect of diet on the genome, epigenome, proteome, and metabolome. In understanding these effects, nutrigenomics attempts to define the relationship between specific nutrients and specific nutrient regimes (diets) on human health. Nutrigenomics, or nutrigenomics, is the study of how foods affect our genes and how individual genetic differences can affect the way we respond to nutrients (and other naturally occurring compounds) in the foods we eat.

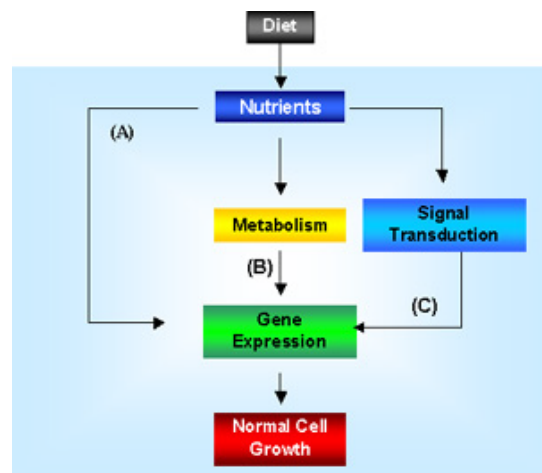
While somewhat controversial, nutrigenomics has been popularized with the idea of personalized nutrition based on genotype. While there is hope that nutrigenomics will ultimately enable such personalized dietary advice, the science is in its infancy and many more fundamental questions must be answered⁶.

Nutrigenomics and Disease Prevention

Throughout the 20th century, nutritional science focused on finding vitamins and minerals, defining their use and preventing the deficiency diseases that they caused. As the nutrition-related health problems of the developed world shifted to overnutrition, obesity and type 2 diabetes, the focus of modern medicine and of nutritional science changed accordingly.

In order to address the increasing incidence of these diet-related-diseases, the role of diet and nutrition has been and continues to be extensively studied. To prevent the development of disease,

nutrition research is investigating how nutrition can optimize and maintain cellular, tissue, organ and whole body homeostasis. This requires understanding how nutrients act at the gene, protein and metabolic levels. As a result, nutrition research has shifted from epidemiology and physiology to molecular biology and genetics⁶.



With this paradigm shift new data has emerged in support of dietary interventions in preventing, mitigating, or treating chronic disease, and certain cancers. The conceptual basis and scientific evidence to support dietary interventions can be found in the following observations:

- Under certain circumstances and in some individuals, diet can be a serious risk factor for a number of diseases.
- Common dietary chemicals can act on the human genome, either directly or indirectly, to alter gene expression or structure.
- The degree to which diet influences the balance between healthy and disease states may depend on an individual's genetic makeup.
- Some diet-regulated genes (and their normal, common variants) are likely to play a role in the onset, incidence, progression, and/or severity of chronic diseases.
- Dietary intervention based on knowledge of nutritional requirement, nutritional status, and genotype, have been used to prevent, mitigate or cure chronic disease.

The emergence and development of nutrigenomics has been possible due to powerful developments in genetic research. With these developments, biochemical disorders with a high nutritional relevance have been linked to a genetic

origin. Such disorders include a polymorphism in the gene for the hormone Leptin which results in gross obesity. While a few other genetic polymorphisms have been described, it is thought that many others result in minor deviations in nutritional biochemistry. The tools to study the physiological impact of these genetic polymorphisms are only now becoming available. Such tools include those that measure the transcriptome - DNA microarray, exon array, single nucleotide polymorphism arrays and genotyping^{5,6}.

The Promise of Nutrigenomics

In nutrigenomics, nutrients are seen as signals that communicate with specific cells in the body. These nutrients may be detected by a sensory system much like those associated with toll-like receptors on cell surfaces. Like the toll receptor, cellular signaling is induced through transcription factors which alter gene expression and protein/metabolite production in accordance with the level of nutrient present in the cell environment. As a result, it is believed that different diets will elicit different patterns of gene and protein expression and metabolite production. Nutrigenomics seeks to describe the patterns of these effects which have been referred to as *dietary signatures*⁶. Such dietary signatures can be examined in specific cells, tissues and organisms and in this way the manner by which nutrition influences homeostasis can be better understood. Genes which are affected by differing levels of nutrients are now being identified and their regulatory pathways are under investigation³. Through the identification of these genes and their regulatory pathways, scientists will soon have a better understanding of how nutrition influences metabolic pathways and homeostasis. Such an understanding will be essential in attempts to prevent the development of chronic diet related diseases such as obesity and type 2 diabetes. In this regard, finding markers of the early phase of diet related diseases for intervention with selected nutrients that could reverse or slow the disease process will expand the application of nutrigenomics. Thus, once a marker has been found and measured, the extent to which an individual is susceptible to disease development may be quantified and personalized dietary recommendations prescribed. Progress in this area will lead to the marketing and distribution of "science-based functional foods" that will keep people healthy according to their individual needs.

