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Integrating Clinical Medicine into Biomedical Graduate Education to Promote Translational Research: Strategies from Two New PhD Programs

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Abstract

For several decades, a barrier has existed between research and clinical medicine, making it difficult for aspiring scientists to gain exposure to human pathophysiology and access to clinical/translational research mentors during their graduate training. In 2005, the Howard Hughes Medical Institute announced the Med Into Grad initiative to support graduate programs that integrate clinical knowledge into PhD biomedical training, with the goal of preparing a new cadre of translational researchers to work at the interface of the basic sciences and clinical medicine. Two institutions, Baylor College of Medicine and the Cleveland Clinic/Case Western Reserve University, developed new PhD programs in translational biology and/or molecular medicine. These programs teach the topics and skills that today's translational researchers must learn as well as expose students to clinical medicine. In this article, the authors compare and contrast the history, implementation, and evaluation of the Translational Biology and Molecular Medicine program at Baylor College of Medicine and the Molecular Medicine program at the Cleveland Clinic/Case Western Reserve University. The authors also demonstrate the feasibility of creating a multidisciplinary graduate program in molecular medicine that integrates pathophysiology and clinical medicine without extending training time. They conclude with a discussion of the similarities in training approaches that exist despite the fact that each program was independently developed and offer observations that emerged during their collaboration that may benefit others who are considering developing similar programs.

The rapid pace of basic science research greatly exceeds the rate at which these findings are being translated into human health improvements.[1] As part of the national effort to shift the

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focus of biomedical research towards translational science, the National Institutes of Health (NIH) implemented the NIH Roadmap in 2004 with the goal of improving human health through advances in understanding disease pathogenesis and the development of disease diagnostics and therapeutics.[2] An essential component of this effort to accelerate translational research is the need for investigators who are skilled in these emerging disciplines.[3] Historically, the research community has looked to MD/PhD-trained physician scientists to fill this role. However, some in the field remain concerned that we are not training sufficient numbers of these physician scientists to meet our growing need.[4–6] Their concerns stem from the fact that MD/PhD-trained physician scientists are focusing their research efforts away from patient-oriented research, are choosing to enter private practice after training, and are facing increased pressure to generate clinical income.[4,7]

Although one potential solution to the shortage of translational researchers is to train more physician scientists, the costs and time associated with such training are substantial. Moreover, biomedical science is increasingly complex, as whole genome sequencing and other high throughput analyses affect important human health questions, thereby reducing the likelihood that individuals, regardless of their training, will possess the range of knowledge and the skills necessary to drive the translational research enterprise forward. Thus, many in the community recognize that multidisciplinary research teams of clinical and basic scientists must be a critical component of the workforce solution, as such teams enable each member to apply his or her specialized skills to important translational research questions.[3–4] These research teams do not, however, obviate the need for training translational researchers; rather, they require that scientists acquire a range of interdisciplinary research and communication skills.[8] Indeed, it is unlikely that the full scope of knowledge and expertise required to be an effective translational researcher can be acquired “on the job,” necessitating the inclusion of translational research skills into graduate training programs.[3]

Most graduate students who are pursuing degrees in biomedical science cite the desire to do clinically-relevant research as a major factor in their decision to become research scientists,[9] which bodes well for developing a PhD-trained translational researcher workforce. The predominant training paradigm, however, limits PhD students to course work largely focused on biochemistry, genetics, and/or molecular biology and training in a specific research discipline.[10] This curriculum does not prepare PhD students to become effective members of research teams because it does not expose them to physiology, pathobiology, and clinical research. Moreover, the language and culture of clinicians is foreign to PhD students,[5,9,11] at least in part because they have limited interactions with medical students and clinicians during their training. Thus, PhD training programs for translational scientists should be interdisciplinary to produce graduates who possess a broad knowledge base and the skills to become effective members, if not leaders, of multidisciplinary research teams that facilitate the “bench-to-bedside” process.[5,9,12–14]

