Back to the Basic Sciences: An Innovative Approach to Teaching Senior Medical Students How Best to Integrate Basic Science and Clinical Medicine

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Abstract

Abraham Flexner persuaded the medical establishment of his time that teaching the sciences, from basic to clinical, should be a critical component of the medical student curriculum, thus giving rise to the "preclinical curriculum." However, students' retention of basic science material after the preclinical years is generally poor. The authors believe that revisiting the basic sciences in the fourth year can enhance understanding of clinical medicine and further students' understanding of how the two fields integrate. With this in mind, a return to the basic sciences during the fourth year of medical school may be highly beneficial. The purpose of this article is to (1) discuss efforts to integrate basic science into the clinical years of medical student education throughout the United States and Canada, and (2) describe the highly developed fourth-year basic science integration program at the University of Pittsburgh School of Medicine. In their critical review of medical school curricula of 126 U.S. and 17 Canadian medical schools, the authors found that only 19% of U.S. medical schools and 24% of Canadian medical schools require basic science courses or experiences during the clinical years, a minor increase compared with 1985. Curricular methods ranged from simple lectures to integrated case studies with hands-on laboratory experience. The authors hope to advance the national discussion about the need to more fully integrate basic science teaching throughout all four years of the medical student curriculum by placing a curricular innovation in the context of similar efforts by other U.S. and Canadian medical schools.

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One of the most important contributions of Abraham Flexner's[1] report was to persuade the medical establishment of his time that teaching the sciences, from basic to clinical, should be a critical component of the medical student curriculum. This proposition gave rise to the notion of the "preclinical curriculum," which is still largely in existence at most medical schools today.

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Recently, medical schools have begun to modify their preclinical curricula with an aim to demonstrate the relevance of basic science to practice and to improve knowledge retention.[2–4] To more closely relate the basic and clinical sciences, the curricula of several medical schools now include patient contact early in the first year concurrent with basic science instruction, modernized content in the preclinical curriculum, and clinical principles integrated into basic science courses.[4] Although most medical educators agree that these changes are valuable and that the use of clinical material in basic science courses enhances the relevance of these courses for students, students' retention of basic science material after the preclinical years is still generally poor.[5] We believe that revisiting the basic sciences in the fourth year can enhance understanding of clinical medicine and further students' understanding of how the two fields integrate. With this in mind, it makes sense to persuade the medical establishment of our time that a return to the basic sciences during the fourth year of medical school, further integrating basic science knowledge into clinical teaching, can be of great benefit.

Advanced experiences in biomedical science during the third and fourth years of medical school are critically important; continuous progress in science and medicine require that students learn how best to integrate and translate basic science into clinical care. Further, some evidence indicates that basic science knowledge that relates causation to disease symptoms can improve diagnostic accuracy.[6] Yet, the total time allotted during medical school to basic science education seems to be declining as clinical material and experiences are incorporated into the traditionally basic science years. In addition, loss of basic science knowledge among medical students who are between the first and second years of medical school has been reported.[5]

Basic science content during the first two years of medical school provides an important foundation for clinical experiences. However, students cannot be expected to adeptly apply basic science concepts to clinical decision making until they have had some degree of clinical training. Thus, a return to the basic sciences during the senior year of medical training, when students are at a more

mature level of learning, is an important pedagogical approach to enable students to better integrate basic science concepts into their clinical experiences. We provide a historical perspective of "back to basic science" efforts, document the current status of integration of basic science in the clinical years of medical student education throughout the United States and Canada, and describe the University of Pittsburgh School of Medicine's (UPSOM's) highly developed program in detail. With this article, we hope to advance the national discussion about the need to more fully integrate basic science teaching throughout all four years of the medical student curriculum, with a special focus on this integration during the senior year.