Chronic Disease Syndrome in SC

An estimated 79 million American adults (1 in 3) have cardiovascular disease (CVD), and millions more are at risk due to the presence of obesity, hypertension, and hyperlipidemia¹. CVD

accounts for 36.3% of U.S. mortality, or 1 out of every 2.8 deaths. SC is a leader in heart disease and in stroke among the U.S states; heart disease is the leading cause of death in SC, accounting for 10,000 deaths annually.² Further, in 2007, SC had the seventh worst obesity rate in the nation, with over 65% of all SC adults either overweight or obese. When examined across race/ethnicity in SC adults, a larger proportion of African-Americans in the state are overweight or obese (73.6%) as compared to Whites (63%)⁷. Recent research has established that inflammation plays a key role in the atherosclerotic process^{8,9}. Endothelial injury and plaque rupture are inflammatory processes that lead to thrombosis, myocardial infarction and stroke. Several proteins participate in the inflammatory processes that are useful for measurement. The most common and clinically useful measure is highly sensitive C-reactive protein (hsCRP), but several other markers have been investigated^{9,10}.

A pharmaceutical approach to prevention of CVD inherently exposes millions of people without disease to the risk of adverse effects and interactions of multiple medications (aspirin—ulcers, bleeding; statins—liver dysfunction/myopathy; fenfluramine and phentermine—valvular heart disease and pulmonary hypertension). A more appealing approach is to identify, test, and use natural phytochemicals with anti-inflammatory and antioxidant activity and few side effects, to not only prevent CVD but promote general wellbeing.

Dietary Interventions to Reduce Chronic Disease Syndrome in SC

One of the most promising candidates currently under investigation in South Carolina is the common table grape. Animal, laboratory, and epidemiologic data indicate that higher intake of polyphenol-rich grapes have anti-inflammatory and potent antioxidant effects that may reduce the risk of CVD and other chronic disease states such as hypertension. These beneficial effects have been attributed to the bioactive constituents resveratrol and flavonoids such as anthocyanins^{11,12}. Recent evidence shows that red wine derived from table grapes (*Vitis vinifera*) may lower the risk of CVD¹³⁻¹⁵. Before proceeding with clinical studies of grape concentrates in clinical populations, the potential bioactive phytochemicals in grapes need to be more fully identified. The molecular mechanisms underlying the effect of grape phytochemicals in CVD prevention are yet to be elucidated, but alterations in cell signaling pathways leading to inflammation are a distinct possibility. Phase I and II trials need to be conducted in a carefully chosen target population with increased inflammation and oxidative stress (overweight/obese but otherwise healthy adults,¹⁶⁻¹⁸ to

determine the maximum tolerable dose, adverse effects and effective dose ranges of grape products.

In contrast to table grapes, research on muscadine (*Vitis rotundifolia*), a native and valuable fruit crop in Southeastern US, including SC and GA, is under-developed. Muscadine is classified under the genus *Vitis* with other grape species, but further classified to a separate subgenus, *Muscadinia*, due to genetic and botanical differences between muscadine and other grapes. Muscadines are well adapted to warm and humid climate in the Southeastern US in which other grapes do not thrive. Muscadines have a higher total phenolic content compared to table grapes and small fruits¹⁹. Recent evidence shows that photochemical constituents of muscadines are distinct and differ from other grapes by having unique phenolic compounds, such as ellagic acid and other anthocyanins in appreciable amounts²⁰⁻²². Anthocyanins are present as 3,5-diglucosides in the muscadine as opposed to 3-glucosides in other grapes, and glycosylation has been shown to be a major determinant of bioavailability^{22,23}. Major phenolics reported in muscadine skins are ellagic acid, myricetin, quercetin, and kaempferol while for the muscadine seeds are gallic acid, catechin, and epicatechin²⁰; most of the polyphenols are concentrated in the seed and skin. Therefore, muscadine seed and skin polyphenols may have different bioactivity, as compared to those of other grapes, due to the presence of unique polyphenols. These unique constituents may act as a source of novel compounds for targeted intervention in the inflammatory pathways. Clinical studies now underway at the Medical University of SC will focus on chemically defined constituents from muscadine seed and skin extracts to determine which ones have the greatest impact on inflammatory markers in patients with metabolic syndrome. Once identified, these extracts will be evaluated in larger trials in and out of SC to evaluate the long-term effects on prevention and/or delay in onset of the diseases associated with metabolic syndrome.