Several published articles have described efforts to enhance the medical knowledge of PhD students through courses on human pathophysiology.[14–15] The Medical Engineering and Medical Physics (MEMP) program created by Harvard University in collaboration with the Massachusetts Institute of Technology also provides comprehensive training, though it is oriented for engineering and physics graduate students.[16] As part of a multi-pronged effort to train both clinicians and scientists, Wake Forest School of Medicine maintains a Molecular Medicine and Translational Science PhD program that includes both basic science and clinical/molecular medicine coursework along with dual PhD and MD mentorship of PhD candidates.[17] While these programs have merit, they do not meet the pressing national need for additional translational researchers.

In 2005, the Howard Hughes Medical Institute (HHMI) announced the Med Into Grad (MIG) initiative to support graduate programs that integrate medicine and pathobiology into PhD biomedical training, with the goal of preparing a new cadre of translational researchers to work at the interface of the basic sciences and clinical medicine.[12] Of the 23 MIG-supported programs, two institutions, Baylor College of Medicine (BCM) and the Cleveland Clinic/Case Western Reserve University (CWRU), developed new PhD programs in translational biology and/or molecular medicine.

In this article, we compare and contrast the history, implementation, and evaluation of BCM's Translational Biology and Molecular Medicine (TBMM) and CWRU's Molecular Medicine (MMED) PhD programs. These programs teach the topics and skills that today's translational researcher must learn as well as exposing students to clinical medicine. We also demonstrate the feasibility of creating a multidisciplinary graduate program in molecular medicine that integrates pathophysiology and clinical medicine without extending training time. We conclude with a discussion of the similarities in training approaches that exist despite the fact that each program was independently developed. These similarities prompted our collaboration to share current practices and evaluate outcomes.

About the TBMM and MMED Programs

Program development

The BCM faculty developed the TBMM program (see Table 1), one of 13 programs in Baylor's Graduate School of Biomedical Sciences, in response to the university's 2003 strategic plan. In November 2004, the Baylor Board of Trustees approved the TBMM program. In late 2004 and early 2005, BCM engaged in a self-study to prepare for accreditation by the Southern Association of Colleges and Schools Commission on Colleges. As a result, BCM instituted a quality enhancement plan (QEP), with the goal of providing students with the knowledge and skills to translate scientific discovery into improved health care. BCM solidified its support for the TBMM program by incorporating it into this QEP. The first class of eight students matriculated in August 2005. As of September 2012, 58 students are enrolled in the TBMM program. Twenty-four students have received PhD degrees, with an average time to completion of five years, which compares favorably with other graduate programs at Baylor that have an average time to completion of six years.

In 2002, the Cleveland Clinic and CWRU formally affiliated to launch the new Cleveland Clinic Lerner College of Medicine (CCLCM). The impetus for the creation of the MMED program (see Table 1) was two-fold--take advantage of the strengths of these two renowned institutions and address the growing gap between bench and bedside. Clinical and research faculty from the Cleveland Clinic and CWRU met weekly in 2003 to design an innovative PhD program that integrated medical knowledge into graduate education and trained graduate students to ask research questions in the context of human biology and disease. In 2005, the CWRU's faculty senate and School of Medicine's faculty council approved the MMED program, and, in 2006, the Ohio Board of Regents accredited it. At the onset, the Cleveland Clinic's leadership awarded credit during their annual performance reviews to clinicians and scientists as an incentive to take part in the MMED program. One of 24 biomedical science programs in CWRU's School of Graduate Studies, the MMED program became the first on-site PhD program at the Cleveland Clinic. The first class of nine students matriculated in July 2007. As of September 2012, 40 students are enrolled in the MMED program and five have received PhDs in molecular medicine, all of whom completed their training in less than five years.