A Historical Perspective

Exposure to basic science principles and appreciation for translational research are important to maintain the *science* of medicine, supporting a paradigm of integrative medical education.[4] Back-to-basic-science courses that enable senior medical students to reexamine important basic science concepts, to examine how basic science facilitates understanding in clinical medicine, to enrich their understanding of the scientific method, or to develop skills for critical appraisal of biomedical literature have been implemented and offered to senior medical students as either required or elective courses with varying degrees of success. Few programs have published descriptions of their curricular innovations[7–12]; even fewer have evaluated them.[10–11]

Patel and Dauphinee[10] at McGill University Faculty of Medicine were among the first to publish a description of a curriculum for fourth-year medical students. The McGill program, developed in the 1970s, was intended to integrate basic sciences and clinical knowledge at a point in the students' educational careers when they could better appreciate the relevance of basic science, given their clinical experiences.[10] Patel and Dauphinee described a series of three-month integrated courses in anatomy, biochemistry, epidemiology, history of medicine, and microbiology.[10] By 1985, 13% (17 of 130) of U.S. medical schools required an integrated basic science course during the clinical years.[11] In 1986, Croen et al[11] published a description of Albert Einstein College of Medicine's eight-week return-to-the-basic-sciences curriculum developed 10 years before their article's publication. The course was placed between the third and fourth years of medical school such that students would already have had one year of clinical exposure and would have an additional clinical year in which to apply what they learned. The course was initially lecture based, but it evolved over the following decade into a multidisciplinary case conference series with separate small-group break-out sessions.

"Back-to-Basic-Science" Programs at U.S. and Canadian Medical Schools

To understand whether and how schools integrate basic science into the clinical medical student curriculum, we searched the Association of American Medical Colleges' (AAMC's) online Curriculum Directory[13] for medical schools in the United States and Canada that require a basic science course or experience in the third or fourth year. We noted any courses that were described as either back-to-basic-science-type courses or that had course titles that suggested this might be the case. We then visited each of the 126 individual U.S. and 17 Canadian medical schools' Web sites as listed on the AAMC Web site as of March 2007,[14] and we reviewed each school's required junior and senior course curriculum in its entirety. We documented the presence or absence of a basic science curriculum in the clinical years and recorded pertinent data gleaned from the Web site. Data collected included the course title, whether the course was required, duration of rotation, and additional information reported on the school's curriculum Web site.

Upon review of the required junior and senior courses offered at each of the U.S. and Canadian medical schools, we found that 24 of 126 U.S. (19%) and 4 of 17 (24%) Canadian medical schools have basic science requirements for the clinical years of medical school (Tables 1 and 2). This is a minor increase from numbers reported in 1985, when a total of 17 of 130 schools (13%) reported such a requirement.[11] Course length ranged from 1 to 12 weeks, with an average duration of 4 weeks. Schools also varied in the number of integrative basic science topics offered during the clinical years, from only 1 course to more than 10. Whereas the goals of the experience were fairly similar across schools (Tables 1 and 2), the course formats and methods by which the courses were taught varied significantly. Curricular methods ranged from simple lectures to integrated case study experiences with hands-on laboratory experience. All 143 of the U.S. and Canadian schools reviewed offered at least one elective in basic sciences during the clinical years, but the extent to which these electives are integrated with clinical medicine is unknown. Two programs without required back-to-basic-science courses noted that their curricula integrate basic science and clinical medicine throughout all four years of medical school training.

The Integrated Life Sciences Program at UPSOM

In 1995, the UPSOM Curriculum Committee articulated the value of revisiting basic science concepts during the traditionally clinical years of instruction, when students were at a more mature level in their training. The committee sought to develop an innovative curriculum that would allow senior medical students to integrate biomedical science with clinical medicine, to enrich their understanding of the scientific method, and to develop skills for critical appraisal of the biomedical literature. To achieve these goals, the Integrated Life Science (ILS) program was developed. A brief, general summary of this program was included in a prior publication.[15]

The ILS curriculum[16] consists of a selection of four-week courses that fit within the sequence of standard rotations during the fourth year of medical school. Students are required to take at least one ILS course and are permitted to select which of the seven ILS courses best fits their needs. Each ILS course stands alone, and students do not take other courses concurrently. While on the ILS selective, students devote themselves full-time to the course. Each ILS course varies in the amount of time devoted to classroom, interactive, and experiential learning, and the specific details for each selective are described below. Each ILS course has its own specific aims and learning objectives, but all share the common goal of fostering scientific learning through understanding the limits of current

Table 1

U.S. Medical Schools With Required Basic Science Courses in the Clinical Years, 2007*