While it appears that certain classes of polyphenols, e.g. anthocyanins, in muscadines contain the bioactives needed for reducing inflammation, the cellular mechanism by which these substances impact disease are complex involving a highly evolved cellular circuitry in which gene expression, either directly or indirectly induced, results in physiologic change. With the recent advancements in systems biology (genomics, proteomics, and metabolomics) we may soon be able to dissect and control cellular circuits, which are regulated by polyphenols. Certainly our ability to control expression of nuclear factor-kappaB and inflammatory cytokines such as TNF-alpha and Il-6 appear to be likely candidates for initial investigations.

Conclusions

The science of nutrigenomics continue to generate much interest and activity with the expectation that many of the disparities in wellness can be prevented, but much remains to be done, and this science is still in its infancy. The promise of nutritional genomics in personalized medicine and health is based on an understanding of our nutritional needs, nutritional and health status, and our genotype. Nutrigenomics could have significant impacts on society – from medicine to agricultural and dietary practices to social and public policies – and its applications are likely to compare to those arising from the human genome project. Chronic diseases (and some types of cancer) may be preventable, or at least delayed, by balanced, sensible diets. Knowledge gained from comparing diet/gene interactions in different populations may provide information needed to address the larger problem of global malnutrition and disease.

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The Integrated Biomedical Science Graduate Program at the University of South Carolina

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5 Review March 31, 200

Until recently, graduate programs in the biomedical sciences were usually based in the traditional medical school departments (microbiology, biochemistry, pharmacology, anatomy, pathology, and physiology) and in biology departments. However, these departments have become increasingly irrelevant as far as the training of PhD students is concerned since biomedical research is now carried out in many parts of a university. Moreover, faculty members from disparate parts of a university are often housed in dedicated biomedical research buildings. At the University of South Carolina, the Medical School departments have combined their doctoral training programs with those of sections of the biology, chemistry and psychology departments, the College of Pharmacy and the School of Public Health to form the Integrated Biomedical Science Graduate program.

15 Graduate students participating in doctoral (PhD) education programs constitute the principal workforce in the biomedical research activities conducted in most research universities and medical schools in the United States. As faculty take on more academic responsibilities, they rely on graduate students to carry out much of the hands-on laboratory work that leads to the generation of knowledge in the form of published papers. The work of graduate students also leads to the generation of further federal, industrial and foundation grants to support research. These grants, through the provision of overhead funds, are nowadays supporting more and more of the mission of medical schools and universities. A strong graduate program attracts the best students who do the best research and, as a result, generate more research papers and grants. The whole university benefits from strong graduate programs in the biomedical sciences because, currently, the National Institutes of Health (NIH) are the leading federal source of research funding.

As the number of grants and students in a university program increase, it becomes possible for the university to obtain separate funding to support graduate students in the form of stipends from training grants from the NIH and also from private organizations such as the Howard Hughes Foundation. In many major universities, such training grants support the majority of graduate students in the biomedical sciences. They also provide support for post-doctoral fellows. The University of South Carolina (USC), unfortunately, has had little success in obtaining training grants from the NIH because of a lack of a critical mass of faculty and existing graduate students in many of its colleges. There has also been a lack of well qualified applicants to many biomedical research

graduate programs at USC. It is a fact of academic life that a strong graduate program generates money that often leads to an even stronger program. It has been evident for many years that a stronger biomedical sciences graduate program is needed so that the university may compete nationally, not only for funds to support its biomedical graduate programs but also for research grants and contracts.

HISTORY

Basic Science departments in American Medical Schools are traditionally organized around the core courses taught in the first two years of medical education: These disciplines are Anatomy (now often contained within Cell Biology and Developmental Biology departments), Pharmacology, Pathology, Biochemistry, Microbiology and Immunology and Physiology. In addition to training medical students in the basic medical sciences, these six departments also frequently offered Doctor of Philosophy (PhD) and Master of Science (MS) degrees.

