On the Cover: The high level of organization in the cerebellum is revealed in the featured image. A 20μm thick parasagittal section from rat cerebellum was immunofluorescently labeled with antibodies against Myelin Basic Protein (green) and Vesicular Glutamate Transporters (red). Sections were counterstained with DAPI. Myelin basic protein is a major constituent of myelin sheaths of oligodendrocytes in the central nervous system, and allows visualization of white matter tracts. Vesicular Glutamate Transporters are present at the presynaptic terminal of excitatory neurons and facilitate the uptake of glutamate from the synaptic cleft. Strong immunoreactivity of glutamatergic terminals is observed in the molecular and granule cell layers.

Acknowledgments: Sabhya Rana, Mayo Clinic Graduate School of Biomedical Sciences student and Dr. Carlos B. Mantilla and Dr. Gary C. Sieck, thesis advisors
# Table of Contents

Mayo Clinic’s Mission, Primary Value, and Value Statements ............................................................... 2

Mayo Clinic Graduate School of Biomedical Sciences Mission and Administration ......................... 2

2017-2018 Academic Calendar ...................................................................................................................... 4

2018-2019 Academic Calendar ...................................................................................................................... 5

Introduction ..................................................................................................................................................... 6

Policies .............................................................................................................................................................. 12

Doctor of Philosophy Program in Biomedical Sciences ........................................................................ 17

M.D. – Ph.D. Program .................................................................................................................................... 28

Basic Science Master’s Degree Program ...................................................................................................... 56

Employee Master’s Degree Program ........................................................................................................... 69

Clinical Master’s Degree Program ................................................................................................................. 85

Course Listings ............................................................................................................................................... 101

Index ................................................................................................................................................................. 143
Mayo Clinic Mission
To inspire hope and contribute to health and well-being by providing the best care to every patient through integrated clinical practice, education and research.

Mayo Clinic Primary Value
The needs of the patient come first.

Mayo Clinic Value Statements
These values, which guide Mayo Clinic’s mission to this day, are an expression of the vision and intent of our founders, the original Mayo physicians and the Sisters of Saint Francis.

Respect
Treat everyone in our diverse community including patients, their families, and colleagues with dignity.

Compassion
Provide the best care, treating patients and family members with sensitivity and empathy.

Integrity
Adhere to the highest standards of professionalism, ethics and personal responsibility, worthy of the trust our patients place in us.

Healing
Inspire hope and nurture the well-being of the whole person, respecting physical, emotional and spiritual needs.

Teamwork
Value the contributions of all, blending the skills of individual staff members in unsurpassed collaboration.

Excellence
Deliver the best outcomes and highest quality service through the dedicated effort of every team member.

Innovation
Infuse and energize the organization, enhancing the lives of those we serve, through the creative ideas and unique talents of each employee.

Stewardship
Sustain and re-invest in our mission and extended communities by wisely managing our human, natural and material resources.

Mayo Clinic Graduate School of Biomedical Sciences Mission
The overriding mission of the Mayo Clinic Graduate School of Biomedical Sciences (MCGSBS) is to train future leaders in biomedical research and education. In order to pursue this goal, we will:

- Enroll outstanding students
• Utilize the unique education, research and clinical practice resources of Mayo Clinic to foster the individual academic strengths of each student;
• Engage students in interactive learning and research experiences that enhance their critical thinking, problem solving, and biomedical knowledge.

A fundamental goal of MCGSBS is to promote an academic environment that supports trainee and faculty development and facilitates biomedical innovation.

---

**Mayo Clinic College of Medicine**

Fredric B. Meyer, M.D.
*Juanita Kious Waugh Executive Dean for Education*

Scott A. Seinola
*Chair, Department of Education Administration*

Eddie L. Greene, M.D.
*Director, Office for Diversity*

---

**Mayo Clinic Graduate School of Biomedical Sciences**

L. James Maher, III, Ph.D.
*Dean*

Bruce F. Horazdovsky, Ph.D.
*Associate Dean*

Joseph C. Loftus, Ph.D.
*Assistant Dean, Mayo Clinic in Arizona*

John D. Fryer, Ph.D.
*Assistant Dean, Mayo Clinic in Florida*

Kim Wolfgram Salz
*Administrator*

Rachel L. Halsrud
*Operations Manager*

Robert L. Klingler
*Operations Manager, Mayo Clinic in Arizona*

Ann L. Johnson
*Operations Manager, Mayo Clinic in Florida*
2017-2018 Academic Calendar

**Summer Quarter (Term 201810)**

Registration for summer quarter courses opens – June 5, 2017  
Registration for summer quarter courses due – June 23, 2017  
Summer quarter begins – July 3, 2017  
Independence Day Holiday (observed) – July 4, 2017  
Last date to register or withdraw – Before one-half of the course is completed  
Labor Day Holiday – September 4, 2017  
Last day of quarter – September 22, 2017

**Fall Quarter (Term 201820)**

Registration for fall quarter courses opens – September 1, 2017  
Registration for fall quarter courses due – September 19, 2017  
Fall quarter begins – September 25, 2017  
Last date to register or withdraw – Before one-half of the course is completed  
Thanksgiving Holiday – Thursday, November 23, 2017  
Last day of quarter – December 15, 2017

**Winter Quarter (Term 201830)**

Registration for winter quarter courses opens – December 4, 2017  
Registration for winter quarter courses due – December 22, 2017  
Winter quarter begins – January 2, 2018  
Last date to register or withdraw – Before one-half of the course is completed  
Last day of quarter – March 23, 2018

**Spring Quarter (Term 201840)**

Registration for spring quarter courses opens – March 5, 2018  
Registration for spring quarter courses due – March 23, 2018  
Spring quarter begins – April 2, 2018  
Last date to register or withdraw – Before one-half of the course is completed  
Memorial Day Holiday – May 28, 2018  
Last day of quarter – June 22, 2018
2018-2019 Academic Calendar

Summer Quarter (Term 201910)

Registration for summer quarter courses opens – June 4, 2018
Registration for summer quarter courses due – June 22, 2018
Summer quarter begins – July 2, 2018
Independence Day Holiday (observed) – July 4, 2018
Last date to register or withdraw – Before one-half of the course is completed
Labor Day Holiday – September 3, 2018
Last day of quarter – September 21, 2018

Fall Quarter (Term 201920)

Registration for fall quarter courses opens – September 1, 2018
Registration for fall quarter courses due – September 18, 2018
Fall quarter begins – September 24, 2018
Last date to register or withdraw – Before one-half of the course is completed
Thanksgiving Holiday – Thursday, November 22, 2018
Last day of quarter – December 14, 2018

Winter Quarter (Term 201930)

Registration for winter quarter courses opens – December 3, 2018
Registration for winter quarter courses due – December 21, 2018
Winter quarter begins – January 2, 2019
Last date to register or withdraw – Before one-half of the course is completed
Last day of quarter – March 22, 2019

Spring Quarter (Term 201940)

Registration for spring quarter courses opens – March 4, 2019
Registration for spring quarter courses due – March 22, 2019
Spring quarter begins – April 1, 2019
Last date to register or withdraw – Before one-half of the course is completed
Memorial Day Holiday – May 27, 2019
Last day of quarter – June 21, 2019
Introduction
Mayo Clinic Graduate School of Biomedical Sciences

History

The Mayo Clinic developed gradually from the family medical practice of Dr. William Worrall Mayo and his sons, Dr. William James Mayo and Dr. Charles Horace Mayo. The elder Dr. Mayo came to Rochester in 1863 to practice medicine. His sons assisted him during their boyhood years and later joined him in the practice of medicine. As the demand for their services increased, the Mayos invited other physicians to work with them.

This pioneering venture in the private group practice of medicine became known in the early 1900s as Mayo Clinic. This name today describes an organization of over 3,300 scientists and medical and surgical specialists working together as a team for the advancement of medical and biomedical education, research in medicine and related sciences, and medical care.

Mayo awarded its first Ph.D. degree in 1917 in affiliation with the University of Minnesota. Since 1984, Mayo has been an independent, degree granting institution. In January 1989, MCGSBS became a separate unit that administers Ph.D. and Master’s degree programs in the biomedical sciences. Enrollment currently includes approximately 190 Ph.D. and M.D.-Ph.D. candidates, and 100 Master’s candidates in biomedical science.

Other educational components of Mayo Clinic include:

- Mayo Clinic School of Graduate Medical Education, organized in 1915 to offer programs of graduate medical education. Enrollment currently includes nearly 1,600 residents and fellows in clinical fields.
- Mayo Clinic School of Medicine (MCSOM), an undergraduate medical school offering the M.D. degree, opened in 1972. Current enrollment includes over 200 students on the Rochester, Minnesota campus. In July 2017, the national medical school will matriculate its first class of 50 students onto the new MCSOM Arizona campus.
- Mayo Clinic School of Health Sciences, organized in 1973 to provide training and certification in the health professions allied to medicine. The school offers 120 programs with an enrollment of more than 1,800.
- Mayo Clinic School of Continuous Professional Development, organized in 1977 to provide continuing education for care providers within Mayo Clinic, nationally and internationally.

Mayo Clinic is accredited by The Higher Learning Commission and is a member of the North Central Association, 230 South LaSalle Street, Suite 7-500, Chicago, Illinois, 60604, www.ncahlc.org, (800) 621-7440.

Mayo Clinic College of Medicine is registered with the Minnesota Office of Higher Education pursuant to Minnesota Statutes sections 136A.61 to 136A.71. Registration is not an endorsement of the institution. Credits earned at the institution may not transfer to all other institutions.

Faculty

All staff appointments are made to Mayo Clinic and this staff constitutes the faculty for the educational programs of Mayo Clinic. The 4,000 plus faculty members include full-time investigators in the
biomedical sciences, clinician investigators, and clinicians. Each member of the staff is full-time salaried and individual staff members have ample opportunity to teach. Members of the staff have the overall responsibility for undergraduate and graduate education in medicine and the biomedical sciences, for continuing education and research, as well as for the care of patients. Graduate faculty privileges are awarded to qualified faculty members with interest in delivering graduate level courses and in supervising candidates for graduate degrees.

Please see listing of graduate faculty and their research interests on the MCGSBS intranet site: http://intranet.mayo.edu/charlie/mayo-clinic-graduate-school-biomedical-sciences/

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**Facilities**

The majority of the educational programs, clinical practice and research are conducted within the facilities of Mayo Clinic, located in downtown Rochester, Minnesota. Mayo Clinic in Jacksonville, Florida; and Phoenix and Scottsdale, Arizona, also participate in Mayo’s clinical practice, education and research programs.

**Telecommunications System**

Mayo Clinic in Rochester, Arizona and Florida are linked via a sophisticated telecommunications system, which provides videoconferencing and data transmission.

Staff and students in Rochester, Arizona and Florida can have live, interactive courses and seminars via TV monitors. In addition, Mayo has a telephone dialing and pager system that ties all three sites together.

**Rochester**

**Campus**

The research activities in Rochester are centered in the Gonda, Guggenheim, Hilton, Opus, Stabile and Medical Sciences Buildings. Study areas and computer labs can be found in the Mitchell Student Center and administrative offices are located in the Guggenheim Building.

The Plummer Building houses Mayo Clinic’s medical library system, one of the largest in the world, containing more than 350,000 bound volumes and 4,300 medical and scientific journal subscriptions, as well as study areas. Access to extensive online medical database resources is readily available. Patient-care activity is centered in the Mayo, Baldwin, and Gonda Buildings. These interconnected buildings, together with Rochester Methodist Hospital, comprise the core of Mayo Clinic’s clinical facilities in downtown Rochester. Saint Mary’s Hospital, located three blocks west of the downtown campus, and Rochester Methodist Hospital are integral to the education programs, providing essential clinical care experiences for students and trainees.

**Community**

With a population of more than 175,000, Rochester and its surrounding communities have the livable qualities of a medium-size town while offering many big-city amenities. It is a dynamic Midwestern city that combines friendliness and geographical compactness with a cosmopolitan flavor. Money magazine has consistently ranked Rochester among the “best places to live” in the United States, based on its quality of life, excellent schools, reasonable cost of living, and affordable housing market.
Rochester offers a stimulating combination of arts and entertainment and education, plus a four-season calendar of sports and recreation. Active civic music and theater programs provide opportunities to participate and enjoy the arts. The University of Minnesota Rochester offers many undergraduate, graduate and postgraduate programs.

The Twin Cities of Minneapolis and St. Paul are an easy 75-minute drive to the north – providing access to metropolitan shopping, sporting and cultural events, and dining. Among the many attractions are the nationally recognized Guthrie Theater, Minnesota Orchestra, Walker Art Center and Mall of America. Both collegiate and professional baseball, basketball, football and hockey teams are based in the Twin Cities.

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**Florida**

**Campus**

Mayo Clinic in Florida’s campus in Jacksonville was established in 1986 as a comprehensive medical facility in the southeastern United States, where advanced programs in education and research support the highest-quality patient care.

Mayo Clinic achieved the vision of establishing an integrated campus in, 2008, when the Mayo Clinic Hospital opened on the campus. The hospital combines the best of high technology with quality patient care and attention to detail. Modern equipment and advanced technologies are used in a nurturing, friendly environment, merging the art of healing with the science of medicine. Mayo Clinic in Florida opened a 9,600 square foot J. Wayne and Delores Barr Weaver Simulation Center in 2013 to take advantage of new technology to advance the delivery of medical education.

Mayo Clinic in Florida recently opened a 10,000-square-foot freestanding Sleep Disorders Center, as well as the Gabriel House of Care, a 30-room, extended-stay patient housing facility for visiting transplant and cancer patients and their families.

In addition to full access to the core facilities on the Rochester campus, researchers at Mayo Clinic in Florida enjoy state-of-the-art facilities on the integrated campus including a rodent behavioral suite, multiphoton in vivo imaging, Ivis in vivo luminescent imaging, electrophysiology core, in vivo microdialysis, and an induced pluripotent stem (iPS) cell facility. The Birdsall Medical Research Building allows researchers to investigate neurological diseases such as Alzheimer’s, Parkinson’s and related diseases. Teams of geneticists, cell biologists and neurologists all benefit from Mayo Clinic’s brain bank in Florida, which houses more than 5,000 specimens. The Griffin Cancer Research Building supports Mayo’s many cancer studies. Faculty members study all stages of tumor progression, including early tumorigenesis, malignant progression, invasion and metastasis.

**Community**

The city of Jacksonville, built along the Atlantic Ocean and the St. Johns River in north Florida, is home to more than one million residents. Known for its miles of beautiful beaches, Jacksonville attracts many visitors for surfing, swimming, wind surfing, fishing and water skiing.

Tennis and golf are also highly popular activities in the region. The international headquarters for the Association of Tennis Professionals (ATP) and the national headquarters of the Professional Golf Association of America are located in Jacksonville.
Jacksonville is home to the annual Gator Bowl and the National Football League team, the Jacksonville Jaguars. The city also sports the Jacksonville Suns, an AA minor league baseball affiliate of the Miami Marlins. Jacksonville University and the University of North Florida field college basketball and baseball teams.