School	Course description
Baylor College of Medicine	Mechanisms and Management of Disease • Goal: To integrate basic science and clinical information about common diseases within a series of modules (immunizations, chest pain, substance abuse, aging) • Format: Lectures, panels, and small-group discussions • Offered July to March of fourth year
Case Western Reserve University School of Medicine	Advanced clinical and scientific studies • 12 weeks of linked experiences integrating basic science and clinical experiences • Intended to result in an area of expertise
Columbia University College of Physicians and Surgeons	Back-to-the-classroom seminars (three options) —Advanced Pathophysiology —Clinical Pharmacology —Clinical Pathology • Goal: Emphasize the foundation of medical knowledge and critical appraisal of data • Format: Lecture/seminar
Dartmouth Medical School	Clinical Pharmacology and Therapeutics; Advanced Medical Sciences • Goal: To update, integrate, and add depth to the student's knowledge and appreciation of the role of the medical sciences in the practice of medicine • Format: Whole-class and small-group teaching, discussion groups, and reading of original research papers • Course presents clinically relevant fundamental and advanced concepts of medical and biological sciences, and its content stresses the clinical impact of very recent advances in molecular medicine, immunology, vascular biology, oncogenesis, genetics, and other medically related fields
Duke University School of Medicine	Capstone course • Four weeks • Covers advanced basic science principles
Eastern Virginia Medical School	Integrated basic science and clinical rotation • Four weeks • Revisits some aspects of basic sciences, exploring application to clinical care
George Washington University School of Medicine and Health Sciences	Continuing Practice of Medicine • Covers advances in basic sciences and clinical application • Course reinforces the implications and applications of the basic sciences to the understanding and management of clinical problems • Topics of ethics and patient management are handled on a more sophisticated level
Harvard Medical School	Advanced Biomedical Sciences Program (five options) —Problems of Osseous Reconstruction —Scientific Bases of Otolaryngology–Head and Neck Surgery —Advanced Basic Science in Reproductive Medicine —Substance Abuse: Addictive Processes —Pain and Palliative Medicine • Four weeks in third or fourth year • Integrative basic science and clinical course
Jefferson Medical College of Thomas Jefferson University	Scientific Foundations of Clinical Medicine • One course; six topics covered • Four weeks • Advanced Basic Science in fourth year
Joan & Sanford I. Weill Medical College of Cornell University	Advanced Basic Science • Goal: To enhance fundamental understanding of the integration of science and medicine • Course covers the latest advances in biomedical science and technology currently applied to the practice of medicine • Includes topics particularly germane to frontline medical practice • Last four weeks of medical school
Johns Hopkins University School of Medicine	Rational Therapeutics • ClinicoPathological Conference • Fourth year • Course builds on the foundation of the second-year pharmacology course and third-year clinical clerkship experiences • Course focuses on therapeutic decision making in the context of clinical problems based on pharmacologic principles
Medical College of Wisconsin	Integrated Selective • Four weeks in fourth year • Course designed to integrate basic/clinical science and/or to address multidisciplinary approaches to patient care

(*Table continues*)

Table 1
(*Continued*)