The University of South Carolina School of Medicine (USCSOM) is one of the younger and smaller medical schools in the United States. It was authorized by the South Carolina legislature and the South Carolina Commission of Higher Education in 1973 and accredited in 1975. It admitted its first class of medical students in 1977 and now has a total of approximately 300 medical students in the four years of the medical curriculum. Unlike most medical schools, the USCSOM has no biochemistry department and teaching of this subject is carried out by the faculty of the Department of Chemistry, a unit of the College of Arts and Sciences. By 1981, four of the five basic science departments at the USCSOM had their own small graduate program, often admitting only one or two students per year, most of whom were recruited locally. These

students were offered few courses dedicated specifically to them and usually took basic science courses along with the medical students. To overcome the lack of resources for graduate students in the individual departments, the biomedical science graduate program at USCSOM was formed by amalgamating these programs under a single administration. Although administration was centralized, lack of funds did not allow optimal recruitment. Most students initially chose a mentor, entered the individual departments at the beginning of their graduate education and remained there.

The Biomedical Sciences Graduate program slowly accepted an increasing number of students as USCSOM grew in the number of faculty and faculty-initiated research projects. Subsequently, the five original basic science departments merged into three. A committee consisting of the overall program academic director and the Director of the Biomedical Program plus representatives of the three departments selected well-qualified candidates whose credentials suggested they would eventually disperse in roughly equal numbers to each of the departments to carry out their thesis research. Many students did not select a potential mentor until they arrived in Columbia and selection could be delayed until rotations had been carried out in a few laboratories.

By 2006, and after administrative reorganization, the USCSOM Biomedical Science Graduate program was admitting 8 to 10 new students per year with a steady state number of about 40 and a budget, exclusive of tuition, of about \$250,000. The entire budget was provided by the Dean. By now, a large proportion of the students admitted were from overseas, mainly from China and India, something that was (and still is) common to most medical graduate programs in the United States and Europe.

From time to time, faculty of the USCSOM who were interested in training graduate students got together to submit a training grant to the NIH but none was successful. A common criticism was that as that there was no critical mass of faculty to teach or mentor the students (only about two thirds of the approximately 35 faculty were well enough funded to pay for a graduate student's research expenses) and, as far as United States citizens were concerned, there was no critical mass of current students or future applicants. The number of American students is important because only these can be supported from NIH training grants. Nevertheless, the graduate program was graduating successful students who obtained post-doctoral positions in prestigious institutions in the US (Harvard University, University of California, MD Anderson Cancer Center, Baylor College of

Medicine, Johns Hopkins University National Institutes of Health and many more). Some students chose to pursue their post-doctoral years abroad in such organizations as the Karolinska Institute (Stockholm, Sweden) and the Imperial Cancer Research Laboratories (London, England).

In addition to the lack of a critical mass of American students in the USCSOM program and the lack of the possibility outside funding, the number and breadth of course offerings changed little. A similar situation pertained in some of the other biomedically-oriented departments at USC.

THE NEED FOR INTEGRATION

In addition to the need to attract a larger number of well-qualified American Graduate Students, a prerequisite for funding from the federal government, USC needed a stronger program to attract the very best new faculty when the university administration identified biomedical science research as one of its growth priorities. The existing small program at the medical school and similar small programs based on traditional teaching departments on the main campus, had become irrelevant, especially as research faculty consolidate into facilities that are based on research interest rather than teaching department.

A critical mass of students and faculty is required for a dynamic program

Clearly, a problem of critical mass existed in many biomedically-oriented departments at the university including the School of Medicine, the Arnold School of Public Health (Exercise Science), the South Carolina College of Pharmacy (Basic Pharmaceutical Sciences) and the College of Arts and Sciences (Departments of Biology, Chemistry (Biochemistry Section) and Psychology. None of the individual departments had sufficient faculty to offer a truly broad range of research opportunities and courses to potential students and none of the individual departmental programs had the sufficient students to offer the peer interactions that are necessary.

What was needed was quite clear:

- More faculty mentors
- More and better qualified students recruited from within the United States
- More choice of research options for the students
- More choice of elective courses
- More (and better attended) seminars
- Better funding for the program as a whole

The need for more faculty in the biomedical sciences was addressed at the beginning of this century by the Centennial Plan and the Faculty Excellence Initiative but major expansion to the size of many competitor universities is a long way off, even though a new biomedical research center, the Discovery Building on the Vista, is under construction which will bring together funded faculty from all parts of the university into a central location (making departmental distinctions even more irrelevant).

It was very clear that none of the obvious problems would ever be solved by remaining in isolation as small departments (or even schools). Moreover, the fragmentation of the graduate programs has become an anachronism as faculty come together in the new biomedical research center. In addition, the organization of university departments based on course offerings to undergraduates and medical students, hindered faculty interactions. What was required was to combine the biomedically-oriented graduate programs into the most flexible format possible. Not only would this offer a much larger and attractive program to potential students but it would also serve to bring faculty together under the aegis of the graduate program and foster more research interactions.