Jacksonville has five regional shopping centers, a zoo, two major museums, eight galleries, a symphony orchestra, and several theaters and nightclubs. The educational system offers nearly 250 public and private schools and 14 regional colleges and universities.

The nationally famous Jacksonville Jazz Festival is held each year in Metropolitan Park and the renowned Jazz Keyboard Competition is held annually at the Florida Theatre.

Jacksonville also is home to One Spark, which is billed as the World’s Crowdfunding Festival. One Spark is an annual event where artists, entrepreneurs and innovators display projects in a 20-square-block, multi-venue gallery in downtown Jacksonville to connect people with great ideas to the resources they need to make them a reality.

Mayo Clinic hosts the National Marathon to Finish Breast Cancer annually in February. Proceeds from the event are designated to Mayo Clinic’s Cancer research. Mayo Clinic also sponsors a cycling team which raises money to support research for transplant, diabetes and multiple sclerosis. Mayo Clinic faculty, staff and students have many opportunities to enjoy the outdoors while increasing awareness and funding to support our mission of advancing the science of healing.

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**Arizona**

**Campus**

Mayo Clinic in Arizona opened in 1987 as the premier academic medical center in the southwestern United States, where medical research and education are fully integrated with delivering the highest-quality patient care. Campuses are located both in Scottsdale and Phoenix. Both campuses offer excellent education facilities, including classrooms, lecture halls, Simulation Center, Center for Procedural Innovation, and extensive library and computer services. Patient care on the Scottsdale campus is centered around a five-story, 240-exam room outpatient clinic. The Mayo Clinic Building offers outpatient surgery; laboratory, diagnostic testing, imaging and pharmacy services; a patient-education library; a staff medical library and a 188-seat auditorium for patient, staff and student education programs.

In the Samuel C. Johnson Research Building and the Mayo Clinic Collaborative Research Building on the Scottsdale campus, Mayo Clinic research teams investigate complex diseases and conditions with a goal of improving care for patients. Areas of focus include a broad range of different cancers, with a particular strength in the blood cancer multiple myeloma; metabolic and endocrine diseases, such as diabetes and obesity; bioinformatics; genomics; and aerospace medicine. The Scottsdale research buildings also house scientists, trainees and students from Arizona State University and TGen (The Translational Genomics Research Institute).

Mayo Clinic Hospital, located on the Phoenix campus, has 268 licensed beds with 21 operating rooms, an emergency room, a transplant center and a full-service clinical laboratory. It also offers diagnostic imaging and noninvasive heart tests, and lung testing services. Mayo Clinic Hospital opened in the fall of 1998 and is the first hospital designed and built by Mayo Clinic. Also on the Phoenix campus are the new Mayo Clinic Education Center, Mayo Clinic Specialty Building and the Mayo Clinic Support Services.
Building. The Phoenix campus also includes a Child Care Center, on-campus hotel accommodations, the Help in Healing Home, American Cancer Society-Hope Lodge, and Hospice of the Valley.

**Community**

Scottsdale is located in the beautiful Sonoran Desert and is one of several cities comprising greater Phoenix, Arizona – the Valley of the Sun, a metropolitan area of over 4.5 million. Scottsdale’s 220,000 residents enjoy a vibrant mix of cultural and recreational opportunities. It has a nationally-recognized park system, championship golf courses, tennis courts, and miles of hiking, biking and equestrian trails. Several lakes just east of the city are popular places for weekend fishing and boating. Scottsdale is one of the world’s foremost art communities, and is home to many art galleries and museums. The Scottsdale Center for the Arts hosts exhibits, music and dance performances, live adult and children’s theater, and outdoor concerts and festivals year-round.

Sports fans will find collegiate and professional football, basketball, baseball and hockey teams in the Phoenix area. Phoenix is home to the Phoenix Open Professional Golf Tournament, Spring Training for 15 Major League Baseball teams, and regularly host major events such as The Super Bowl. Regional attractions include hiking and rafting in the Grand Canyon and Sedona red rock area, and snow skiing two hours away, near Flagstaff. Numerous vacation opportunities are nearby in California, Nevada, and Mexico, and the ski resorts of northern Arizona and the western Rocky Mountains.

Scottsdale has over 5,500 retail shops, ranging from specialty boutiques and major department stores to outlets and malls. There are 90 public and private schools and two colleges within the city limits. Arizona State University-Tempe and University of Arizona-Phoenix are nearby.

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**Graduate Student Association**

The Mayo Graduate Student Association is comprised of Ph.D. students pursuing graduate degrees at MCGSBS. Membership includes a representative from each track, a representative from the first year students, representatives from Arizona and Florida, a MCGSBS Education Committee member, a representative from the M.D.-Ph.D. program, and the past president. Its purpose is to facilitate interaction among graduate students, and among students, faculty and administration. It provides a means for students to give input concerning coursework and curriculum and other MCGSBS issues.
Policy
Policy

Stipends
Students accepted into the Ph.D. program receive a fellowship, which includes stipend, tuition and fees. The stipend, provided by Mayo Clinic Graduate School of Biomedical Sciences (MCGSBS), continues until successful thesis defense or up to five years, whichever comes first, contingent upon satisfactory performance. Students have up to 30 days after successful thesis defense for completion of all requirements. Support for additional years beyond the fifth (fourth for M.D.-Ph.D. students) must be provided by the advisor. Stipends for all graduate students are set at a uniform level (planned for $29,000 for 2017-2018) and are reviewed at regular intervals.

Students who are accepted into the M.D.-Ph.D. program are provided a fellowship with stipend, tuition and fees. The stipend is provided by Mayo Clinic School of Medicine (MCSOM) while the student is in medical school. MCGSBS provides up to four years of funding for the Ph.D. portion of the program. Extensions in the Ph.D. program beyond four years must be financially supported by the advisor. MCSOM and MCGSBS tuition and fees are provided by a full fellowship for students accepted into this combined M.D.-Ph.D. program, with satisfactory performance.

Clinical residents and research fellows accepted into the Master’s program receive the usual stipend for residents or fellows at their level of training.

Employees pursuing Master’s degrees on a part-time basis receive their usual employee salary.

Tuition
Annual tuition for graduate students is $27,000 for Ph.D. students. Tuition is $700 per quarter credit. Tuition is provided by a full fellowship for students who are enrolled in the Ph.D and M.D.-Ph.D. degree programs of MCGSBS. Extramural sources of funds are used to defray tuition when appropriate and all eligible students are expected to apply for individual extramural awards.

Registration
Registration for MCGSBS courses is accomplished through the Registrar’s Office and must be made online before the applicable deadline (see Academic Calendar). Mayo courses are primarily intended for individuals appointed to the degree programs of MCGSBS. Others may enroll if they show appropriate prerequisites and secure the course director’s approval. Enrollment in some courses is severely limited; degree candidates are given preference for these courses. Registration information is available on the MCGSBS intranet site.

Registration for credit
• Unless provided through a fellowship or scholarship, students will be billed for tuition.
• Tuition is refunded if a course is cancelled.

Changes in registration
• The current tuition refund policy is available on the Financial Aid intranet site.
• Retroactive registration after a course is completed is not permitted.
• Students who wish to register for a course after the registration deadline date must have written permission from the course director. Students will be allowed to register for courses up to 50% of completion.
Grading System

MCGSBS uses two grading systems:

- A Outstanding
- A- Excellent
- B+ Very Good
- B Acceptable
- B- Marginal/below standards expected
- C+ Below standards
- C Poor/lowest performance to receive credit
- F Unsatisfactory

The Grade Point Average (GPA) is based on:

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<thead>
<tr>
<th>Grade</th>
<th>GPA</th>
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<tbody>
<tr>
<td>A</td>
<td>4.0</td>
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<tr>
<td>A-</td>
<td>3.7</td>
</tr>
<tr>
<td>B+</td>
<td>3.3</td>
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<tr>
<td>B</td>
<td>3.0</td>
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<tr>
<td>B-</td>
<td>2.7</td>
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<tr>
<td>C+</td>
<td>2.3</td>
</tr>
<tr>
<td>C</td>
<td>2.0</td>
</tr>
<tr>
<td>F</td>
<td>0.0</td>
</tr>
</tbody>
</table>

The grading system to be used is determined by the course director at the time the course is established. A grade of “S”, “P”, or “N” is not considered in determination of GPA. A grade of “F” is considered in determination of the GPA if the course is assigned the standard letter grading scale. The GPA, which is recorded on the official transcript, is calculated by dividing the sum of all grade points earned by the sum of all credits assigned grade points. Students do not receive credits for courses in which they received an “F” grade. In addition to the grades, the transcripts show the following, if applicable (see list below). Students have a maximum of one year to make up any deficiency. If the deficiency is not corrected within the year, the transcript will show an “F” or “N” for the course.

- CRX Credit by examination
- I Incomplete
- PD Proficiency demonstrated and transfer credits awarded
- R Indicates a student registered for a course, did not attend and did not officially withdraw
- W Withdrawn
- WVD Course waived
- T Transfer course
- X Continuous registration/multi-term. A course that is continued over more than one quarter is given an “X” until the final quarter, when a grade is assigned. Credits are counted in the quarter the grade is entered.
- Z Repeated course

Students may retake a course one time to improve their grade with the permission of their program director and the course director. The higher grade will appear on the transcript and will be used in computation of the GPA.

Definition of Credit Hour

Credit is determined by the number of contact hours per week. A one-hour lecture per week equals one credit per quarter. A quarter is usually 12 weeks. In some courses, credit is also given for laboratory time.
Course Numbering

Graduate courses are designated with a 5— or 6— number. The 5— level courses are introductory graduate courses. The 6— level courses are MCGSBS core courses and the track courses considered to be at the boundary of what is known or done in a particular field. They can be expected to be exceptionally rigorous.

Residence Requirement

Regardless of how many transfer credits are awarded, candidates for graduate degrees from MCGSBS must complete a minimum period in residence after admission to their degree program. For Ph.D. degree candidates, the minimum period of residence will be two years, and for Master’s degree candidates the period is one year.

Transcript Request

Official transcripts will be issued by the Registrar’s Office only upon receipt of a written request with the student’s signature and social security number. E-mail requests will not be accepted.

Transcript Request forms can be found on the Office of Student Financial Aid and Registrar internet site.

Student Responsibility

Each graduate student must complete all requirements for a degree established by MCGSBS and the student’s track. It is the student’s personal responsibility to be aware of and to understand these requirements. A student’s advisor may not assume these responsibilities, nor substitute, waive, or exempt the student from any established requirement or academic standard. Such exemptions may, however, be proposed for consideration by MCGSBS. MCGSBS reserves the right to modify requirements at any time.

Extensions

Ph.D. appointments are for up to five years and M.D.-Ph.D. appointments are for up to four years in the Ph.D. program. Extensions beyond the fifth year for Ph.D. students and beyond four years for M.D.-Ph.D. students are permitted with evidence of satisfactory performance and a recommendation signed by at least four of the five members of the student’s Thesis Advisory Committee and the program director. Each extension is for a maximum of one year. If a Ph.D. student is extended into a sixth year or an M.D.-Ph.D. student into a fifth year, the student’s stipend and benefits must be provided by the advisor.

Extension Request forms can be found on the MCGSBS intranet site.

Confidentiality of Student Records

The Family Educational Rights and Privacy Act (FERPA) afford students certain rights with respect to their education records. The FERPA policy is available on the MCGSBS Policies and Procedures intranet site.
Equal Opportunity/Affirmative Action

MCGSBS is committed to equal opportunity and affirmative action in the appointment process. This policy is in accord with the policy of Mayo Clinic which is to seek and select persons for appointment, employment or admission, and to train, advance, promote, transfer and compensate such persons on the basis of individual capability, potential or contribution to the programs and goals of the institution. In making these selections and subsequent personnel decisions, Mayo Clinic is committed to pursuing affirmative action efforts to strengthen the participation of women, minorities, veterans, and persons with disabilities.

Additionally, Mayo Clinic respects, supports, and observes the laws, directives, and regulations of the state and federal laws that prohibit discrimination. Each department chair, administrator, supervisor and employee of Mayo Clinic is responsible for conducting appointment and employment activities in support of and in compliance with this policy.

MCGSBS policies and procedures are available on the MCGSBS Policies and Procedures intranet site.
Doctor of Philosophy Program in Biomedical Sciences
The Doctor of Philosophy Program in Biomedical Sciences

Purpose and Philosophy
The Biomedical Sciences Ph.D. Program is intended to train students in the most modern approaches to biomedical research, and to assist with development of analytical, technical, oral, and written communication skills, which allow students to become independent investigators of the most important and challenging problems in biomedical research.

Students are provided with a supportive atmosphere where they can find role models and mentors to emulate in the development of their research skills and begin acculturation into the biomedical research community. Courses introduce students to the body of information most important to their subsequent research endeavors and other educational activities facilitate the development of independent learning skills. Students are assisted with formulation of career goals and pathways which best utilize their individual talents and skills.

Mayo Clinic’s Ph.D. program places heavier emphasis on research training than on course work. This philosophy is a natural outgrowth of the institution’s long history as a center for investigation in the life sciences. Courses are, nevertheless, an integral part of the Ph.D. program providing the intellectual foundation necessary for a well-rounded scientist. A minimum of 42 credits is required of all Ph.D. students. Mayo Clinic’s graduate level courses in specific disciplines of the basic sciences will be adequate preparation for most students. All Ph.D. candidates must complete at least two years of full-time registration at Mayo to be eligible for the degree.

Admission Requirements

To be considered for admission to the Ph.D. program, applicants should:

1. Hold a bachelor’s degree from an accredited college or university with a minimum 3.0 grade point average based on a 4.0 scale.

2. Received scores on the verbal, analytical, and quantitative aptitude tests of the Graduate Record Examination indicating strong academic ability.

3. Completed at least one year of coursework, with demonstrated competence (B average or above), in the following undergraduate courses:
   - Biology
   - Calculus
   - Chemistry
   - Physics

In addition, foundation courses in biochemistry, molecular biology, cell biology and physiology are highly recommended. Biomedical Engineering and Physiology students are encouraged to have courses in quantitative science and engineering (e.g., signal processing, computer science, instrumentation).

4. Supply supporting documents, including:
   - Official transcripts
   - Official copies of GRE or MCAT scores
   - Three letters of recommendation
Foreign applicants must take the Test of English as a Foreign Language (TOEFL) to be considered for an appointment.

Each track may establish additional requirements.

Inquiries regarding admission to the Ph.D. Program in the Biomedical Sciences should be directed to:

Mayo Clinic Graduate School of Biomedical Sciences │ 200 First Street Southwest │ Rochester, MN 55905 │
(507) 538-1160
phd.training@mayo.edu

Completed applications must be submitted by December 1. Authority to make appointments rests with the Mayo Clinic Graduate School of Biomedical Sciences Education Committee. The application fee is $50.