Faculty and financial support

Both programs required significant buy-in from the basic science and clinical faculty for leadership and curriculum development. Ongoing program activities also require faculty to serve as thesis advisors, clinical mentors, and thesis/qualifying exam committee members, as well as on other program-specific committees (e.g., governance, curriculum, admissions). The participation of clinicians was critical for developing clinically-relevant curricula (e.g., in areas such as human research ethics) and remains vital for training students in clinical medicine that is relevant to students' thesis projects.

As part of BCM's 2003 strategic plan, Baylor committed to providing support for the TBMM program, including partial financial support for both first-year student stipends and administration, such as a full-time program administrator. The Cleveland Clinic's Lerner Research Institute provides partial support (50%) for first-year student stipends and subsidizes tuition costs in subsequent years, and it supplies additional administrative support, including a Molecular Medicine department office with a program administrator, recruiting/admissions coordinator, education coordinator, and evaluation coordinator. Both programs also obtained competitive funding from the HHMI MIG program (2006–2014) and from NIH T32 training awards.

Curricular design

Each program's curriculum provides graduate students with a foundation in human physiology and pathophysiology, as well as training in the traditional biomedical sciences, like cell and molecular biology, genetics, and biochemistry. The didactic curriculum for the TBMM program includes ten established graduate courses, which span 11 months. These first-year courses provide students with a knowledge base in biology and molecular technologies, which are crucial for further training in molecular medicine research skills. A competency-based approach guided our development of additional course work in translational research, pathophysiology, research ethics, clinical research design, biostatistics, and animal disease models (five courses in total). In addition, students complete three to four nine-week research rotations to assist them in selecting their thesis project and mentors. In their second year, students begin an individualized clinical project experience that focuses on the disease topic of their thesis project and is supervised by their clinical mentor (see Table 2 for examples of students' thesis topics and related clinical activities). Another second-year course introduces students to leadership concepts, including time management, team building, and conflict resolution. Finally, enrichment activities--such as journal clubs and seminars focused on translational research, and basic and clinical faculty research talks--provide opportunities for students to interact with their peers and the faculty, as well as to gain further appreciation of contemporary bench-to-bedside research endeavors.

Developing the first on-site PhD program at the Cleveland Clinic required the creation of a new curriculum designed to integrate the principles of basic science and human biology. The core curriculum spans 13 months and begins with a course in human physiology and disease, followed by five courses, covering cellular/molecular biology, metabolism, genetics, and immunology. It concludes with a course focusing on the principles of clinical and translational research, including ethical and regulatory issues along with biostatistics and epidemiology. Concurrently, students complete a laboratory techniques course, three 12-week research rotations, and a research seminar series. Interspersed throughout the program are enrichment activities covering basic, translational, and clinical topics (e.g., autopsy conferences, journal clubs, etc.) to provide students with opportunities to hone their research abilities and to network with faculty. In their second year, students complete a clinical experience course that both includes clinical elements (e.g., inpatient and ambulatory

experiences, observations of surgeries/diagnostic procedures, etc.) that are specific to the student's dissertation topic and is supervised by a clinical mentor (see Table 2). Students also complete two elective courses.

Dual mentoring with basic scientists and clinicians

In both programs, each student has two mentors whose roles are to guide the student's thesis research project, supervise his or her exposure to clinical medicine, and provide training in translational and/or clinical research. For TBMM students, the thesis mentor may be an MD, PhD, or MD/PhD researcher, who advises the student on his or her thesis research. The clinical mentor (typically a clinician) works with the student to design appropriate clinical activities, provide guidance on translational research projects and clinical research training, encourage collaborations with clinicians and other research team members, and advise on the clinical relevance of the student's thesis research project. For MMED students, the clinical mentor works with the student to create an individualized clinical experience proposal and provides clinical insight on the student's thesis research. The clinical mentor (typically a clinician) works closely with the thesis advisor (typically a basic/translational scientist). In both programs, both mentors are voting members of the student's thesis advisory committee and participate in the student's qualifying exam.