The Solution

The solution was quite clear. Combine the graduate programs of the various biomedically-oriented departments across the USC campus. Students would be recruited for the joint program, *The Integrated Biomedical Science Graduate Program* (IBMSGP), and would enter their first year without any commitment to a mentor or department. In this “umbrella” year, all students would take one of two lecture tracks: Molecular and Cellular Biology or Neuroscience, both of which would teach the fundamentals of the biology of cells and between which the student could easily switch. During the umbrella year, students would spend three rotation periods in laboratories of their choice selected from a menu of more than 90 potential mentors from all participating departments on the main campus located in the center of Columbia and at the Medical School located on the Veterans’ Administration Hospital campus. By the end of the first year, after successful completion of all core courses, the student would affiliate with the department of their chosen mentor and spend the remainder of their time pursuing a PhD degree in the department of their mentor. This period would be about five and a half years, a time that is usual for earning a PhD in the biomedical sciences in the United States.

The IBMSGP was proposed to Vice-President Harris Pastides, now the USC President. The formation of the IBMSGP was agreed and the program recruited its first students for the fall of 2008.

Funding

The various departments contributed monies to the pool of stipend support according to the number of faculty who might draw students from the program. However, there was a need for administrative support. In addition, a potential problem was that, in a single year, one department or school might get fewer students than justified by the stipend money contributed. This could lead to an early collapse of the program if departments felt that they were putting in more than they got out. To avoid this and to pay for administrative costs, the USC Office of Research and Economic Development, the Graduate School and the USC INBRE program contributed an additional \$120,000 per year for three years.

The First Year

With little advertising, other than a web site and word of mouth, the IBMSGP recruited students starting in late 2007 for admission in August 2008. A higher number of American and foreign applicants were received than in previous years. Twenty-six students were admitted. Twelve of these were from overseas (India, China and Nepal) and fourteen were from the United States. The American students included seven minority students (five African Americans and two Hispanic Americans). Five of these were graduates from the Post-baccalaureate Research Education Program (PREP) that is funded by the NIH and which is described by Dr Bert Ely in this issue of JSCAS. This large proportion of minority students means that in five years, the IBMSGP is expected to graduate a significant proportion of African American PhDs in the biomedical sciences in the United States.

The result of the integration of graduate programs in the biomedical sciences has clearly led to more applications, both from the United States and abroad. But has there been an improvement in their credentials? The GRE scores of American students in the medical school’s former biomedical science graduate program, verbal and quantitative, were 47th and 54th percentile respectively. This rose to 62nd and 70th percentile for the non-minority students admitted in 2008 and the numbers remain similar for those interviewed for fall 2009. The overseas students also showed better GRE scores.

The foreign students continuing from the former program had scores in the 60th and 78th percentiles which rose to 71st and 83rd percentiles for 2008 admissions into the integrated program. This increase also seems to be reflected in the scores of overseas students interviewed for 2009. These improved GRE scores resulted in the IBMSGP admissions being second only to students admitted to the USC PhD program in mathematics among the sciences; naturally the mathematics doctoral students have extraordinarily high scores in the quantitative section of the GRE.

The NIH-PREP admits four or five under-represented minority students per year, as described in the article by Bert Ely. The program is designed to help minority students gain better credentials to enter graduate schools by allowing them to work in a biomedical research environment for two years. These potential PhD students usually fail to enter graduate school immediately after earning a baccalaureate degree for a number of reasons, among which are low GRE scores and low GPAs. Although PREP scholars usually fail to obtain higher GRE scores after the PREP, they succeed in a number of other ways including in their GPAs. Thus, the IBMSGP has admitted minority students with less than stellar GRE scores in the hope that

such scores are not a predictor of success in graduate school. This hope has been borne out in that GPAs of the minority students in the first semester of graduate school are not significantly different from those of the other students in the IBMSGP.

Conclusion

The IBMSGP at USC is now entering its second year with an increased number of better qualified students being admitted and more faculty participation with a consequent greater choice of mentors and research projects. The program is already well-funded for the education of minority students through the PREP grant from NIH, grants from the Alfred P. Sloan Foundation and another NIH grant: The South Carolina Initiative for Minority Development. The challenge now is to obtain outside funding for the program as a whole. The IBMSGP has attracted the attention of the staff of the Centers for Disease Control in Atlanta, particularly because of its large minority participation. It is anticipated that a senior administrator from the CDC will work with the administrative staff of the IBMSGP in the pursuit of such funding.