Falsifying or omitting information on or accompanying the application may disqualify an applicant from admission or subject a student to dismissal.

The application and supporting documents become the property of MCGSBS upon receipt.

The average number of years to degree is 5.2.

**Core Courses**

The core curriculum has been designed to provide a common fundamental knowledge base and technical language supporting multiple discipline-specific, advanced fields.* With advice from a first year advisor and/or the program director, the core credits are chosen from the following courses:

**Summer**

**CORE 6000**  Responsible Conduct of Research ...............................................................1 cr.
**CORE 6150**  Genome Biology (begins in late July) .............................................................3 cr.

**Fall**

CORE 6100  Chemical Principles of Biological Systems.........................................................3 cr.
CORE 6200  Basic Graduate Immunology...............................................................................3 cr.

**Winter**

**CORE 6000**  Responsible Conduct of Research ...............................................................1 cr.
**CORE 6250**  Molecular Cell Biology ..................................................................................3 cr.
**CORE 6400**  Molecular Genetics ......................................................................................3 cr.
**CORE 6770**  Virology and Gene Therapy ...........................................................................3 cr.

**Spring**

CORE 6050  Critical Thinking and Scientific Writing............................................................2 cr.
CORE 6300  Molecular Biophysics .......................................................................................3 cr.
**CORE 6450**  Molecular Pharmacology and Receptor Signaling ........................................2 cr.
**CORE 6510**  Molecular Mechanisms of Human Disease ..................................................3 cr.
**CORE 6001  Responsible Conduct of Research Refresher Course...................................................0 cr.

*Students in Biomedical Engineering and Physiology are not subject to the same core requirements. Please refer to the specific Biomedical Engineering and Physiology track requirements.

** Required of all students.

***The NIH requires Responsible Conduct of Research (RCR) instruction at least once during each career stage, and at a frequency of no less than once every four years. Ph. D. and M.D.–Ph.D. students will be notified by MCGSBS when they are required to take the refresher course and no grade will be assigned.

---

**Area of Specialization/Track**

In addition to the core courses, track courses are also required. These courses are chosen with the aid and approval of the student’s advisor. Courses required by the different tracks are outlined in the next section. Any remaining credits needed to meet the 42 required credits may be selected from any area that the student and advisor deem appropriate and necessary. The typical program structure is as follows:

Year I Core, track course work, and laboratory rotations

Year II Advanced courses and commencement of thesis research

Year III, IV, & V Primarily thesis research with some additional advanced courses, seminars and journal clubs.

All students enrolled in the Ph.D. program are full-time students. Full-time enrollment each quarter may include any combination of course work, laboratory rotations or research. This does not preclude students from registering for research before course work is complete. These students retain full-time enrollment status and will be graded on the S-N scale. No credit hours will be assigned, and research is not calculated in the GPA. Students who have completed all course work and are engaged in full-time thesis research must register for research each quarter.

**Laboratory Rotations**

Each student must complete three laboratory rotations in three different laboratories for six credits. Rotations must be done in the laboratories of faculty with full graduate faculty privileges. These credits count towards the track credits required. Students who have participated in a Mayo Summer Undergraduate Research Fellowship (SURF) or the Mayo Post-baccalaureate Program may substitute this experience for one lab rotation. Students entering the Ph.D. program with a relevant Master’s degree may petition MCGSBS to waive one laboratory rotation. A minimum of 42 credits will still be required for graduation.

**Advisor**

A Ph.D. degree mentor must have full graduate faculty privileges and must be selected after three laboratory rotations have been completed.
Official Degree Planning Tools

The use of a degree program planning tool is required and allows students to list the course work to fulfill degree requirements, including transfer credits. Fifty percent of the credits counting toward degree must be graded on the A-F grading system.

For students who matriculated prior to July 2015, submission of the Degree Program Form (DPF) to MCGSBS remains a graduation requirement. This is required by December 31 of the second academic year.

Effective May 1, 2016, students who matriculated July 2015 or later are expected to complete and submit a Degree Planning Tool (DPT) form to their program director by March 31 of the first academic year. This form lists all course work proposed to fulfill degree requirements, including transfer credits. The DPT should be updated as courses are completed and must be reviewed with the program director. Frequency of review is at the program director’s discretion.

Changes in Approved Degree Program Plan

For students who matriculated prior to July 2015, the approved Degree Planning Form (DPF) must be fulfilled in every detail to meet graduation requirements. Any alterations in the original program plan must be requested in writing and approved by the program director, advisor, and MCGSBS.

For students who matriculated July 2015 or later, any changes in courses that differ from the original Degree Planning Tool (DPT) form must be reviewed with the student’s program director and advisor to ensure the changes will still fulfill graduation requirements.

Minimum Grade Requirements

Students are expected to maintain a grade point average of 3.0 in didactic course work. Students whose performance falls below this standard in a given quarter will be placed on academic probation, as described in the Deficiencies and Unsatisfactory Progress and Warning, Probation and Dismissal policies outlined on the MCGSBS Policies and Procedures intranet site.

Transfer Credits

A total of 21 credits may be transferred into the Ph.D. Program.
Core Course Policy

Students who wish to transfer graduate credits to substitute or to waive credits for a Mayo core course must contact the Mayo course director and their program director. To substitute or to waive core course credits, the student is required to prove competence by taking an exam dictated by the course director on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo core course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Track Required Course Policy

Students who wish to transfer graduate credits to substitute or to waive credits for a track required course must contact the Mayo course director and their program director. To substitute or to waive track required course credits, at the Mayo course director’s and the program director’s discretion the student is required to prove competence by taking an exam on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the track required course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Elective Course Policy

Students who wish to transfer graduate credits to substitute for a Mayo elective course must contact the Mayo course director and their program director. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo course, the student may request the transfer credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

External Courses Policy

Students who wish to transfer credits not in substitution for a MCGSBS course(s) may request credit for graduate courses taken at another institution if they received a grade of A or B. The request must have the approval of the student’s program director and MCGSBS. A description of the course from the course catalog or a course outline must accompany the request. The time interval since the credits were earned is a consideration in such decisions. Credits must normally have been earned within the previous five years, as determined by the program director.

Qualifying Examinations

The qualifying examinations are intended to test the student’s fund of information in the sciences related to the chosen field of study and to evaluate the student’s ability to reason critically.

Written Qualifying Examination

The written qualifying examination must be completed before September 30 of the third year for Ph.D. students depending on track and before September 30 of the second year for M.D.-Ph.D. students. MCGSBS must be informed of the exam date three weeks in advance so that the Ph.D. Written Qualifying Examination Report form can be sent to the exam chair. The written qualifying examination will test the
breadth of biomedical knowledge, and analytic and critical reasoning skills. The content and format of the examination is determined by each track. The written qualifying examination may be taken no more than twice. If it is not passed on the first attempt, the exam must be retaken by the end of the quarter following the quarter in which the exam was first taken. Failing the examination once will result in the student being placed on academic probation. Failing the examination twice will result in dismissal.

**Oral Qualifying Examination Committee**

Oral qualifying exam committee composition requires approval of the program director and the Mayo Clinic Graduate School of Biomedical Sciences Education Executive Committee before September 30 of the third year for Ph.D. students, depending on track, and before September 30 of the second year for M.D-Ph.D. students. All members must have graduate faculty privileges.

The oral qualifying exam committee must consist of:

- A minimum of four members from four different independent research programs
- Three of the four must have full graduate faculty privileges, including the committee chair
- Two of the four must be designated by the program director as experienced examiners

**Oral Qualifying Examination**

When MCGSBS is notified that the written qualifying examination has been passed, the oral qualifying examination may be taken. MCGSBS must be informed of the date of the examination three weeks in advance so that the Ph.D. Oral Qualifying Examination Report form can be sent to the oral qualifying examination committee chair. The oral qualifying examination must be completed before December 31 of the third year for Ph.D. students, depending on track, and before December 31 of the second year for M.D.-Ph.D. students. All approved committee members must be present at the exam. Any absent member is considered a dissenting vote. Only one dissenting vote will be allowed for a “Pass” or “Conditional Pass.” In the event of a Conditional Pass, the specific requirements that must be satisfied by the student must be listed on the back of the Ph.D. Oral Qualifying Examination Report form. The oral qualifying examination may be taken no more than twice. If it is not passed on the first attempt, the exam must be retaken by the end of the quarter following the quarter in which the exam was first taken. Failing the examination once will result in the student being placed on academic probation. Failing the examination twice will result in dismissal.

**Thesis**

**Thesis Advisory Committee**

Ph.D. candidates are expected to submit to the MCGSBS office the composition of their Thesis Advisory Committee no later than December 31 of the student’s third year, depending on track. M.D.-Ph.D. students are expected to submit to the MCGSBS office the composition of their Thesis Advisory Committee no later than December 31 of their first year in the Ph.D. program. The student’s advisor, who is chair of the committee, must have full graduate faculty privileges. M.D.-Ph.D. student thesis advisory committees must include a member of the M.D.-Ph.D. Executive Committee, either as a voting member or ex-officio.

Thesis advisory committee composition requires approval of the program director and the Mayo Clinic Graduate School of Biomedical Sciences Education Executive Committee. All members must have graduate faculty privileges.

The Thesis Advisory Committee must consist of:
• The committee must consist of five members; any additional members beyond five will be ex-officio.
• Three faculty members must have Full Faculty Privileges (FF), including the chair.
• A minimum of two members must be Experienced Examiners (each track may have additional requirements).
• Two faculty members must have mentored a student to Ph.D. degree.
• The committee for M.D.-Ph.D. students must include a member of the M.D.-Ph.D. Executive Committee either as a voting member or ex-officio.

**Thesis Proposal**
A written thesis proposal, presentation and thesis committee discussion of the proposal must be completed by December 31 of the student’s third year for Ph.D. students, depending on track, and by December 31 of the second year for M.D.-Ph.D. students. This requirement may be accomplished during the oral qualifying examination or at a separate committee meeting for this purpose. The Thesis Advisory Committee must be approved prior to this committee discussion.

The Mayo Institutional Review Board must review all protocols for research involving the use of human subjects. It is the candidate’s responsibility to secure approval of any such protocols before the research is undertaken.

**Preparation of thesis**
The thesis is the most important document that the Ph.D. candidate will prepare during the course of graduate study and is a record of the scientific accomplishments that justify the awarding of the degree. The thesis is archival. Consequently, MCGSBS has developed standards for its format and style, which should be closely followed. MCGSBS Thesis Guidelines for Ph.D. thesis are available on the MCGSBS intranet site under For Students/General Forms/Resources. The student’s advisor must sign a form indicating that he/she has read the thesis and that it is ready for defense prior to distribution to the thesis advisory committee members. The Verification that the Thesis is Ready to Defend form can be accessed on the MCGSBS intranet site under For Students/General Forms/Resources. The thesis must be submitted to the Thesis Advisory Committee at least three weeks prior to the final oral examination.

Students enrolled in the M.D.-Ph.D. program must submit their final thesis to their Thesis Advisory Committee and the Verification of Thesis Corrections form must be signed and submitted to the MCGSBS office before they can resume studies in Mayo Clinic School of Medicine (MCSOM).

**Student Progress**
Students must have meetings every six months with their Thesis Advisory Committees. Ph.D. students are required to have their first meeting at 2.5 years. Students are expected to register each quarter and will be contacted if they have not registered.

M.D.-Ph.D. students should form their thesis committee by December 31 of their first year in the Ph.D. phase of the program and have a thesis committee meeting prior to December 31 of their second year in the Ph.D. phase of the program, and every six months thereafter. M.D.-Ph.D. student thesis advisory committees must include a member of the M.D.-Ph.D. Executive Committee, either as a voting member or ex-officio.

To remain in good standing, compliance with these requirements is expected. Continuation of stipend depends upon remaining in good standing.
Publication Requirement
Ph.D. thesis research must make a substantial contribution to the biomedical literature and preparing work for publication is an important part of research training. The expectation is that student thesis research will result in multiple publications, with the requirement for graduation of a minimum of one peer-reviewed first-authored original paper accepted for publication. Students are required to indicate in publications their affiliation with and support from MCGSBS. Exceptions to the publication requirement must be submitted as a recommendation from the Thesis Advisory Committee with endorsement from the program director, and approval determined by the Mayo Clinic Graduate School of Biomedical Sciences Education Committee. This policy was effective April 1, 2008.

Final Oral Examination
The final oral examination will be scheduled after 1) the written qualifying and oral qualifying examinations have been passed, 2) all course work shown on the Degree Program form has been completed, and 3) a copy of the title page of the thesis is filed in the MCGSBS office. MCGSBS must be informed of the date of the examination three weeks in advance so that the Ph.D. Final Oral Examination Report form can be sent to the Thesis Advisory Committee chair. The exam will be open to the Mayo public. Members of the Thesis Advisory Committee should receive copies of the thesis at least three weeks prior to the final oral examination.

Voting members of the Thesis Advisory Committee must be present in real time via physical presence or video- or teleconferencing at the final oral examination. Only one dissenting vote will be allowed for a “Pass.” Any absent voting member is considered a “Fail” vote. Passage of the final oral examination requires a minimum of four passing votes, otherwise a determination of “Fail” must be made. Thus, no more than one Thesis Advisory Committee member may be absent for the final oral examination. The final oral examination may be taken no more than once. Failing the examination will result in dismissal. PhD appointments in MCGSBS will continue no more than 30 days beyond a successful thesis defense date.

Final Thesis Corrections
After the student has passed the final oral examination, the student has no more than 30 days to complete all degree requirements. The chair of the Thesis Advisory Committee must sign a form indicating he/she is satisfied that the final corrections to the thesis have been made and before the student will be cleared for graduation. MCGSBS will not certify completion of degree requirements until the final thesis has been submitted.

Graduation
Students are granted degrees four times a year: February, May, August, and November. The May date involves a formal ceremony as part of the Mayo Clinic graduation exercises in conjunction with MCSOM. No ceremony is held in February, August, and November, but students who graduate at one of these times are encouraged to participate in the May ceremony.