Evaluation of the TBMM and MMED Programs

With substantial support from the HHMI's MIG initiative leadership, we used a multi-step evaluation process to align our current strategies with our desired outcomes, visited other MIG institutions, and implemented program-specific evaluation measures/methods (see Table 3). First, in 2006, program directors from the MIG institutions[12] met to discuss evaluating the overall initiative, beginning with reporting on the instructional strategies and preliminary outcomes from each institution. Next, outside consultants introduced components of a logic model[18] and discussed strategies (e.g., dual mentoring from a clinician and a basic scientist) and outcomes (e.g., students' increased understanding of pathobiology) common to many MIG programs. HHMI staff then charged program directors with developing logic models and evaluation plans for their respective programs.

To help program directors build their evaluation capacity, HHMI staff implemented a peer evaluation cluster program (PECP), which they had used for other HHMI initiatives.[19] The PECP required that each MIG program director host one site visit and attend two others at assigned institutions. Each site visit lasted approximately a day and a half and involved reviewing the host institution's logic model, meeting with students/faculty, discussing instructional strategies, and reviewing evaluation methods/plans. Shortly after each site visit, the visiting team prepared a formal report for the host institution. For example, Baylor visited Rice University and the University of Alabama, while the Cleveland Clinic visited Harvard University and the University of North Carolina. Baylor and the Cleveland Clinic also visited each other on two occasions and identified approaches to measure short-term outcomes for their shared instructional activities (see Table 3). In addition to continuing our current evaluation process, we intend to direct future efforts toward tracking the career paths of TBMM and MMED graduates.

Comparing and Contrasting the TBMM and MMED Programs

For several decades, a barrier has existed between research and clinical medicine, making it difficult for aspiring scientists to gain exposure to human pathophysiology and access to clinical/translational research mentors during their graduate training.[5,13,15,20]

The TBMM and MMED programs were developed independently to address the bench-to-bedside gap, at different times, with different levels of pre-existing institutional and curricular resources, yet the overall design of both programs is similar (see Table 1). In addition, both programs reside at an institution with a medical school, admit a similar number of graduate students, and engage a large multidisciplinary faculty. Moreover, students in both programs have a thesis mentor and a clinical mentor, the latter of whom is charged with guiding the student's clinical experiences relevant to his or her thesis topic and with ensuring the clinical relevancy of the student's thesis research project. Next, the curriculum for both programs focuses on human physiology and pathophysiology, with foundational course work in molecular medicine and research skills. Also, the format of the qualifying examination for both programs requires students to prepare a research proposal that includes a clinical or translational research aim. Finally, both programs employ a range of enrichment activities to expose students to the culture and practice of translational research and clinical medicine, including: faculty research presentations, student research project presentations, journal clubs, annual retreats with distinguished outside speakers, and shared classes with medical students from their respective medical schools. These strong similarities are less surprising when viewed in the context of the common goals for translational research training established by each program.

Nonetheless, there are differences between the TBMM and MMED programs in the student populations, approaches to clinical training, roles of the clinical mentor, and curriculum, all of which have a bearing on the students' training experience. First, students pursuing the graduate portion of their MD/PhD training can enroll in the TBMM program, while there are no MD/PhD students in the MMED program, per a CWRU policy that prevents students from selecting the MMED option for their PhD training. This distinction reflects differences in institutional policies rather than in anticipated outcomes, and it provides TBMM program MD/PhD students who are interested in the clinical/translational focus of the program the opportunity to gain exposure to clinical research and to integrate translational activities into their graduate training. It is possible though that MD/PhD trainees will pursue careers that incorporate clinical medicine, and our outcome evaluations in the future will need to take this possibility into account. Next, the approach to clinical training differs between programs. The TBMM program's clinical project requires students to gain exposure to clinical research, while the MMED program's clinical experience has students explore different aspects of clinical medicine without a requirement for firsthand exposure to clinical research. Also, in the TBMM program, a student's clinical mentor may be his or her primary thesis mentor as well, while in the MMED program, a student's basic/translational science mentor must be his or her thesis advisor. In addition, the TBMM program requires an average commitment of half a day per week for two years (about 350 hours), in contrast to the 30 required hours for the MMED program; however, both programs encourage students to extend their exposure to clinical medicine beyond the required hours. Finally, the MMED program curriculum requires twice as many classroom contact hours as the TBMM program curriculum (558 versus 255 hours). However, the number of overall contact hours for both programs are quite similar when the clinical experience is included (605 and 608 hours respectively).