School	Course description
New York University School of Medicine	Advanced Basic Science • Rising fourth-years • In-depth seminar- and original-literature-based selective in advanced science • Students select from several topics drawn from the frontiers of translational medicine and biomedical technology • Topics include stem cell therapy, models of multigenic disease, vaccine development, neurobiology of pain, ion channels and disease, DNA technology in medicine, anatomy for surgeons, and the microbiology of bioterrorism
Saint Louis University School of Medicine	Basic Science Clinical Correlations • Series of monthly one-hour lectures • Course integrates knowledge regarding mechanisms underlying disease processes with basic clinical hallmarks of diseases and provides new insights into disease diagnosis, treatment, and prevention • Course also indicates areas of controversy and application of emerging technologies (e.g., DNA microarrays)
University of California–Davis School of Medicine	Special Study Modules • Course promotes integration of basic or applied sciences and clinical medicine at an advanced level • Course provides opportunities to practice and refine fundamental skills in critical appraisal and analysis of emerging scientific developments • Course provides learning experiences, expertise, and resources to help students appreciate the ways in which multidisciplinary teams of scientists and clinicians collaborate in the pursuit of new knowledge through research
University of California–San Diego School of Medicine	From Principles to Practice • Course improves integration of basic science into clinical medicine • Students review four complex cases in small groups facilitated by faculty and conduct outside research to explore each case
University of Kentucky College of Medicine	Advanced Clinical Pharmacology and Anesthesiology • Fourth year • Course integrates basic and clinical sciences • Students review clinical pharmacology and observe a variety of drug treatments in the operating room and pain clinics
University of Michigan Medical School	Science in Clinics (Clinical Medicine Correlations) • Four weeks in fourth year • Course teaches basic science content at an advanced level within a clinically relevant context • Course aims to enhance problem-solving abilities and promote understanding of the mechanisms of disease processes and how they lead to development of treatment standards
University of Missouri–Columbia School of Medicine	Advanced basic science selectives (Four options) —Search and analyze the literature —Integrate and evaluate data —Produce a paper or presentation —Conduct original research with mentors from the basic or clinical sciences • Course revisits the biomedical sciences in the context of a patient, disease, diagnosis, or problem
University of Pennsylvania School of Medicine	Frontiers in Medical Science • Scattered one- to two-week seminars • Basic science seminars reinforce understanding of mechanisms of disease • Example: Clinical therapeutics and medical genetics
University of Pittsburgh School of Medicine	Integrated Life Science Course (six options) —Clinical Pharmacology —Science of Resuscitation —Neoplasia and Neoplastic Disease —Infectious Disease in Obstetrics, Gynecology and Reproductive Medicine —Molecular Medicine —Surgical Integrated Life Sciences • Four-week selective in four year • Course designed to revisit the basic sciences in an integrative and multidisciplinary fashion through specially designed courses
University of Texas Medical Branch at Galveston	Basic Sciences/Humanities • Four weeks in fourth year • Course emphasizes the integral role of the sciences and humanities in the practice of medicine
University of Toledo College of Medicine	Basic science selective • Four weeks in fourth year • Course provides opportunity for students to solidify and reintegrate basic science into their clinical world • Students revisit basic sciences having had exposure to clinical medicine
Virginia Commonwealth University School of Medicine	Update of Basic Sciences and Clinical Medicine • Four weeks in fourth year

* Details of basic science curricula were ascertained directly from the Web sites of the schools. See the text for details.

Table 2

Canadian Medical Schools With a Required Basic Science Curriculum in the Clinical Years, 2007*

School	Course description
Laval University Faculty of Medicine (Quebec City, QC)	Clinical Sciences: Pharmacotherapy
McGill University Faculty of Medicine (Montreal, QC)	Back to Basics • Reenforcement of basic science concepts as they relate to the experience of clinical practice • Course allows students to explore, in depth, additional areas of particular interest in clinical, basic science, and medical humanities
Memorial University of Newfoundland Faculty of Medicine	Integrated Basic, Community Health, and Clinical Sciences Fourth-year rotation
University of Ottawa Faculty of Medicine	Back to Basics
University of Saskatchewan College of Medicine	Microbiology and Infectious Diseases

* The Canadian medical schools that offer back-to-basic-science curricula included limited detail about course structure on their Web sites.

medical knowledge, interactive didactic sessions, journal clubs, experiential components such as observation or performance of laboratory procedures, and critical appraisal of pertinent scientific literature. Additionally, each ILS course has been developed to be broadly based and multidisciplinary (Table 3), emphasizing bench-to-bedside fundamentals. The first four ILS courses were Neoplasia and Neoplastic Diseases; Clinical Pharmacology; Integrated Surgical Life Sciences; and Infectious Disease in Obstetrics, Gynecology, and Reproductive Medicine. Curriculum Committee reviews revealed these courses to be successful, and three more courses were added in the following five years: Molecular Medicine, Science of Resuscitation, and Neuroscience. Each ILS course is directed by one or two faculty members who recruit additional faculty as needed, develop the course's learning objectives and syllabus, and to

Table 3

Integrated Life Science Course Options at the University of Pittsburgh School of Medicine