To graduate in February, August or November students must have all requirements completed by the first working day of the month prior to the graduation month. To graduate in May, students must have a draft of the thesis to their advisor by March 1. All other requirements including the final oral examination must be successfully completed by April 1, except submittal of the thesis. The final copy of the thesis must be submitted by May 1. Students should keep in mind that Ph.D. appointments in MCGSBS will continue no more than 30 days beyond a successful thesis defense date when scheduling the thesis defense.
Students are allowed no more than 30 days to complete Ph.D. degree requirements after a successful thesis defense. This policy was effective November 1, 2014. If a student does not meet the thesis deadline, he/she will be required to re-defend his/her thesis.
Graduation deadlines:

<table>
<thead>
<tr>
<th>To graduate in:</th>
<th>Requirements must be completed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>January 1</td>
</tr>
<tr>
<td>May</td>
<td>-Draft of thesis to advisor by March 1</td>
</tr>
<tr>
<td></td>
<td>-All requirements including final oral examination must be completed by April 1, except final submittal of final thesis</td>
</tr>
<tr>
<td></td>
<td>-Thesis submitted by May 1</td>
</tr>
<tr>
<td>August</td>
<td>July 1</td>
</tr>
<tr>
<td>November</td>
<td>October 1</td>
</tr>
</tbody>
</table>
M.D.-Ph.D. Program

The M.D.-Ph.D. program is a highly competitive program for students with exceptional academic records and previous research experience. Both the M.D. and Ph.D. degrees may be earned in an integrated seven-to-eight-year program. Students follow the Mayo Clinic School of Medicine (MCSOM) curriculum for two years. Step 1 of the United States Medical Licensing Examination (USMLE) must be taken by the end of the second year and a passing score must be documented before entry into the Ph.D. phase of the dual degree. Students then begin Mayo Clinic Graduate School of Biomedical Sciences (MCGSBS) training. The advanced course work in the track and the thesis research are undertaken and usually completed in the next three to four years. During the final two years, students complete the MCSOM curriculum.

The elements of the Ph.D. training for students enrolled in the M.D.-Ph.D. program are generally the same as those for non-M.D.-Ph.D. candidates, except for laboratory rotations. M.D.-Ph.D. students are required to take the following courses:

- **CORE 6000** Responsible Conduct of Research
- **CORE 6100** Chemical Principles of Biological Systems (all tracks except BMEP)
- **CORE 6150** Genome Biology
- **CORE 6300** Molecular Biophysics (required for BMEP)

*Plus two additional courses from the list of intermediate and advanced quantitative biology courses:

- **BMB 6000** Biological Macromolecules
- **BMB 6030** Data Analysis and Mathematical Modeling in Biomedical
- **BMB 6040** Research Fractals and Chaos in Biosciences
- **BMB 6050** Biological Kinetics
- **BMB 6675** Protein Structure and Dynamics
- **BMEP 6350** Advanced Concepts in Molecular Biophysics
- **CORE 6300** Molecular Biophysics

- **CTSC 5600** Statistics in Clinical and Translational Research
- **CTSC 5601** Utilizing Statistics in Clinical Research
- **CTSC 5610** Introductory Statistical Methods II
- **CTSC 5650** Survival Analysis
- **CTSC 5740** Systematic Reviews and Meta-Analyses

*BMEP students satisfy this requirement through BMEP track required courses.

M.D.-Ph.D. students are also required to take two M.D.-Ph.D. selectives:

- **MDPH 5150** Medical Scientist Survival Skills I
- **MDPH 5200** Medical Scientist Survival Skills II

M.D.-Ph.D. students are required to register for the weekly M.D.-Ph.D. conference each year during the Ph.D. phase of the program:

- **MDPH 5300** Weekly MD-PhD Conference
Track requirements
Students must complete all required track courses, journal clubs and seminars, except the MGS laboratory rotations. The laboratory rotation requirement for M.D.-Ph.D. students is satisfied by completing three one-month, full-time rotations. It is recommended that one rotation be completed before entering medical school, the second between the first and second years of medical school and the third between medical school and graduate school (after taking USMLE Step 1).

MDPH 5000 Laboratory Rotation for M.D.-Ph.D. Students

Waived courses

CORE 6050 Critical Thinking & Writing – waived for M.D.-Ph.D. students in the Neurobiology of Disease track

CORE 6200 Basic Graduate Immunology – waived for M.D.-Ph.D. students in the Immunology track

CORE 6510 Molecular Mechanisms of Human Disease – waived for M.D.-Ph.D. students in the Clinical and Translational Science Track

BMEP 6700 Physiology from Cells to Organisms – waived for M.D.-Ph.D. students in the Biomedical Engineering and Physiology Track (and students with existing MD if pass WQE)

MPET 5808 Introduction to Molecular Pharmacology – waived for M.D.-Ph.D. students in the Molecular Pharmacology and Experimental Therapeutics track

M.D.-Ph.D. student thesis advisory committees must include a member of the M.D.-Ph.D. Executive Committee, either as a voting member or ex-officio.
Biochemistry and Molecular Biology – Ph.D. Degree

D. J. Katzmann, Ph.D., *Program Director*
J. R. Hawse, IV, Ph.D., *Associate Program Director*

Biochemistry and Molecular Biology Track:
*Biochemistry and Structural Biology | Cell Biology | Genetics | Cancer Biology*

### Course Work

#### CORE Courses (10 credits required)
- **CORE 6000**  Responsible Conduct of Research .......................................................... 1 cr.
- **CORE 6100**  Chemical Principles of Biological Systems .............................................. 3 cr.
- **CORE 6150**  Genome Biology .......................................................................................... 3 cr.
- **CORE 6250**  Molecular Cell Biology ............................................................................... 3 cr.

#### Lab Rotations (6 credits maximum, a minimum of 3 rotations)
- **MGS 5102**  Lab Rotations (8 weeks) .............................................................................. 2 cr.
  M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

#### Track Requirements (8 credits required)
- **BMB 5200**  BMB Works in Progress (1 cr. /yr.)* .......................................................... 2 cr.
- **BMB 6500**  BMB Journal Club (1 cr. /yr.)** ................................................................. 4 cr.
- **BMB 6900**  BMB Thesis Proposal .................................................................................. 2 cr.

*Two credits maximum. Students must attend all years enrolled in the program and present annually from Year 2. At least 70% attendance is required. **Four credits maximum. Students must attend all years enrolled in the program and present annually at the journal club and also attend the associated BMB Seminar. At least 70% attendance is required at both the journal club and seminar.

#### Intermediate Courses (6 credits required)
- **BMB 5000**  Introduction to Cancer Biology .................................................................... 3 cr.
- **BMB 5400**  Developmental Biology ............................................................................. 2 cr.
- **CORE 6050**  Critical Thinking and Writing ................................................................... 2 cr.
- **CORE 6300**  Molecular Biophysics ............................................................................... 3 cr.
- **CORE 6400**  Molecular Genetics .................................................................................. 3 cr.
- **CORE 6510**  Molecular Mechanisms of Human Disease ........................................... 3 cr.

#### Advanced Courses (7 credits required)
- **BMB 5350**  Hormones and Cancer ............................................................................... 1 cr.
- **BMB 6000**  Biological Macromolecules ....................................................................... 3 cr.
- **BMB 6030**  Data Analysis and Math Modeling in Biomedical Research ......................... 3 cr.
- **BMB 6040**  Fractals and Chaos in Bioscience ................................................................. 2 cr.
- **BMB 6050**  Biological Kinetics ..................................................................................... 3 cr.
- **BMB 6070**  Cancer Biology II: Molecular Mechanisms .............................................. 3 cr.
- **BMB 6075**  Epigenetics of Cancer and Addiction ......................................................... 3 cr.
- **BMB 6320**  Special Topics in Cancer Biology ................................................................. 1 cr.
- **BMB 6650**  Receptor Trafficking and Signaling .............................................................. 2 cr.
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMB 6660</td>
<td>Transcription, Chromatin and Epigenetics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMB 6665</td>
<td>Current Topics in Nucleic Acids Biochemistry</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMB 6675</td>
<td>Protein Structure and Dynamics</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

**Electives (5 credits required)**
Any courses approved for graduate credit.

**Other Journal Clubs (maximum of 4 credits: 2 Advanced and 2 Elective)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMB 6510</td>
<td>Cancer Biology Journal Club</td>
<td>1cr. /qtr.</td>
</tr>
<tr>
<td>BMB 6520</td>
<td>Current Topics in Aging Research</td>
<td>1cr. /qtr.</td>
</tr>
<tr>
<td>BMB 6801</td>
<td>Concepts of Vesicular Trafficking Journal Club</td>
<td>1cr. /qtr.</td>
</tr>
</tbody>
</table>

Courses to be selected in consultation with your thesis advisor.

**Research**
BMB 6890  Research in Biochemistry and Molecular Biology
Must enroll every quarter once a thesis laboratory is selected. Directed research projects under the supervision of a faculty advisor.

**Qualifying Exams and Thesis Research**
Students are expected to complete their rotations and select the laboratory for their thesis studies within six months of joining the program.

**Written Qualifying Exam**
Written qualifying exam: Students take the written qualifying exam at the end of the first year. The exam is a one-day exam held at the beginning of July. The exam consists of demonstrating critical evaluation and understanding of two published primary research papers relevant to the broad field of Biochemistry and Molecular Biology as covered in the core courses CORE 6100, CORE 6150 and CORE 6250 as well as the intermediate courses, CORE 6400 and BMB 5000. Three sets of papers reflecting the three areas of emphasis of the track: BSB, CBG and CB, will be made available to the students three days before the exam, and the student then selects two papers from which a series of specific questions are answered. The questions will cover foundation of knowledge in addition to synthesis of concepts. The exam is prepared and graded by the faculty and a pass rate of 70% is required for successful completion of the exam.

**Oral Qualifying Exam**
Students are expected to take the oral qualifying exam during the winter of the second year, approximately one year after joining their thesis laboratory. Before taking the exam, the student must prepare a final version of their thesis proposal and circulate it to their thesis committee at least two weeks before the examination. The thesis proposal serves as a springboard for faculty to probe the student’s background knowledge, ability to propose and defend hypotheses, and design experiments to test these hypotheses. The oral qualifying exam committee must conform to MCGSBS requirements and be approved by the program director.

**Thesis Proposal**
The written thesis proposal now matches the new format of NIH R01 grants and, hence, is limited to 14 pages, including illustrations but not including references. In the student’s own words, the proposal
should outline the rationale for the proposed project and how it is to be executed. The proposal is subdivided into the following sections.

- Abstract: Summary of your project (1 page).
- Specific Aims: Describe briefly the aims of your project and hypotheses (1 page).
- Significance: Put your project into context with what is known about this area of biology and show the importance of the questions you are asking (2-3 pages).
- Innovation: How is the project you are proposing novel and groundbreaking (~1 page).
- Approach: Describe what you plan to do and how you plan to do it. Include preliminary data for each aim that sets the scene and supports your hypotheses (8-10 pages).

Reflecting the importance the track puts on the quality of this document and the role it plays in planning your thesis studies, 2 credits are given for preparing and defending the proposal.
Biomedical Engineering and Physiology – Ph.D. Degree

C. B. Mantilla, M.D., Ph.D., Program Director
A. Manduca, Ph.D., Associate Program Director

Biomedical Engineering and Physiology has four major areas of emphasis:
Biomechanics | Biomedical Imaging | Molecular Biophysics | Physiology

Course Work

CORE Courses (6 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CORE 6050</td>
<td>Critical Thinking and Scientific Writing</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CORE 6300</td>
<td>Molecular Biophysics</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>

Track Requirements (24 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEP 5200</td>
<td>Mathematics in Biomedical Engineering and Physiology</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 5452</td>
<td>Biomechanics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5704</td>
<td>Bio-Instrumentation and Signal Processing</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5800</td>
<td>Introduction to Medical Imaging</td>
<td>6 cr.</td>
</tr>
<tr>
<td>BMEP 6600</td>
<td>Biomedical Engineering and Physiology Seminars</td>
<td>1 cr.</td>
</tr>
<tr>
<td>BMEP 6650</td>
<td>BMEP Journal Club</td>
<td>1 cr.</td>
</tr>
<tr>
<td>BMEP 6700</td>
<td>Physiology from Cells to Organism</td>
<td>6 cr.</td>
</tr>
</tbody>
</table>

*BMEP 6700 students may exclude these in accordance with M.D.-Ph.D. requirements.
Also waived for students matriculating with an MD degree, contingent upon passing WQE.

Lab Rotations (6 credits maximum, a minimum of 3 rotations)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGS 5102</td>
<td>Lab Rotations (8 weeks)</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

Research

BMEP 6890  Research in Biomedical Engineering and Physiology

Must enroll every quarter once a thesis laboratory is selected. Directed research projects under the supervision of a faculty advisor.

Biomechanics Emphasis | Requirements (10 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEP 5250</td>
<td>Anatomy for Biomedical Engineering &amp; Physiology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 5450</td>
<td>Laboratory Methods in Biomedical Image Processing</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5453</td>
<td>Fundamental Concepts in Biomechanics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5460</td>
<td>Finite Element Methods</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5802</td>
<td>Advanced Principles of Biomechanics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6470</td>
<td>Two-Dimensional Digital Signal Processing</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 6710</td>
<td>Numerical Methods in Biomedical Research</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6840</td>
<td>Laboratory Methods in Biomechanics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6857</td>
<td>Tutorial in Cellular Mechanics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6861</td>
<td>Tutorial in Skeletal Muscle Physiology</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>
### Biomedical Imaging Emphasis | Requirements (minimum of 11 credits required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEP 5100</td>
<td>Radiological Health</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 5160</td>
<td>Radiation Physics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5250</td>
<td>Anatomy for Biomedical Engineering &amp; Physiology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 5450</td>
<td>Laboratory Methods in Biomedical Image Processing</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5460</td>
<td>Finite Element Methods</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5550</td>
<td>Image Guided Procedures in Biomedical Applications</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 5740</td>
<td>Magnetic Resonance Imaging Systems</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6100</td>
<td>Medical Health Physics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6151</td>
<td>Radiation Oncology Physics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6302</td>
<td>Tutorial in Ultrasonic Imaging</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6304</td>
<td>Tutorial in Physiological Imaging</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6305</td>
<td>Seminars in Machine Learning</td>
<td>1 cr.</td>
</tr>
<tr>
<td>BMEP 6420</td>
<td>Wave Propagations and Biomedical Applications</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6470</td>
<td>Two-Dimensional Digital Signal Processing</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 6490</td>
<td>Advanced Topics in Biomedical Image Processing</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6500</td>
<td>Special Topics in Imaging Science</td>
<td></td>
</tr>
<tr>
<td>BMEP 6704</td>
<td>Digital Signal Processing I</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 6705</td>
<td>Digital Signal Processing II</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 6710</td>
<td>Numerical Methods in Biomedical Research</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6730</td>
<td>Laboratory Methods in Magnetic Resonance Imaging</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6740</td>
<td>Advanced Topics in Magnetic Resonance Imaging</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6750</td>
<td>Magnetic Resonance Technical Seminar</td>
<td>1 cr.</td>
</tr>
<tr>
<td>BMEP 6770</td>
<td>Fuzzy Logic Theory and Applications</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 6853</td>
<td>Readings in Biomedical Engineering</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

### Molecular Biophysics Emphasis | Requirements (minimum of 11 credits required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6100</td>
<td>Chemical Principles of Biological Systems</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6450</td>
<td>Molecular Pharmacology and Receptor Biology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMEP 6350</td>
<td>Advanced Concepts in Molecular Biophysics</td>
<td>4 cr.</td>
</tr>
</tbody>
</table>

Additional Courses:
- Choose at least three of the following:
  - BMB 6000  Biological Macromolecules                                        | 3 cr.   |
  - BMB 6030  Data Analysis and Mathematical Modeling in Biomedical Research  | 1 cr.   |
  - BMB 6050  Biological Kinetics                                              | 3 cr.   |
  - BMB 6675  Protein Structure and Dynamics                                   | 2 cr.   |
  - CORE 6150 Genome Biology                                                   | 3 cr.   |
  - CORE 6250 Molecular Cell Biology                                           | 3 cr.   |
  - CORE 6400 Molecular Genetics                                               | 3 cr.   |

### Physiology Emphasis | Requirements (10 credits required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEP 6830</td>
<td>Laboratory Methods in Physiology</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

Additional Courses:
- Choose at least three of the following:
BMEP 6000  Tutorial in Exercise Physiology ................................................................. 2 cr.
BMEP 6300  Tutorial in Neurophysiology ................................................................. 3 cr.
BMEP 6855  Tutorial in Cardiovascular Physiology .................................................. 3 cr.
BMEP 6856  Tutorial in Respiratory Physiology ......................................................... 3 cr.
BMEP 6858  Tutorial in Smooth Muscle Physiology .................................................. 2 cr.
BMEP 6859  Tutorial in Renal Physiology ................................................................. 2 cr.
BMEP 6860  Tutorial in Endocrine Physiology ......................................................... 2 cr.
BMEP 6861  Tutorial in Skeletal Muscle Physiology ................................................ 2 cr.
BMEP 6862  Tutorial in Neuromotor Control Physiology ........................................ 2 cr.
BMEP 6870  Systems Physiology I .............................................................................. 3 cr.
BMEP 6871  Systems Physiology II ............................................................................. 3 cr.
BMEP 6872  Systems Physiology III .......................................................................... 3 cr.