Program Features to Consider

The MIG initiative[12] highlights how different institutions have integrated human pathophysiology and medicine into their graduate curricula. Unfortunately, the lack of published data on these programs has made it difficult to define which strategies to expose graduate students to the bench-to-bedside continuum are most effective and feasible. We collaborated to learn more about the design, implementation, and evaluation of two new PhD programs at geographically separate institutions, and several observations emerged

during our collaboration that may benefit others who are considering developing similar programs.

- Both programs matriculated graduate students with varied backgrounds (e.g., computer science, mathematics, bioengineering). Some students did not have experience with common laboratory techniques, while others lacked sufficient knowledge of anatomy/histology to learn human pathophysiology. We offered enrichment activities to address these gaps without having to revise the core curricula.
- While the programs' clinical experiences vary in duration, some design principles are essential: (1) maximize each student's exposure to disease processes, preferably in his or her thesis topic area; (2) consult with legal representatives at clinical sites to ensure compliance with institutional policies; and (3) create venues where students can discuss insights about research and medicine.
- Consistently, students have reported that interacting with patients during the clinical experience helped to "put a face" on disease processes and served as a powerful motivator during their thesis research. We recommend providing similar opportunities for graduate students to foster their appreciation for the impact that disease has on actual patients.
- Basic scientists not engaged in clinical or translational research may not appreciate the time that graduate students devote to clinical activities outside of their laboratory responsibilities. We recommend that institutional leadership both reward clinical and basic science faculty for their teaching/mentoring contributions and showcase when students' clinical activities foster collaborations between basic scientists and clinicians.
- Students have reported that they appreciate clinicians who "get" graduate education and do not treat them as "mini medical students," which is especially important during seminars when clinicians may focus on treatment rather than disease mechanisms. MD/PhDs and clinicians who receive extramural research support seem more comfortable with their role on students' thesis and qualifying exam committees.
- Our comprehensive approach to evaluation improved our ability to make timely curricular improvements and obtain NIH funding to support our two new, still unproven translational graduate programs. This feature is also important for the long-term maintenance of our programs as the experience of the Markey Trust demonstrates how insufficient outcomes data makes it challenging to identify financial resources to sustain curricular initiatives.[15]

The NIH's Roadmap and the Clinical and Translational Science Awards emphasize the need for clinicians and basic scientists to work collaboratively to promote the clinical significance of basic science research.[2,11] We have the opportunity now in graduate education to explore different instructional models designed to prepare these translational researchers. We must also compare these training programs to determine what effect they may have on graduates' career trajectories and if they are indeed producing translational researchers to fill the gaps identified in the community.

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Table 1

Features of the Translational Biology and Molecular Medicine (TBMM) Program at Baylor College of Medicine and the Molecular Medicine (MMED) Program at the Cleveland Clinic/Case Western Reserve University