Course title	Coordinators' discipline (degrees)	Clinical disciplines represented	Basic science disciplines represented
Neoplasia and Neoplastic Disease	Oncology (PhD and MD)	• Clinical oncology • Ethics of clinical trials • Quality-of-life issues	• Biostatistics • Apoptosis and cell cycle • Genetics • Molecular and cell biology • Experimental design • Epidemiology
Clinical Pharmacology	Clinical pharmacology (PhD and MD)	• Clinical pharmacology • Drug use in liver and renal disease • Drug use in elderly, pediatric, and pregnant patients • Adverse drug reactions • Drug interactions • Therapeutic drug monitoring	• Pharmacogenetics • Pharmacokinetics • Pharmacotherapy of hypertension, ischemic heart disease, asthma, epilepsy, heart failure • Toxicology
Infectious Disease in Obstetrics, Gynecology and Reproductive Medicine	Obstetrics–gynecology (PhD and MD)	• Gynecology • Obstetrics • Infectious disease • Reproductive medicine	• Physiology • Microbiology • Pathology
Surgical Life Sciences	General surgery (PhD and MD)	• Clinical imaging • Surgery • Clinical anatomy	• Anatomy • Pathology • Pathophysiology
Molecular Medicine	Pediatrics (MD and MS)	• Internal medicine • Pediatrics • Cardiology • Pulmonology	• Molecular biology • Forensic science • Molecular genetics
Science of Resuscitation	Emergency medicine (PhD and MD)	• Cardiology • Pulmonology • Resuscitation • Ethics	• Physiology • Anatomy • Pharmacology

whom the students are accountable. Both clinicians and basic scientists teach the courses (Table 3), providing opportunities for these two groups to interact and for students to learn the clinical and basic science perspectives simultaneously from individuals who are actively working in these areas.

UPSOM has several methods of ongoing assessment of the success of the medical school curriculum. There is a curriculum committee, an evaluation subcommittee of the curriculum committee, and an annual curriculum colloquium which involves 120 faculty and students. The results of the detailed reports from each of these committees, of which the first two meet several times a year, have confirmed the ongoing success of the ILS initiative. In fact, it was because of the success of the ILS courses, as noted by the three committees, that the ILS initiative was expanded with three additional ILS courses in 2000. Furthermore, the primary goal of the ILS curricular initiative was to demonstrate to students how basic science and clinical science are integrated by exposing students with clinical experience to basic science. We have met that goal by fully integrating the ILS courses into the fourth-year medical student curriculum as described in the following section.

Neoplasia and neoplastic disease

This course examines the relationship between basic science and clinical management of the cancer patient and how basic science translates to treatment decisions. For example, the central role of receptor tyrosine kinases and angiogenesis in cancer development and progression are reviewed. Students learn about deregulated expression of ErbB receptor tyrosine kinase family members in breast cancer cells and the role that these and their downstream effectors, such as Src, play in the development and malignancy of the disease. Then, rational, targeted approaches to breast cancer treatment are covered, including methods that interfere with ErbB signaling, such as Herceptin, a recombinant monoclonal antibody that targets ErbB2.[17] Students also learn how inhibition of angiogenesis with agents such as bevacizumab—an antibody that targets vascular epidermal growth factor, a protein secreted by cancerous cells to promote blood vessel growth—has been used to successfully treat colon cancer and may become an approach to treating a variety of cancers, especially in combination with other therapeutic agents.[18] Thus, this course provides students with an opportunity to reflect on the continuum of knowledge, beginning with fundamental concepts discovered at the laboratory bench, and extending through translational hurdles to application at the patient's bedside.

During this course, students attend formal lectures, participate in a journal club, and rotate through a number of different outpatient cancer clinics. Several lectures directly address how clinicians and basic scientists interact to understand and treat specific cancers. For a given lecture session, a clinician who treats the disease presents along with a researcher who is involved in experimental approaches toward understanding an important molecular and/or cell biologic aspect of that particular disease. Through a journal club, students learn how to critically evaluate a scientific paper. In addition, each student must propose a clinical trial concept, giving sufficient scientific background and rationale to justify the experimental approach. The level of sophistication of this course is aimed specifically toward the fourth-year student; students in their preclerkship years of education would have neither the knowledge base nor the clinical experience to benefit from the highly integrated structure of this course.