Qualifying Exams and Thesis Research
During the first two years of the program, each student is expected to select a laboratory and thesis advisor. This occurs largely as a result of lab rotations. By the beginning of the second year all students should select an area of emphasis. Students may combine areas. At the beginning of the second year, all students must take and satisfactorily pass a comprehensive qualifying exam, consisting of both written and oral components. The written qualifying exam focuses on required core curriculum courses taken in the first year and tests the conceptual integration of material in these courses. The oral qualifying exam will include a presentation of proposed research and tests the synthesis of course work and research interests.

During the second year of the program it is expected that all students will have selected a thesis advisor and a Thesis Advisory Committee, which is required to consist of a minimum of three Experienced Examiners from the BMEP Experience Examiners list and approval of the Biomedical Engineering & Physiology Education Committee. A thesis proposal, presentation, and thesis committee discussion of the proposal must be completed by December 31 of the third year.

Each student is expected to meet with their Thesis Advisory Committee at least twice a year to discuss progress towards their dissertation research. The Thesis Advisory Committee will decide when the research has progressed sufficiently so that a dissertation can be written, and the student will then write their dissertation and publicly defend it.
Clinical and Translational Science – Ph.D. Degree

A. J. Windebank, M.D., Program Director
S. C. Ekker, Ph.D., Associate Program Director

Course Work

CORE Courses (10 credits required)
CORE 6000 Responsible Conduct of Research ................................................................. 1 cr.
CORE 6100 Chemical Principles of Biological Systems ......................................................... 3 cr.
CORE 6150 Genome Biology ..................................................................................................... 3 cr.
*CORE 6510 Molecular Mechanisms of Human Disease ....................................................... 3 cr.
*Clinical and Translational Science M.D.-Ph.D. students may exclude this in accordance with M.D-Ph.D. requirements.

Lab Rotations (6 credits maximum, a minimum of 3 rotations)
The track education committee will guide students to a minimum of one rotation each in laboratory-based translational research (wet bench); patient-based translational research (human studies, clinical trials, CRU-based); and population-based translational research (epidemiology, statistics, health outcomes, biomedical ethics, community engagement).

MGS 5102 Lab Rotations (8 weeks) ......................................................................................... 2 cr.
M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

Track Requirements (12 credits required)
CTSC 5010 Clinical Research Protocol Development ............................................................ 2 cr.
CTSC 5020 Regulatory Issues in Clinical Research ............................................................. 1 cr.
CTSC 5300 Introduction to Clinical Epidemiology ................................................................ 1 cr.
CTSC 5600 Statistics in Clinical and Translational Research ............................................. 2 cr.
CTSC 5601 Utilizing Statistics in Clinical Research ............................................................... 1 cr.
CTSC 5720 Clinical Trials: Design and Conduct .................................................................... 1 cr.
CTSC 6110 CTS Works in Progress ....................................................................................... 1 cr.
(Students gain credit only for quarters in which they present. Minimum one credit required.)
CTSC 6120 Case Studies in Translation ............................................................................... 2 cr.
CTSC 6130 CTS Journal Club .............................................................................................. 1 cr.
(Students gain credit only for quarters in which they present. Minimum one credit required.)
Grant Writing Workshop ........................................................................................................ 0 cr.
Writing for Scientific Publication Workshop ......................................................................... 0 cr.

Research
CTSC 6890 Research in Clinical and Translational Science
Must enroll every quarter once a thesis laboratory is selected. Directed research projects under the supervision of a faculty advisor.

Advanced and Elective Courses (14 credits required)
Forty-two credits are required for graduation. In addition to the core and track requirements, courses should be selected after consultation between the student, their advisor, and the program director/associate program director. Depending on the student’s area of concentration (laboratory, patient
or population-based translational science) additional advanced courses will be selected from either CTSC track courses or MCGSBS core courses in the basic science disciplines.

### Clinical Trials

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5190</td>
<td>Complementary and Alternative Medicine Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5240</td>
<td>Principles and Practices of Pediatric Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5250</td>
<td>Science Beyond the Lab: Intersections of Science, Society and Policy</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5260</td>
<td>Methods and Foundations in Biomedical Ethics</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5261</td>
<td>Biomedical Ethics II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5262</td>
<td>Biomedical Ethics III</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5721</td>
<td>Advanced Topics in Clinical Trials: Protocol Development and Implementation</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

### Community-Engaged and Health Disparities Research

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5070</td>
<td>What Researchers Need to Know about Community-Engaged Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5080</td>
<td>What Researchers Need to Know about Eliminating Health Disparities</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

### Translation

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5140</td>
<td>Epigenetics &amp; Epigenomics: Impact on Translational Research and Future Medical Practice</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5190</td>
<td>Complementary and Alternative Medicine</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5202</td>
<td>Independent Study of Laboratory Methods</td>
<td>1-2 cr.</td>
</tr>
<tr>
<td>CTSC 5270</td>
<td>Hepatobiliary Pathobiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5271</td>
<td>Pathobiology of Digestive Disease</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5280</td>
<td>Applied Enteric Neurosciences in Health and Disease</td>
<td>1 cr.</td>
</tr>
<tr>
<td>MPET 6820</td>
<td>Regenerative Medicine</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

### Clinical Epidemiology

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5290</td>
<td>GI Population Sciences</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5310</td>
<td>Clinical Epidemiology II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5390</td>
<td>Advanced Applied Epidemiological Methods</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5500</td>
<td>Genetic Epidemiology: Association Studies</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

### Quantitative and Qualitative Methods

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5610</td>
<td>Introductory Statistical Methods II</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CTSC 5640</td>
<td>Logistic Regression</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5641</td>
<td>Propensity Scoring Methods</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5650</td>
<td>Survival Analysis</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5690</td>
<td>Critical Appraisal of Statistical Methods in Medical Literature</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5710</td>
<td>Practical Data Collection</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5810</td>
<td>Qualitative Research Design, Methods, and Analysis</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5820</td>
<td>Introduction to Survey Research</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>
**Health Services and Comparative Effectiveness Research**

CTSC 5201  Independent Study for Clinical Practice Issues .................................................. 1-2 cr.
CTSC 5740  Systematic Reviews and Meta-Analyses ............................................................. 2 cr.
CTSC 5760  Medical Decision Making ...................................................................................... 1 cr.
CTSC 5761  Evidence-based Medicine for Clinical Researchers ............................................ 1 cr.
CTSC 5770  Diagnostic Testing Strategies ................................................................................ 1 cr.
CTSC 5850  Introduction to Psychological and Behavioral Measurement .......................... 1 cr.
CTSC 5860  Behavioral Interventions in Clinical Research .................................................... 1 cr.
CTSC 5870  Social & Behavioral Foundations of Health in Health Sciences Research ............... 1 cr.
CTSC 5910  Economic Evaluation in Health Care .................................................................. 1 cr.
CTSC 5930  Introduction to the U.S. Health Care System ...................................................... 1 cr.
CTSC 5940  Secondary Data Analysis ....................................................................................... 1 cr.

**Biomedical Informatics**

CTSC 5960  Introduction to Medical Informatics .................................................................... 2 cr.
CTSC 5961  Health Information Technology Evaluation: Clinical Informatics Methods ................ 1 cr.

**Qualifying Exams and Thesis Research**

The qualifying examination for the CTS track is both a written and an oral examination. The written qualifying examination which covers the breadth of material in the core courses is divided into two parts. The first part of the examination is comprised of short answer essay questions covering statistics, epidemiology, biochemistry and genome biology. The second part of the examination is preparing a short proposal based on a translational research question. The exam will be prepared and graded by the faculty responsible for teaching the courses. This examination will be offered two times each year. The exam must be completed successfully before the end of the second year in the program.

For the oral qualifying exam, students will submit a written thesis proposal and defend their thesis research proposal. The proposal should summarize the goals, methods, and rationale for the research project. The specific guidelines for the form of this proposal are available from the CTS pre-doctoral associate program director. This proposal must be submitted to the oral qualifying exam committee four weeks prior to the examination. The oral examination will be composed of two or three parts. The first part will be an oral presentation by the student of his/her proposal; the second part will be a discussion between the student and the oral qualifying exam committee about this proposal.

If there were any conditional elements or weaknesses identified at the time of the written qualifying examination, the committee may then add a third part to the examination which will include a wide-ranging discussion of either the area of deficiency or course work material covered by the student during the first two years. Students will be notified after their written qualifying examination whether this third component should be expected during the oral qualifying exam. The oral qualifying exam must be completed within six months of completing the written qualifying exam.
Written Qualifying Examination

The Written Qualifying Examination (WQE) tests your breadth of biomedical knowledge, as well as your analytical and critical reasoning skills.

This examination must be completed before the end of your second year in the program. The Center for Clinical and Translational Science (CTSC) predoctoral programs education specialist will assist you in selecting a date to take it.

These courses must be completed before you take the exam:

- CORE 6000 — Responsible Conduct of Research
- CORE 6100 — Chemical Principles of Biological Systems
- CORE 6150 — Genome Biology
- CTSC 5010 — Clinical Research Protocol Development
- CTSC 5020 — Regulatory Issues in Clinical Research
- CTSC 5300 — Introduction to Clinical Epidemiology
- CTSC 5600 — Statistics in Clinical Research
- CTSC 5601 — Utilizing Statistics in Clinical Research
- CTSC 5720 — Clinical Trials: Design and Conduct

The examination involves preparing a short proposal based on a translational research question the student generates from recent scientific articles. Generally, the subject matter is outside of the student's area of research training.
Immunology
Immunology – Ph.D. Degree

K. E. Hedin, Ph.D., Program Director

Course Work

CORE Course (16 credits required)
CORE 6000  Responsible Conduct of Research ................................................................. 1 cr.
CORE 6100  Chemical Principles of Biological Systems ....................................................... 3 cr.
CORE 6150  Genome Biology .................................................................................................. 3 cr.
**CORE 6200  Basic Graduate Immunology ........................................................................ 3 cr.
**CORE electives* ................................................................................................................. 6 cr.

* Ph.D. students may take any core courses approved for graduate credit as electives.
** Immunology M.D.-Ph.D. students may exclude these in accordance with M.D.-Ph.D. requirements.

Lab Rotations (6 credits maximum, a minimum of 3 rotations)
MGS 5102  Lab Rotations (8 weeks).......................................................................................... 2 cr.
M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

Track Requirements (4 credits required)
During the first two years, students must take a total of four credits as follows: IMM 6863 for one credit each for each of the first and second years. The final two credits can be taken from a combination of any of the following: IMM 6862, IMM 6863, IMM 6867, or one credit can be from a journal club in another track.

IMM 6862  Current Topics in Cell Activation and Signaling .................................................. 1 cr.
IMM 6863  Current Topics in Immunology ........................................................................... 1 cr.
IMM 6867  Current Topics in Clinical and Translational Immunology ................................. 1 cr.

Track Tutorials (12 credits required)
Students are required to take the following tutorial courses.

IMM 6877  Tutorial in Molecular Basis of Immune Recognition ........................................ 2 cr.
IMM 6879  Tutorial in Cellular Activation ............................................................................. 2 cr.
IMM 6880  Tutorial in Immunopathology ............................................................................. 2 cr.
IMM 6882  Tutorial in Mucosal Immunity ............................................................................ 2 cr.
IMM 6884  Tutorial in Tumor Immunology .......................................................................... 2 cr.
IMM 6885  Tutorial in the Generation and Function of B Cells ........................................... 2 cr.

Electives (4 credits required)
Any courses approved for graduate credit. In addition, before completion of the program, all students are encouraged to attend the one week long summer course in advanced immunology sponsored by the American Association of Immunologists.

Research
IMM 6890  Research in Immunology
Must enroll every quarter once a thesis laboratory is selected. Directed research projects under the supervision of a faculty advisor.
Qualifying Exams and Thesis Research
By the end of the first year of the program, each student is expected to select a laboratory and thesis advisor. At the end of the second year, all students take a written and oral qualifying exam. The written exam precedes the oral exam and is administered over two consecutive half-day sessions. This exam covers fundamental Immunology, including the material taught in the core Immunology course and the six required Immunology tutorials. The exam is prepared and graded by the faculty responsible for teaching the courses.

Within two months after passing the written exam, all students must take and satisfactorily pass an oral qualifying exam, but no later than October 31 of the third year. Immunology track students are required to have five faculty members on their exam committee, the composition of which will be determined by the Immunology program director with input from the student and the advisor. The student and advisor may choose two examiners and the Immunology program director drawing from a designated pool of examiners, will choose the remaining three.

A written thesis proposal, presentation, and Thesis Advisory Committee discussion of the proposal must be completed by the middle of the student’s third year. Immunology track degree candidates, however, are strongly encouraged to complete this requirement within two months of successfully passing the oral qualifying exam. The composition of the Thesis Advisory Committee will be determined by the mentor with input from the student and must be approved by the Immunology program director and MCGSBS. The Thesis Advisory Committee must consist of a minimum of five faculty members; three members must have full privileges.
Molecular Pharmacology and Experimental Therapeutics – Ph.D. Degree

R. M. Weinshilboum, M.D., Program Director
L. Wang, M.D., Ph.D., Program Co-Director
K. A. Campbell, Ph.D., Associate Program Director

Course Work

CORE Courses (12 credits, all required courses)
CORE 6000  Responsible Conduct of Research ................................................................. 1 cr.
CORE 6100  Chemical Principles of Biological Systems ......................................................... 3 cr.
CORE 6150  Genome Biology ..................................................................................................... 3 cr.
CORE 6250  Molecular Cell Biology .......................................................................................... 3 cr.
CORE 6450  Molecular Pharmacology and Receptor Signaling ............................................ 2 cr.