Characteristic	TBMM program	MMED program
Students	• 9–12 students enrolled per year • ≤25% students are MD/PhD candidates • Students apply directly to program	• 7–10 students enrolled per year • No MD/PhD students • Students apply directly to program
Faculty	• > 150 faculty • 46% PhD, 36% MD, 18% MD/PhD • From 8 basic science and 11 clinical departments • Each student has a basic science and a clinical thesis mentor, one of whom is designated as the primary mentor. Both serve on student's thesis committee.	• Currently 108 faculty • 64% PhD, 27% MD, 9% MD/PhD • From 10 laboratory and 14 clinical departments • Each student has a basic or translational science thesis advisor. A clinician serves as the clinical mentor. Both serve on the student's thesis and qualifying exam committees.
Core curriculum	Focused on human physiology and pathophysiology, as well as training in molecular, translational, and clinical research methodologies. Courses include: • Foundation in genetics, immunology, physiology, and histology (6 courses; 104 contact hours) • Pathophysiology (3 courses; 48 contact hours) • Research skills and ethics (6 courses; 103 contact hours) • 3 laboratory rotations (9 weeks each; in year 1) • Electives are optional	Begins with "Human Physiology and Disease" and concludes with "Principles of Clinical/Translational Research." Courses include: • Physiology, cell biology, metabolism/pharmacology, genetics, gene regulation, bioinformatics, and immunology (6 courses; 304 contact hours) • Statistics, epidemiology, ethics, and laboratory research methods (2 courses; 140 contact hours) • Advanced research in medicine series with medical students (50 contact hours; in years 1–2) • 3 laboratory rotations (12 weeks each; in year 1) • 2 required electives (84 contact hours)
Required clinical experience	Clinical projects tailored to complement each student's thesis project • Student preparation: ethics training, immunizations, criminal background check, and medical liability insurance • Average commitment: half a day per week in years 2–3 (~350 contact hours); optional until PhD completion • Required elements: (1) exposure to clinical medicine, (2) attend diagnostic and research conferences, and (3) exposure to clinical research • Participation in clinical research (optional) • Activities directed by clinical mentor	Individually designed experience starting in year 2 that aligns with thesis topic and is directed by the student's clinical mentor • Students must devote a minimum of 30 contact hours in the required elements: (1) attend ambulatory clinic, (2) attend clinical laboratory, and (3) observe operation/interventional procedure • Attend clinical seminars/grand rounds (optional) • Graded on pass/fail basis by clinical mentor • Students encouraged to continue with their clinical mentor during years 3–5

Characteristic	TBMM program	MMED program
	• Project sites include hospital, clinic, and global health settings	
Enrichment activities	• Presentations of ongoing research projects by potential mentors to 1st year students • Leadership training (year 2) • Bench-to-bedside journal club covering 5 human disease topics per year (weekly, years 1–2) and seminars (4 per year; all years) complementing journal clubs, outside speaker • Student research presentations (year 3 onwards) • Annual retreat--poster and talks by TBMM students, talks by basic/clinical mentor pairs, and external keynote speaker	• Clinical Connections seminar presentations by clinical mentors to highlight molecular advances in clinical interventions (6 per year; all years) • Year 1 molecular medicine journal club • Controversies in biomedicine series to discuss divisive research topics (6 per year; all years) • Elective autopsy conferences (2 per week; all years) • Student-led annual research retreat with keynote speaker and student presentations and posters

Table 2

Examples of Students' Thesis Topics and Related Clinical Experience Activities for the Translational Biology and Molecular Medicine (TBMM) Program at Baylor College of Medicine and the Molecular Medicine (MMED) Program at the Cleveland Clinic/Case Western Reserve University