Molecular medicine

This course teaches students the basics of molecular biology, including differential gene expression, types of DNA mutation (e.g., missense versus nonsense), genomic imprinting, and how molecular techniques, such as gene array, single nucleotide polymorphism genotyping, and whole-genome association analyses, are employed to investigate, diagnose, and treat disease. A major focus of the course is on genetic diseases that have been well characterized at the molecular level, such as cystic fibrosis, Duchenne muscular dystrophy, Huntington disease, and Prader–Willi syndrome. For example, cystic fibrosis results from mutation of the cystic fibrosis transmembrane conductance regulator (CFTR), the most common mutation being delta F508, which eliminates the amino acid phenylalanine located at position 508 in the protein, resulting in a misfolded protein and, as a consequence, protein degradation in the cell's endoplasmic reticulum.[19] Students learn about this and other CFTR mutations, the role of CFTR in maintaining cellular homeostasis, and research aimed at identifying targets for therapy. In addition, students learn about nonsense mutations, the mechanisms underlying their formation, and how high-throughput small molecular library screening has contributed to the identification of a drug that targets this mutation and has the potential to treat several diseases caused by such mutations.[20]

The course includes lectures, a journal club, and a visit to a crime lab. Interpretation of medical literature is stressed throughout the course, and, by the end of the course, students are expected to be comfortable reading medical reports that use molecular techniques. In addition, at the conclusion of the course, students understand basic molecular biology techniques and gain an intensive basic science understanding of several diseases that are well characterized at the molecular level.

Clinical pharmacology

This course examines issues of clinical pharmacology in four complementary themes: general clinical pharmacology, rational drug prescribing, disease-specific clinical topics, and special attention topics (reviewed by Tofovic et al[12]). In a given session of this course, students learn the best pharmacological treatment for a given condition, review the basic science that underlies the mechanism of action of the treatment, and discuss the basic concepts that are pertinent to understanding potential adverse reactions. For example, the principles of pharmacogenomics, which deals with inherited differences in drug responses, and individualized drug therapy, are reviewed, including genetic polymorphisms of drug-metabolizing enzymes and drug targets that, for example, underlie differential responses to statins or diuretics, among other drugs.[21]

Infectious disease in obstetrics, gynecology, and reproductive medicine

This course provides students with an understanding of the pathogenesis associated with organisms relevant to the female reproductive tract and an understanding of transmission of

organisms to the fetus. Research and clinical laboratory experiences expose students to contemporary laboratory techniques, including those used to identify pathogenic organisms. On a given day, a student may evaluate a patient with a particular reproductive-tract infection and then, later that same day, visit a basic science lab that specializes in the organism that causes the infection. At the conclusion of this course, students have gained an in-depth understanding of the unique organisms responsible for female reproductive-tract infections, are able to recognize the clinical manifestations of these infections, understand the potentially serious long-term consequences of sexually transmitted diseases, and understand the implications of maternal infections during pregnancy for fetal and neonatal development.

Surgical integrated life sciences

In this course, students review basic anatomic and embryologic principles and how to apply this knowledge in surgical interventions. For example, the anatomy and development of the abdominal wall are reexamined, and students then learn how to reconstruct the abdominal layers in cases of hernia. Students gain experience with diagnostic modalities in the anatomic areas of the digestive tract, the gynecologic and genitourinary systems, and the thoracocardiopulmonary complex. At the completion of the course, students have gained an appreciation of the dynamic role that anatomy plays in diagnostic reasoning and therapy in specialties such as surgery, radiology, and pathology.

Science of resuscitation

This course provides students with an understanding of how bench research in acute resuscitation is translated into clinical practice. The primary evidence that forms the basis of current advanced cardiac life support (ACLS) protocols is critically evaluated along with the practical actions advocated by ACLS. Students participate in structured laboratory experiences in resuscitation research that include direct involvement in bench work; these experiences emphasize how the physiological principles of resuscitation have been discovered. Each student is required to generate a written critique of an existing clinical problem or to propose a new clinical research project that considers the basic science of resuscitation and addresses important confounding variables that plague the field.

Summary and Discussion

The ILS program at UPSOM is an innovative, feasible, and well-received educational intervention to meet the current demands of training medical students to integrate basic biomedical knowledge into their clinical experiences. The program provides an opportunity for students to revisit and solidify their basic science knowledge after having had exposure to clinical medicine and, consequently, to assimilate biomedical science into their clinical practice. The success of this program is evident in the positive reception by both students and faculty; the number of courses has grown "by popular demand." After learning of the success of the initial course offerings in the mid-1990s, teams of basic science and clinical faculty and students developed new selectives in areas relevant to the students' future career plans. UPSOM has several methods of ongoing assessment of the success of the medical school curriculum. In addition to the curriculum committee, which has centrally governed oversight[2] of all courses (including ILS), a curriculum colloquium comprising 120 faculty and students and an evaluation subcommittee review all courses. The detailed reports from each of these committees, which meet several times a year, have confirmed the ongoing success of the ILS initiative. In fact, because of the success of the ILS courses as noted by the three committees, the ILS initiative was expanded.