Lab Rotations (6 credits maximum, a minimum of 3 rotations)
MGS 5102  Lab Rotations (8 weeks) .......................................................................................... 2 cr.
M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

Track Requirements (12 credits required)
MPET 5100  Pharmacology Seminar Series (required attendance; no credit)
*MPET 5808  Introduction to Molecular Pharmacology ........................................................ 4 cr.
MPET 6800  Research Seminars in Pharmacology (1 cr. /yr.) ................................................ 4 cr.
MPET 6805  Drug Metabolism and Pharmacogenomics ........................................................ 2 cr.
CTSC 5600  Statistics in Clinical and Translational Research ............................................. 2 cr.
*MPET M.D.-Ph.D. students may exclude these in accordance with M.D.-Ph.D. requirements.

Track Tutorials (6 credits required, 3 tutorials required)
MPET 6000  Essentials in Patch Clamp Technique ................................................................. 2 cr.
MPET 6400  Introduction to Principles of Pharmacokinetics ............................................... 2 cr.
MPET 6655  Mechanisms of Cell Growth and Death ............................................................. 2 cr.
MPET 6811  Tutorial in Cardiovascular Pharmacology ......................................................... 2 cr.
MPET 6812  Tutorial in Receptor Biology .............................................................................. 2 cr.
MPET 6813  Tutorial in Systems Pharmacology ................................................................. 2 cr.
MPET 6814  Cellular Pharmacology of Agents that Target Cancer ..................................... 2 cr.
MPET 6815  Neurobehavioral Pharmacology ........................................................................ 2 cr.
MPET 6820  Regenerative Medicine ..................................................................................... 2 cr.

Electives (6 credits required)
Any courses approved for graduate credit; select in consultation with your thesis advisor.

Research
MPET 6890  Research in Pharmacology
Directed research projects under the supervision of a faculty advisor, must enroll every quarter once a thesis laboratory is selected.
Qualifying Exams and Thesis Research

Written qualifying exam: Ph.D. students can take the written qualifying exam at the end of the first or second year, but no later than September 30 of the third year. M.D.-Ph.D. students must take the written qualifying exam before December 31 of the second year. The written exam covers the fundamentals of pharmacology, including the material covered in Molecular Pharmacology and Receptor Signaling (CORE 6450), Introduction to Molecular Pharmacology (MPET 5808), Drug Metabolism and Pharmacogenomics (MPET 6805) as applied in a laboratory setting. In addition, each student is asked to write an “NIH-style grant” based on data in a recent research article in one of the fields of molecular pharmacology. The exam is prepared and graded by the faculty.

Oral qualifying exam: The oral qualifying exam must be taken by December 31 of the student’s third year. In this exam, students orally present a preliminary thesis proposal, which serves as a springboard for faculty to probe the student’s background knowledge, ability to propose hypotheses, and design experiments to test hypotheses. The oral qualifying exam committee must conform to the MCGSBS requirements and be approved by the program director.

Thesis proposal: A written thesis proposal in the format of an NIH R01 grant must be presented to your Thesis Advisory Committee within two months of completing the oral qualifying exam. The proposal should be divided into the following sections:

- **Abstract:** Summary of your project.
- **Specific Aims:** Describe briefly the aims of your project and hypotheses.
- **Significance and Innovation:** Put your project into context with what is known about this area of biology and show the importance of the questions you are asking.
- **Approach:**
  A. Background and Preliminary Data: Describe the results you (and others) have obtained, in your host laboratory (and in collaboration), that set the scene for your proposal and supports your hypotheses.
  B. Rationale: Here, you summarize AGAIN your key background and preliminary data facts, and say why they support your hypothesis and approach. Explain why in general you chose your particular specific aims/experiments/approach to test your hypothesis.
  C. Research Plan: Describe what you plan to do and how you plan to do it. Break this down by specific aims. Include expected outcomes and potential pitfalls for each aim.
# Neurobiology of Disease – Ph.D. Degree

P. J. McLean, Ph.D., *Program Director, Mayo Clinic in Florida*
A. J. Bieber, Ph.D., *Associate Program Director, Mayo Clinic in Rochester*
O. A. Ross, Ph.D., *Associate Program Director, Mayo Clinic in Florida*

## Course Work

### CORE Courses (12 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>*CORE 6050</td>
<td>Critical Thinking and Scientific Writing</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CORE 6100</td>
<td>Chemical Principles of Biological Systems</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6150</td>
<td>Genome Biology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6250</td>
<td>Molecular Cell Biology</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>

*Neurobiology of Disease M.D.-Ph.D. students may exclude these in accordance with M.D.-Ph.D. requirements.

### Lab Rotations (6 credits maximum, a minimum of 3 rotations)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGS 5102</td>
<td>Lab Rotations (8 weeks)</td>
<td>6 cr.</td>
</tr>
</tbody>
</table>

M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

### Track Requirements (21 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6210</td>
<td>Neurobiology of Disease</td>
<td>3 cr.</td>
</tr>
<tr>
<td>NBD 6401</td>
<td>Practical Neuroanatomy</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6600</td>
<td>Neuroscience Journal Club (1 cr. / yr.)*</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6650</td>
<td>Works in Progress (1 cr. / yr.)*</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6852</td>
<td>Topics in Neuroscience Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>NBD 6854</td>
<td>Basic Neuroscience</td>
<td>5 cr.</td>
</tr>
<tr>
<td>NBD 6860</td>
<td>Advanced Topics in Neurobiology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6900</td>
<td>NBD Thesis Proposal</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

*Two credits maximum.

### Suggested Electives (3 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>NBD 5600</td>
<td>Behavioral Neurology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>NBD 6855</td>
<td>Concepts in Cell Growth and Regeneration</td>
<td>2 cr.</td>
</tr>
<tr>
<td>BMMP 6300</td>
<td>Tutorial in Neuropysiology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>MPET 6820</td>
<td>Regenerative Medicine</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CORE 6200</td>
<td>Basic Graduate Immunology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6400</td>
<td>Molecular Genetics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6450</td>
<td>Molecular Pharmacology</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

### Research

NBD 6890    Research in the Neurobiology of Disease

Directed research projects under the supervision of a faculty advisor, must enroll every quarter once a thesis laboratory is selected.
 Forty-two credits are required for graduation. In addition to the core and track requirements, additional courses should be selected after consultation between the student and his/her advisor. Any courses offered by the MCGSBS may be taken for elective credit.

**Qualifying Exams and Thesis Research**

Written Qualifying Exam: The written qualifying exam will be taken by first year students at the end of the first year. There will be a single written qualifying exam composed of knowledge-based and research-based questions based on assigned research articles.

Oral Qualifying Exam: The oral qualifying exam is a critical step on the road to acquiring the Ph.D. You are strongly encouraged to discuss the oral exam with the program director well in advance of the end of your 6th quarter.

- **Timing:** The graduate school formally allows students to delay their oral exam until the end of the 2nd year. While this remains an option, oral qualifying exams should be scheduled no earlier than the 6th quarter, but before the end of your 8th quarter (basically towards the end of your second year).

  Students should write a Thesis proposal that is disseminated to members of their oral exam committee at least 3 weeks before the exam. This document should take the form of an F31 fellowship grant as described in the MCGSBS Program book and will be used as the basis for your oral exam. Paperwork must be filed with the graduate school at least three weeks before the scheduled exam.

- **Committee Composition:** The oral exam committee will always include two designated examiners, one of whom should be a member of the NBD Education Committee in order to ensure that all candidates meet a standard level of general background knowledge and to ensure that each candidate is tested fairly on the basis of their readiness for advancement to candidacy, rather than upon the quality of their preliminary data, the nature of their research project, or the influence of their faculty mentor. In addition to 2 or 3 standing members, additional members (minimum of 4) will be chosen for their expertise in the general area of research relevant to the student’s proposal. These members may be the faculty mentor or may be selected from the current group of neuroscience faculty involved in education. All members must be approved by the NBD Education Committee (program director and site-specific associate directors) and should be selected after extensive discussion between the student and their faculty mentor.

- **Proposal Format:** The exam will be driven by a well-written, in-depth proposal focused upon the student’s general research area. This proposal must include a clear hypothesis, logical specific aims and experimental goals, and an extensive introduction and review of the current literature relevant to the topic. The proposal will not require preliminary data – such data may be included in order to justify a certain aim or experimental objective, but will not form the basis for questioning and will not determine the outcome of the examination. Students will generally receive ample instruction into the format and expected content of the proposal during the basic neuroscience core course, the scientific writing course, and the special topics course. Again: the primary emphasis of the oral exam proposal will be the construction of a clear hypothesis, logical aims, carefully crafted experimental design, and an extensive literature review and synthesis. Preliminary data are optional.

- **Exam Format:** The oral exam will emphasize general neuroscience knowledge, the ability to generate hypotheses, the ability to “think on your feet”, and the ability to diagram and explain scientific concepts (a “chalk talk” format). The exam will also probe the depth of knowledge specific to the proposed area of research. Ultimately, any aspect of scientific thinking and general scientific
knowledge is fair game, but the intention of this exam is not to trick or confuse but rather to provide a fair and supportive environment in which each student can prove their readiness for advancement to candidacy.

After successfully passing the oral qualifying exam, students will schedule a thesis proposal meeting which will also serve as the first official thesis committee meeting. This meeting can happen at any time after advancement to candidacy, but must be completed by the end of the 10th quarter. Students must prepare an updated, polished thesis proposal that specifically outlines the hypothesis, specific aims, and experimental objectives of their Ph.D. research. This proposal must be provided to the thesis committee at least two weeks before the thesis proposal meeting. The committee will review the proposal and determine whether it represents an appropriate starting point for a thesis project. The initial thesis proposal is not a contract between the student and the committee – all Ph.D. projects evolve in response to actual experimentation and the final thesis research may differ substantially from the original proposal. An important aspect of successful Ph.D. training is constant communication with the thesis committee.

Fellowships: All eligible students are strongly encouraged to apply for pre-doctoral funding via the National Research Service Award (NRSA) mechanism (F31). The thesis proposal format is intended to assist in the preparation of a competitive NRSA application. Further information is available at http://grants.nih.gov/training/nrsa.htm or from Dr. Bruce Horazdovsky in the MCGSBS office.

Lab Changes: Changes in thesis advisor is strongly discouraged after the 6th quarter. If changes are requested after this time they will be approved at the discretion of the program director.
Virology and Gene Therapy
Virology and Gene Therapy – Ph.D. Degree

Y. Ikeda, D.V.M., Ph.D., Program Director
M. A. Barry, Ph.D., Associate Program Director

Course Work

CORE Courses (16 credits required)
CORE 6000  Responsible Conduct of Research................................................................. 1 cr.
CORE 6100  Chemical Principles of Biological Systems...................................................... 3 cr.
CORE 6150  Genome Biology ......................................................................................... 3 cr.
CORE 6200  Basic Graduate Immunology ......................................................................... 3 cr.
CORE 6250  Molecular Cell Biology .................................................................................. 3 cr.
CORE 6770  Intro to Virology and Gene Therapy.............................................................. 3 cr.

Lab Rotations (6 credits maximum, a minimum of 3 rotations)
MGS 5102  Lab Rotations (8 weeks) .................................................................................. 2 cr.
M.D.-Ph.D. students satisfy this requirement with three one-month full-time rotations.

Track Requirements (6 credits required)
VGT 6740  Viruses and Vectors Journal Club (1 cr./yr.) ...................................................... 3 cr.
VGT 6745  Current Topics in VGT (1 cr./yr.)................................................................. 3 cr.

Track Tutorials (8 credits required)
Tutorials will be presented in the areas of Virology and Gene Therapy and in related areas. Students are required to take all four of the tutorials.

IMM 6884  Tutorial in Tumor Immunology (even years) .................................................. 2 cr.
VGT 6884  Viral Disease Tutorial (odd years).................................................................... 2 cr.
VGT 6886  Tutorial in Molecular Virology (odd years)..................................................... 2 cr.
VGT 6888  Gene and Cell Therapy Tutorial (even years)................................................... 2 cr.

Electives (6 credits required)
Any course approved for graduate credit, including elective core courses.

Research
VGT 6890  Research in Virology and Gene Therapy
Directed research projects under the supervision of a faculty advisor, must enroll every quarter once a thesis laboratory is selected
DESCRIPTION OF BASIC SCIENCE MASTER’S DEGREE PROGRAM AND TRACK REQUIREMENTS
MASTER OF SCIENCE PROGRAM IN BIOMEDICAL SCIENCES

The Master of Science (M.S.) Program in Biomedical Sciences is available only to:

1) Physicians enrolled in clinical residency programs and/or research fellowships of the Mayo School of Graduate Medical Education (basic science specialty requirements described below – clinical science specialty requirements described in a later section). Potential candidates for the degree must hold appointments of sufficient duration to complete degree program requirements.

2) Employees (see Employee Master’s Program requirements)

3) Candidates for the Ph.D. in good academic standing, who are unable to complete all the requirements for the doctorate degree. Requirements are outlined in the MCGSBS Master’s Degree Option for Ph.D. Students Policy on the intranet site.

TUITION

Tuition may be covered by a MCGSBS scholarship for Mayo graduate courses taken to meet Master’s degree requirements. Mayo will not reimburse other costs that may be associated with the degree program.

APPLICATION

Candidates must complete a Master’s Program in Biomedical Sciences Application form. The application must be approved by the track Program director and MCGSBS. This form is available from the MCGSBS office.

TIME REQUIREMENT

All requirements must be satisfied within 30 days of the thesis defense.

REGISTRATION REQUIREMENT

At least 75% of the coursework for the Master’s degree must be completed in MCGSBS. Enrollment in the degree program for a minimum of one year is required. It is expected that a minimum of one year will be devoted to research.

MINIMUM CREDIT REQUIREMENTS

Students must complete a minimum of 12 credits in basic biomedical sciences and 12 additional credits in the track. (See individual specialty track descriptions for specific course requirements. The biomedical science credit requirement does not apply to the Clinical and Translational Science track). Six of the 12 credits in the track must be didactic credits. It is expected that a minimum of one year will be devoted to research. Students are not admitted to a specialty track unless there is reasonable assurance that course work required for completion of degree requirements is available.
TRANSFER CREDITS

A total of 6 didactic credits may be transferred into the Basic Science Master’s Program.