Program	Student's thesis topic	Clinical mentor's department and examples of student's clinical activities
TBMM	Functional and population studies of polymorphisms in nuclear receptor coregulators	Medicine (breast cancer clinic) • Shadowed clinical mentor in breast cancer prevention clinic and breast cancer clinic in community hospital • Participated in setting up a tissue bank for a single-nucleotide polymorphism (SNP) study on breast cancer samples (developed institutional review board protocol, attended tissue bank development meetings, and managed bank) • Attended tumor boards and breast cancer genetics conferences • Attended medicine grand rounds • Attended clinical research education sessions organized by Office of Research to enhance skills in clinical trial design and conduct
	Adoptive immunotherapy for CD70-positive malignancies using genetically modified T cells	Pediatrics (hematology-oncology) • Shadowed physician at hematology-oncology ward rounds • Observed clinical trial enrollment for cytotoxic T cell (CTL) trials • Observed patients undergoing CTL infusions for treatment of nasopharyngeal carcinoma under clinical research protocol (phase II trial) • Wrote clinical case report with clinical mentor • Attended weekly CTL infusion clinical research meetings and took meeting minutes • Attended clinical research education sessions organized by Office of Research to enhance skills in clinical trial design and conduct
MMED	Immunomodulation in T cell mediated inflammation of the intestine	Gastroenterology • Observed physician-patient encounters in pouchitis clinic and inflammatory bowel disease clinic • Observed anal biopsy, ileostomy closure, and total proctocolectomy surgeries • Reviewed gastrointestinal pathophysiology with clinician • Observed colonoscopies • Attended endoscopies to see variety of procedures and assisted with consenting patients and processing tissue biopsies and blood samples for thesis research • Attended gastroenterology case conferences
	The role of tau on adult neurogenesis within the mammalian central nervous system	Neurology • Shadowed physician during work-ups of newly referred patients with suspected dementia • Observed psychologist's assessment of patients' cognitive and behavioral traits • Discussed clinical findings of MRI scans with neurologist

Program	Student's thesis topic	Clinical mentor's department and examples of student's clinical activities
		• Observed interventional treatment procedures • Attended Alzheimer association support group meetings • Attended neurology grand rounds and team meetings

Table 3

Strategies, Outputs, Outcomes, and Methods to Evaluate the Translational Biology and Molecular Medicine (TBMM) Program at Baylor College of Medicine and the Molecular Medicine (MMED) Program at the Cleveland Clinic/Case Western Reserve University

Strategies (approaches to achieve goals)	Outputs (direct results of program activities)	Outcomes (anticipated results in 1–6 years)	Methods (approaches to measure outcomes)
Develop and implement strategies/ processes for student recruitment and selection	• Number of qualified applicants and grant-eligible program matriculants • Number of graduates pursuing translational/clinical postdocs or jobs in industry	• Attract and admit qualified graduate students interested in translational and/or clinical research careers	• Demographics from applications • Student matriculation questionnaire • Annual research interest questionnaire for students • Exit interviews with graduates
Design new courses and/or modify existing courses to emphasize molecular biology, ethics, pathophysiology, and biostatistics/ epidemiology	• Number and type of courses/activities • Number and nature of program changes • Percent of students assigning positive ratings to courses/activities	• Identify successful approaches to train graduate students in medicine and pathobiology • Help faculty refine teaching skills to facilitate active learning in translational contexts	• Curriculum meetings/retreats • Student course evaluations • Student assessments of faculty • Class meetings with students • Focus groups (students/faculty) • One-on-one interviews with students
Create unique clinical experiences, enrichment activities, and dual-mentoring approach for students	• Types of clinical experiences for students • Student and clinical mentor's perceptions of clinical experience • Number of new collaborations between basic scientists and clinicians attributed to program	• Help students gain understanding of culture and practice of medicine • Develop a cadre of clinicians experienced in training graduate students • Improve faculty perceptions about the co-mentoring of graduate students	• Student logs of clinical experience • Student course evaluations • Periodic faculty questionnaires • One-on-one interviews with students • Training sessions for clinical faculty
Assess student performance	• Number of students making satisfactory progress towards thesis degree • Number of students presenting translational/ clinical research at regional/ national meetings • Number and type of students' scholarly products • Number of students passing qualifying exam • Number of students with translational/ clinical research aim to thesis	• Improve students' knowledge of and skills in basic, translational, and clinical research methods • Have students conduct medically relevant research	• Faculty/peer assessments of student performance/research • Thesis committee reports (two per year) • Annual review of students' progress • Annual review of students' curriculum vitae • Students' performance on qualifying exam and thesis

Impact (anticipated results in 7–10 years)

- Integrate basic, translational, and clinical research in the preparation of scientists
- Facilitate basic science discoveries to translational and clinical applications
-