By returning to the basic sciences in the senior year of medical school, when students' clinical reasoning and analytical skills are more mature, students gain a more meaningful understanding of the pathophysiology of diseases and targeted therapeutics. Students often report that they wished they had paid more attention during the first two years of basic science courses. This suggests that senior medical students are better able to appreciate the relevance of basic science concepts to clinical medicine once they have experienced substantial time on the clinical wards.

Only a limited number of medical schools have published descriptions of successful basic science curricula for their senior medical students, and nearly half of these come from outside the United States.[7–11,22] In Israel, a fairly sophisticated and integrative back-to-basic-science course was implemented at Ben-Gurion University for senior medical students, but it was only a one-week course ranging from 22 to 35 hours in total.[9] In England, the University of Manchester has made great strides to integrate basic science concepts into clinical training by using problem-based learning experiences (PBLs) in the third and fourth years of medical school, and evidence of growth has been reported in basic science knowledge between the third and fourth years.[22] The successful use of PBLs to better integrate clinical and basic science has also been reported; Harvard Dental School developed PBLs throughout their four-year program to help accomplish basic and clinical integration goals.[23] Still, few schools seem to have required basic science curricula integrated into the fourth year of medical training. In fact, one published report notes that strengthening basic science education in the clinical years poses a far greater challenge than incorporating clinical experiences into the traditional basic science years; the report describes the experiences of eight unnamed U.S. medical schools as they attempted to do so.[8] The authors describe several failed attempts to reinforce basic science during the clinical clerkships, such as a creative proposal to include basic scientists on ward rounds, another to add PBLs to clerkships, and another to include a seminar series on basic science issues in the fourth year.[8] Examples demonstrating the difficulties encountered by other medical schools as they attempted to create and sustain such curricula speak to the value of the approach of the ILS curriculum at UPSOM and similar successful innovations elsewhere. The UPSOM ILS curriculum is also distinctive in that it offers a broad selection of topics and is multidisciplinary by definition. In contrast, relatively few other programs offer students a choice for their basic science selection or cross more than two disciplines of medicine.

A majority of U.S. and Canadian medical schools offer nonrequired one- to four-week basic science electives during the fourth year of training, but few of these report integration of basic science with

clinical medicine during those electives. One example of a successful integrative elective is a women's health elective developed at the University of Michigan Medical School in 2002.[7] The elective correlates anatomy, physiology, histology, and pathophysiology with clinical medicine during a four-week block, and it incorporates input from teachers across multiple disciplines. However, only the small proportion of students who choose that elective benefit from its multidisciplinary nature.

During the past few years, appeals for greater collaboration among clinical and basic science departments have highlighted the need to provide scientists and physicians with opportunities to exchange ideas, to understand and value each other's perspectives, to teach each other, and to jointly teach tomorrow's physicians.[24–26] This need has been driven largely by increasingly rapid changes in science and medical technology, the push to move medically relevant discoveries from bench to bedside faster and more efficiently, and the increasing reliance of clinical medicine on recent discoveries.[15] Educational innovations such as the ILS course and the Scholarly Project requirement at UPSOM[25,27] are two examples of how basic science and research can be successfully integrated into the medical curriculum to achieve these goals.

In summary, the ILS course developed by UPSOM is an innovative approach to (1) reinforce basic science knowledge after students have begun to develop and apply diagnostic reasoning, (2) educate senior medical students about the ways that multidisciplinary teams of scientists and clinicians collaborate in their pursuit of new knowledge, and (3) demonstrate application of basic science through examples of translation into technologies and practices that improve care at the individual and community levels. Further, the ILS program may inspire motivated students to pursue additional training in scholarly investigation during residency and beyond. Further work is needed to define in more detail the ways in which students benefit from ILS-like programs, including whether and how integration of basic sciences into the clinical curriculum helps students become better thinkers and better lifelong learners.

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