Core Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a Mayo core course must contact the course director and their program director. To substitute or to waive core course credits, the student is required to prove competence by taking an exam dictated by the course director on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo core course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Track Required Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a track required course must contact the course director and their program director. To substitute or to waive track required course credits, at the course director’s and the program director’s discretion the student is required to prove competence by taking an exam on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the track required course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Elective Course Policy
Students who wish to transfer graduate credits to substitute for a Mayo elective course must contact the course director and their program director. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo course, the student may request the transfer credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

External Courses Policy
Students who wish to transfer credits not in substitution for a Mayo course(s) may request credit for graduate courses taken at another institution if they received a grade of A or B. The request must have the approval of the student’s program director and MCGSBS. A description of the course from the course catalog or a course outline must accompany the request. The time interval since the credits were earned is a consideration in such decisions. Credits must normally have been earned within the previous five years, as determined by the program director.

ADVISOR

A Master’s degree advisor must have MCGSBS full or Master’s graduate faculty privileges. List of Faculty with Privileges can be found on the MCGSBS intranet site.
OFFICIAL DEGREE PROGRAM FORM

Students are expected to submit their Degree Program Form (DPF) to MCGSBS before the end of the first year of registration. The form must include the minimum number of courses/credits necessary to fulfill degree requirements (credits may vary depending on the chosen track but the minimum MCGSBS credit requirement must be met) and be approved by the track program director. Fifty percent of the credits on the degree program must be graded on the A-F grading system. The DPF is available on the MCGSBS intranet site under For Students/General Forms/Resources.

CHANGES IN APPROVED PROGRAM

The approved degree program must be fulfilled in every detail to meet graduation requirements. Alterations in the program must be requested in writing and approved by the track program director, the student’s advisor, and MCGSBS.

MINIMUM GRADE REQUIREMENTS

Students are expected to maintain a grade point average of 3.0 in didactic course work. Students whose performance falls below this standard in a given quarter will be placed on academic probation, as described in the Deficiencies and Unsatisfactory Progress and Warning, Probation and Dismissal policies outlined on the MCGSBS Policies and Procedures website.

EXAMINATIONS

Written Examination: A comprehensive written examination must be taken before completion of the training program. MCGSBS must be informed of the date of the examination three weeks in advance so that the Master’s Written Examination Report form can be sent to the track program director. The written examination may be taken no more than twice. If it is not passed on the first attempt, it must be retaken by the end of the quarter following the quarter in which it was first taken. Failing the examination twice will result in dismissal. The written examination must be passed before the final oral examination may be scheduled.

Final Oral Examination: Candidates for the Master’s degree are expected to pass the final oral examination before completion of the Mayo residency or fellowship training program. The final oral examination may be taken after: 1) the written examination has been passed, 2) all course work shown on the Degree Program Form has been completed, and 3) the thesis is reviewed. MCGSBS must be informed of the date of the examination three weeks in advance so that the Master’s Final Oral Examination Report form can be sent to the Thesis Advisory Committee chair.

The student’s advisor must sign a form indicating that he/she has read the thesis and that it is ready for defense prior to distribution to the Thesis Advisory Committee members. The Verification that the Thesis is Ready to Defend form can be accessed on the MCGSBS intranet site under For Students/General Forms/Resources. The form must be submitted to the MCGSBS office. The thesis must be submitted to the Thesis Advisory Committee at least three weeks before the Final Oral Examination.
Voting members of the Thesis Advisory Committee must be present in real time via physical presence or video- or teleconferencing at the final oral examination. Only one dissenting vote will be allowed for a “Pass.” Passage of the final oral examination requires a minimum of three passing votes; otherwise a determination of “Fail” must be made. Thus, no more than one Thesis Advisory Committee member may be absent for the final oral examination. The final oral examination may be taken no more than twice. If it is not passed on the first attempt, it must be retaken by the end of the quarter following the quarter in which the exam was first taken. Failing the examination twice will result in dismissal.

THESIS

Thesis Protocol: The protocol must be submitted to MCGSBS during the first quarter in the program. This protocol must clearly define the candidate’s role in the project and must have sufficient detail to permit review by an advisory committee. An Outline for Master’s Thesis Protocols is available on the MCGSBS intranet site. The protocol must be submitted with the form, Recommended Action on Thesis Protocol for Basic Science Master’s Degree, also available on the intranet site.

The Mayo Institutional Review Board must review all protocols for research involving the use of human subjects. It is the candidate’s responsibility to secure approval of any such protocols before the research is undertaken.

Thesis Advisory Committee: With the thesis protocol, students must submit the Master’s Thesis Advisory Committee form recommending the members of their thesis advisory/ final oral examining committee and the Degree Program form. All members must have graduate faculty privileges and the chair must have a minimum of Master’s graduate faculty privileges. The examining committee must consist of four members, one of whom is the student’s advisor, who serves as chair of the committee. Any additional Thesis Advisory Committee members beyond four will be designated as “ex-officio” and will not vote at the final defense.

No member other than the chair may be from among a student’s research advisors. No more than two members of the committee may have teaching/examining privileges. The recommended committee must be approved by the track program director and MCGSBS.

Progress Meetings: The Master’s Thesis Advisory Committee must meet every six months from the date of committee approval. Documentation of student progress, signed by all members of the Thesis Advisory Committee, should be submitted to MCGSBS after each of these meetings.

Preparation of Thesis: The thesis is the most important document that the Master’s candidate will prepare during the course of graduate study and is a record of the scientific accomplishments that justify the awarding of the degree. The thesis is archival. Consequently, MCGSBS has developed a standard for its format and style, which should be closely followed. Guidelines for Master’s thesis are available on the MCGSBS intranet site under For Students/General Forms/Resources.

Final Thesis Corrections: After the student has passed the final oral examination, the chair of the Thesis Advisory Committee must sign a form indicating he/she is satisfied that the final corrections to the thesis have been made. The chair must sign before the student will be cleared for graduation. MCGSBS will not certify completion of degree requirements until the final thesis has been submitted.
GRADUATION

Students are granted degrees four times a year: February, May, August, and November. Students must have all requirements completed by the first working day of the month prior to the graduation month. Students are allowed no more than 30 days to complete Master’s degree requirements after a successful thesis defense. This policy is effective November 1, 2014. If a student does not meet this deadline, he/she will be required to re-defend his/her thesis.

<table>
<thead>
<tr>
<th>To graduate in:</th>
<th>Requirements must be completed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>January 1</td>
</tr>
<tr>
<td>May</td>
<td>April 1</td>
</tr>
<tr>
<td>August</td>
<td>July 1</td>
</tr>
<tr>
<td>November</td>
<td>October 1</td>
</tr>
</tbody>
</table>
## BIOCHEMISTRY AND MOLECULAR BIOLOGY

D. J. Katzmann, Ph.D., *Program Director*  
J. R. Hawse, IV, Ph.D., *Associate Program Director*

### Biochemistry and Molecular Biology Track:
Biochemistry and Structural Biology; Cell Biology and Genetics; Cancer Biology Sub-tracks

### Basic Science Master’s Degree
This Master’s degree track in Biochemistry and Molecular Biology is open only to residents and research fellows in the Mayo School of Graduate Medical Education. It offers a flexible course for Master’s study that can be designed to emphasize one of three areas of specialty: Biochemistry and Structural Biology (BSB), Cell Biology and Genetics (CBG) or Cancer Biology (CB).

### Course Requirements

#### Biomedical Science Requirements (12 credits required)
- **CORE 6000** Responsible Conduct of Research................................................................. 1 cr.
- **CORE 6100** Chemical Principles of Biological Systems .................................................. 3 cr.
- **CORE 6150** Genome Biology ......................................................................................... 3 cr.
- **CORE 6250** Molecular Cell Biology ................................................................................ 3 cr.
- Additional biomedical science credits ................................................................................. 2 cr.

#### Intermediate Courses (6 credits required)*
- **BMB 5000** Introduction to Cancer Biology................................................................. 3 cr.
- **BMB 5400** Developmental Biology................................................................................ 2 cr.
- **CORE 6300** Molecular Biophysics.................................................................................. 3 cr.
- **CORE 6400** Molecular Genetics..................................................................................... 3 cr.
- **CORE 6510** Molecular Mechanisms of Human Disease............................................... 3 cr.

#### Advanced Courses (6 credits required)*
- **BMB 5350** Hormones and Cancer .............................................................................. 1 cr.
- **BMB 6000** Biological Macromolecules......................................................................... 3 cr.
- **BMB 6030** Data Analysis and Math Modeling in Biomedical Research ....................... 3 cr.
- **BMB 6040** Fractals and Chaos in Bioscience................................................................. 2 cr.
- **BMB 6050** Biological Kinetics ...................................................................................... 3 cr.
- **BMB 6070** Cancer Biology II: Molecular Mechanisms................................................. 3 cr.
- **BMB 6075** Epigenetics of Cancer and Addiction.......................................................... 3 cr.
- **BMB 6320** Special Topics in Cancer Biology-Genomics of Cancer.............................. 1 cr.
- **BMB 6650** Receptor Trafficking and Signaling.............................................................. 2 cr.
- **BMB 6660** Transcription, Chromatin, and Epigenetics .................................................. 2 cr.
- **BMB 6665** Current Topics in Nucleic Acids Biochemistry ......................................... 3 cr.
- **BMB 6675** Protein Structure and Dynamics.................................................................. 2 cr.

*Other Journal Clubs (maximum of 4 credits: 2 Advanced and 2 Intermediate)*
BMB 6510  Current Topics in Cancer Biology................................................................. 1 cr.
BMB 6520  Current Topics in Aging Research**.............................................................. 1 cr./qtr.
BMB 6801  Concepts of Vesicular Trafficking Journal Club........................................ 1 cr.
*Courses to be selected in consultation with your project advisor.
** Two credits maximum.

Research
It is expected that a minimum of one year will be devoted to research.

Written Qualifying Exam
The Master’s candidate must pass the BMB Written Qualifying Exam to complete the degree requirements. Students take the written qualifying exam once they have completed the core courses and have considered whether to take the others featured in the exam. The exam is a one-day exam held at the beginning of July. The exam consists of demonstrating critical evaluation and understanding of two published primary research papers relevant to the broad field of Biochemistry and Molecular Biology as covered in the core courses CORE 6100, CORE 6150 and CORE 6250 as well as the intermediate courses, CORE 6400 and BMB 5000. Three sets of papers reflecting the three areas of emphasis of the track: BSB, CBG and CB, will be made available to the students three days before the exam, and the student then selects two papers from which a series of specific questions are answered. The questions will cover foundation of knowledge in addition to synthesis of concepts. The exam is prepared and graded by the faculty and a pass rate of 70% is required for successful completion of the exam.
Basic Science Master's Degree

The Master’s degree track in Clinical and Translational Science is open only to residents and research fellows in the Mayo School of Graduate Medical Education, and other Mayo faculty and students who are interested in expanding their clinical research experience. Potential candidates for the degree must hold Mayo appointments of sufficient duration to complete program requirements.

Program Requirements:
1. Research Proposal - Due January 1 following a September admission, July 1 following a March admission.
2. Attend BOTH “Write Winning Grants” and “Writing for Biomedical Publications” workshops. (Held annually)
3. Comprehensive Written Examination - Held third Tuesday of January, April and September. Prior to taking the exam, the following courses must be completed: CTSC 5010, CTSC 5300, CTSC 5310, CTSC 5390, CTSC 5600, CTSC 5601, CTSC 5610, CTSC 5690 and CTSC 5720.
4. Course Work (see below)
5. Thesis Defense

Course Work

The curriculum for the Master’s degree consists of 24 credits. The student must complete all of the required courses listed below. The elective credits may be chosen from those listed below or other courses listed in the MCGSBS catalog with approval.

Core Courses (1 credit required)
CORE 6000 Responsible Conduct of Research ................................................................. 1 cr.

Track Requirements (15 credits required)
CTSC 5010 Clinical Research Protocol Development ......................................................... 2 cr.
CTSC 5020 Regulatory Issues in Clinical Research .............................................................. 1 cr.
CTSC 5300 Introduction to Clinical Epidemiology ............................................................... 1 cr.
CTSC 5310 Clinical Epidemiology II ................................................................................. 1 cr.
CTSC 5390 Advanced Applied Epidemiological Methods .................................................. 2 cr.
CTSC 5600 Statistics in Clinical and Translational Research .......................................... 2 cr.
CTSC 5601 Utilizing Statistics in Clinical Research ............................................................ 1 cr.
CTSC 5610 Introductory Statistical Methods II ................................................................. 3 cr.
CTSC 5690 Critical Appraisal of Statistical Methods in the Medical Literature ............... 1 cr.
CTSC 5720 Clinical Trials: Design and Conduct ................................................................. 1 cr.
Write Winning Grants Workshop ................................................................................. 0 cr.
Writing for Biomedical Publication Workshop ............................................................ 0 cr.

Elective Courses (8 credits required)

Clinical Trials
CTSC 5190 Complementary and Alternative Medicine ................................................. 1 cr.
CTSC 5240 Principles and Practices of Pediatric Research ........................................................... 2 cr.
CTSC 5250 Science Beyond the Lab: Intersections of Science, Society and Policy ...................... 1 cr.
CTSC 5260 Methods and Foundations in Biomedical Ethics ....................................................... 1 cr.
CTSC 5261 Biomedical Ethics II ........................................................................................................ 1 cr.
CTSC 5262 Biomedical Ethics III ......................................................................................................... 1 cr.
CTSC 5721 Advanced Topics in Clinical Trials: Protocol Development and Implementation.. 2 cr.

Community-Engaged and Health Disparities Research
CTSC 5070 What Researchers Need to Know About Community-Engaged Research .............. 1 cr.
CTSC 5080 What Researchers Need to Know About Eliminating Health Disparities ............... 1 cr.

Translation
CTSC 5140 Epigenetics & Epigenomics: Impact on Translational Research and Future Medical Practice.................................................................................................... 2 cr.
CTSC 5141 Medical Epigenetics and Epigenomics Journal Club ................................................. 1 cr.
CTSC 5202 Independent Study for Laboratory Methods ............................................................... 1-2 cr.
CTSC 5270 Hepatobiliary Pathobiology ............................................................................................ 1 cr.
CTSC 5271 Pathophysiology of Digestive Disease ........................................................................... 1 cr.
CTSC 5280 Applied Enteric Neurosciences in Health and Disease .............................................. 1 cr.
CTSC 6120 Case Studies in Translation .......................................................................................... 2 cr.
MPET 6820 Regenerative Medicine.................................................................................................. 2 cr.

Clinical Epidemiology
CTSC 5290 GI Population Sciences ................................................................................................... 1 cr.
CTSC 5500 Genetic Epidemiology: Association Studies ................................................................. 1 cr.

Quantitative and Qualitative Methods
CTSC 5640 Logistic Regression .......................................................................................................... 1 cr.
CTSC 5641 Propensity Scoring Methods .......................................................................................... 1 cr.
CTSC 5650 Survival Analysis ............................................................................................................. 1 cr.
CTSC 5710 Practical Data Collection ............................................................................................... 1 cr.
CTSC 5810 Qualitative Research Design, Methods, and Analysis .................................................. 1 cr.
CTSC 5820 Introduction to Survey Research ..................................................................................... 1 cr.

Health Services & Comparative Effectiveness Research
CTSC 5201 Independent Study for Clinical Practice Issues .......................................................... 1-2 cr.
CTSC 5740 Systematic Reviews and Meta-Analyses ........................................................................ 2 cr.
CTSC 5760 Medical Decision Making ............................................................................................ 1 cr.
CTSC 5761 Evidence-based Medicine for Clinical Researchers ..................................................... 1 cr.
CTSC 5770 Diagnostic Testing Strategies ......................................................................................... 1 cr.
CTSC 5850 Introduction to Psychological and Behavioral Measurement ....................................... 1 cr.
CTSC 5860 Behavioral Interventions in Clinical Research ............................................................ 1 cr.
CTSC 5870 Social & Behavioral Foundations of Health in Health Sciences Research .................. 1 cr.
CTSC 5910 Economic Evaluation in Health Care ............................................................................ 1 cr.
CTSC 5920 Introduction to Health Care Systems Engineering: Optimization ............................. 1 cr.
CTSC 5930 Introduction to the U.S. Health Care System ................................................................. 1 cr.
CTSC 5940 Secondary Data Analysis ............................................................................................... 1 cr.
Biomedical Informatics
CTSC 5960 Medical Informatics for the Clinical Researcher ......................................................... 2 cr.
CTSC 5961 Health Information Technology Evaluation: Clinical Informatics Methods ............ 1 cr.

Other MCGSBS courses

Research
It is expected that a minimum of one year will be devoted to research.
IMMUNOLOGY

K. E. Hedin, Ph.D., Program Director

Basic Science Master’s Degree
The Master’s degree track in Immunology is open only to residents and research fellows in the Mayo School of Graduate Medical Education.

Course Requirements

Biomedical Science Requirements (12 credits required)
Students are expected to complete 12 credits of course work selected from the Biomedical Sciences core curriculum. CORE 6000 and CORE 6200 must be selected. Students with extensive background in particular areas of the core curriculum will have the opportunity to test out of the core courses.

Track Requirements (4 credits required)
Each student will be expected to take a minimum of four credits offered by the Immunology faculty in areas specific to the student’s research interest. IMM 6863 must be taken at least once. The three remaining credits in Current Topics can be any combination of the following journal clubs:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMM 6862</td>
<td>Current Topics in Cell Activation and Signaling</td>
<td>1 cr.</td>
</tr>
<tr>
<td>IMM 6863</td>
<td>Current Topics in Immunology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>IMM 6867</td>
<td>Current Topics in Clinical and Translational Immunology</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Written Examination
The Master’s candidate must pass the Immunology written qualifying exam to complete the degree requirements.

Track Tutorials (8 credits required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>IMM 6877</td>
<td>Tutorial in Molecular Basis of Immune Recognition</td>
<td>2 cr.</td>
</tr>
<tr>
<td>IMM 6879</td>
<td>Tutorial in Cellular Activation</td>
<td>2 cr.</td>
</tr>
<tr>
<td>IMM 6880</td>
<td>Tutorial in Immunopathology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>IMM 6882</td>
<td>Tutorial in Mucosal Immunity</td>
<td>2 cr.</td>
</tr>
<tr>
<td>IMM 6884</td>
<td>Tutorial in Tumor Immunology</td>
<td>2 cr.</td>
</tr>
<tr>
<td>IMM 6885</td>
<td>Tutorial in the Generation and Function of B Cells</td>
<td>2 cr.</td>
</tr>
</tbody>
</table>

Students who are not currently enrolled in a degree program must first obtain a signature from the IMM graduate program before enrolling in any IMM tutorial course.

Research
It is expected that a minimum of one year will be devoted to research.
MOLECULAR PHARMACOLOGY & EXPERIMENTAL THERAPEUTICS

R. M. Weinshilboum, M.D., Program Director
L. Wang, M.D., Ph.D., Program Co-Director
K. A. Campbell, Ph.D., Associate Program Director

Basic Science Master’s Degree

The Master’s degree track in Molecular Pharmacology and Experimental Therapeutics offers a Master’s degree within the Biomedical Sciences Program. This track is only open to residents and research fellows in the Mayo Clinic School of Graduate Medical Education.

Course Requirements

Biomedical Science Requirements (12 credits required)

Students are expected to complete 12 credits of introductory Biomedical Sciences courses chosen from the core curriculum. These 12 credits must include CORE 6000, Responsible Conduct of Research.

Track Requirements (8 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE</td>
<td>6450</td>
<td>Molecular Pharmacology and Receptor Signaling</td>
</tr>
<tr>
<td>MPET</td>
<td>5808</td>
<td>Introduction to Molecular Pharmacology</td>
</tr>
<tr>
<td>MPET</td>
<td>6805</td>
<td>Drug Metabolism and Pharmacogenomics</td>
</tr>
</tbody>
</table>

Track Tutorials (4 credits required from the following)

<table>
<thead>
<tr>
<th>Course</th>
<th>Credits</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPET</td>
<td>6000</td>
<td>Essentials in Patch Clamp Techniques</td>
</tr>
<tr>
<td>MPET</td>
<td>6400</td>
<td>Introduction to Principles of Pharmacokinetics</td>
</tr>
<tr>
<td>MPET</td>
<td>6655</td>
<td>Mechanisms of Cell Growth and Death</td>
</tr>
<tr>
<td>MPET</td>
<td>6811</td>
<td>Tutorial in Cardiovascular Pharmacology</td>
</tr>
<tr>
<td>MPET</td>
<td>6812</td>
<td>Tutorial in Receptor Biology</td>
</tr>
<tr>
<td>MPET</td>
<td>6813</td>
<td>Tutorial in Systems Pharmacology</td>
</tr>
<tr>
<td>MPET</td>
<td>6814</td>
<td>Cellular Pharmacology of Agents that Target Cancer</td>
</tr>
<tr>
<td>MPET</td>
<td>6815</td>
<td>Neurobehavioral Pharmacology</td>
</tr>
</tbody>
</table>

Research

Students will identify a research advisor on entry into the degree program. It is assumed that the equivalent of 12 months will be spent in full-time academic work, which will consist primarily of research, but will also involve advanced course work.
MASTER OF SCIENCE PROGRAM IN BIOMEDICAL SCIENCES FOR MAYO EMPLOYEES

The Master’s Degree in Biomedical Sciences is designed to develop the individual’s information base in a basic science field and to enable the individual to become competent in acquiring knowledge independently. This Master’s program emphasizes course work and a final project and does not include a research thesis.

The Master’s program provides the Mayo employee with an organized plan of study to enhance their professional development. The Master’s degree is the culmination of this educational program and documents the acquisition of a high level of knowledge in a particular area of science. Although employees currently do not receive direct salary benefit from earning a Master’s degree, receipt of the degree may make the employee qualified for a job of a higher classification, should one become available.

ELIGIBILITY

Enrollment is restricted to permanent Mayo employees. Applicants must have received a bachelor’s degree from an accredited college or university, must have taken appropriate undergraduate science courses to adequately prepare for the Master’s program, must have a minimum undergraduate grade point average that demonstrates a record of academic excellence, and must have received scores on the verbal, analytical, and quantitative aptitude tests of the Graduate Record Examination (GRE) indicating strong academic ability. Applicants, who meet these criteria and have a strong letter of support from their Mayo supervisor, are eligible for admission. Alternatively, an applicant may be asked by the program to register for six credits from the core curriculum of MCGSBS. If a 3.0 GPA is maintained in those courses, the applicant may be eligible for admission.

TUITION

Tuition may be covered by a MCGSBS scholarship for Mayo graduate courses taken to meet Master’s degree requirements. Mayo will not reimburse other costs that may be associated with the degree program.

APPLICATION

Candidates must complete a Master’s Program in Biomedical Sciences Application form. The application must be approved by the track program director and MCGSBS. This form is available from the MCGSBS office. Supporting documents include transcripts from previous colleges, GRE scores, supervisor’s endorsement and three letters of recommendation.

TIME REQUIREMENT

All requirements for the Master’s degree must be completed within five years. The five-year period begins on the date the letter of acceptance is sent to the student. Permanent Mayo employees whose Mayo employment terminates are required to notify MCGSBS; their MCGSBS appointments will also end.
REGISTRATION REQUIREMENT

At least 75% of the coursework for the Master’s degree must be completed in MCGSBS.

MINIMUM CREDIT REQUIREMENTS

Students must complete a minimum of 36 credits including CORE 6000, “Responsible Conduct of Research.” Six of the credits in the track must be didactic credits. The selection of the courses to be used to meet these requirements will be determined by the student and the track program director.

TRANSFER CREDITS

A total of 9 didactic credits may be transferred into the Employee Master’s Program.

Core Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a Mayo core course must contact the Mayo course director and their program director. To substitute or waive core course credits, the student is required to prove competence by taking an exam dictated by the course director on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo core course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Track Required Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a track required course must contact the course director and their program director. To substitute or to waive track required course credits, at the course director’s and the program director’s discretion the student is required to prove competence by taking an exam on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the track required course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Elective Course Policy
Students who wish to transfer graduate credits to substitute for a Mayo elective course must contact the course director and their program director. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo course, the student may request the transfer credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

External Courses Policy
Students who wish to transfer credits not in substitution for a Mayo course(s) may request credit for graduate courses taken at another institution if they received a grade of A or B. The request must have the approval of the student’s program director and MCGSBS. A description of the course from the course catalog or a course outline must accompany the request. The time interval since the credits were earned is a consideration in such decisions. Credits must normally have been earned within the previous five years, as determined by the program director.
ADVISOR

A Master’s degree advisor must have MCGSBS full or Master’s graduate faculty privileges. List of Faculty with Privileges can be found on the MCGSBS intranet site.

OFFICIAL DEGREE PROGRAM FORM

Students are expected to submit their Degree Program Form (DPF) to MCGSBS on or before completing 15 credits of coursework. The form must include the minimum number of courses/credits necessary to fulfill degree requirements (credits may vary depending on the chosen track but the minimum MCGSBS credit requirement must be met) and be approved by the track program director. Fifty percent of the credits on the degree program must be graded on the A-F grading system. The DPF is available on the MCGSBS For Students/General Forms/Resources intranet site.

CHANGES IN APPROVED PROGRAM

The approved degree program must be fulfilled in every detail to meet graduation requirements. Alterations in the program must be requested in writing and approved by the track program director, the student’s advisor, and MCGSBS.

MINIMUM GRADE REQUIREMENTS

Students are expected to maintain a grade point average of 3.0 in didactic coursework. Students whose performance falls below this standard in a given quarter will be placed on academic probation, as described in the Deficiencies and Unsatisfactory Progress and Warning, Probation and Dismissal policies outlined on the MCGSBS Policies and Procedures website.

EXAMINATIONS

Written Qualifying Examination: At the completion of the required coursework, students must pass the track written qualifying examination. MCGSBS must be informed of the date of the examination three weeks in advance so that the Master’s Written Qualifying Examination Report form can be sent to the track Program director. The examination is designed to evaluate the student’s depth and breadth of knowledge in the student’s track and related fields of study. The written qualifying examination may be taken after courses on the Degree Program Form are completed. The written qualifying examination may be taken no more than twice. If it is not passed on the first attempt, it must be taken within six months. Failing the examination twice will result in dismissal. The written qualifying examination must be passed before the Master’s final project review may be scheduled.

Master’s Project Review: At the completion of the Master’s scholarly review article (final project), students must review their document with the Employee Master’s Advisory Committee. MCGSBS must be informed of the date at least three weeks in advance so that the Master’s Final Project Review Report Form can be sent to the Employee Master’s Advisory Committee chair. Members of the Employee Master’s Advisory Committee should receive copies of the scholarly review article (final project) at least three weeks prior to the final review.
Voting members of the Employee Master’s Advisory Committee must be present in real time via physical presence or video- or teleconferencing at the review. Only one dissenting vote will be allowed for a “Pass.” Thus, no more than one Employee Master’s Advisory Committee member may be absent for the review. In the case where a student fails the review, the committee will recommend to the student and to MCGSBS remedial studies that should be undertaken by the student before the student reviews his/her review article (final project) again with the Employee Master’s Advisory Committee. The review may occur no more than twice. If it is not passed on the first attempt, it must be taken within six months. Failing the review twice will result in dismissal.

SCHOLARLY REVIEW ARTICLE (FINAL PROJECT)

Master’s degree tracks will specify the requirements for a scholarly review article (final project) to be completed as a required component of the degree program. This scholarly review article (final project) needs to be under the supervision of a faculty member with graduate faculty privileges. The scholarly review article (final project) needs to be approved by the track Program director.

Employee Master’s Advisory Committee: The Employee Master’s Advisory Committee must consist of four members, one of whom is the student’s advisor, who serves as chair of the committee. Any additional members beyond four will be designated as “ex-officio.” All members must have graduate faculty privileges and the chair must have a minimum of Master’s graduate faculty privileges. No more than two members may have teaching/examining privileges. The composition of this committee will be determined by MCGSBS upon recommendation by the student and the student’s track Program director. The recommendations are submitted on the Employee Master’s Advisory Committee form available on the MCGSBS intranet site.

GRADUATION

Students are granted degrees four times a year: February, May, August, and November. Students must have all requirements completed by the first working day of the month prior to the graduation month.

<table>
<thead>
<tr>
<th>To graduate in:</th>
<th>Requirements must be completed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>January 1</td>
</tr>
<tr>
<td>May</td>
<td>April 1</td>
</tr>
<tr>
<td>August</td>
<td>July 1</td>
</tr>
<tr>
<td>November</td>
<td>October 1</td>
</tr>
</tbody>
</table>
The Biochemistry and Molecular Biology (BMB) Track offers a flexible course for Employee Master’s study that can be designed to emphasize one of three areas of specialty: Biochemistry and Structural Biology (BSB), Cell Biology and Genetics (CBG) or Cancer Biology (CB). The requirements for the Employee Master’s Degree in Biochemistry and Molecular Biology conform to the general requirements of the MCGSBS in which a total of 36 credits are required for graduation.

### Course Requirements

#### Core Courses (10 credits required)

- **CORE 6000** Responsible Conduct of Research .......................................................... 1 cr.
- **CORE 6100** Chemical Principles of Biological Systems ........................................... 3 cr.
- **CORE 6150** Genome Biology .................................................................................... 3 cr.
- **CORE 6250** Molecular Cell Biology .......................................................................... 3 cr.

#### Track (5 credits required)

- **BMB 6300** Master’s Scholarly Review Article (Final Project) .................................... 3 cr.
- **BMB 6500** BMB Journal Club (1 cr./yr.)* .................................................................. 2 cr.

*Two credits maximum. Students must attend all years after completing the written qualifying exam and present at least once. The second journal club credit may be obtained by taking and presenting at the Cancer Biology Journal Club.

#### Intermediate Courses (6 credits required)

- **BMB 5000** Introduction to Cancer Biology ............................................................. 3 cr.
- **BMB 5400** Developmental Biology ........................................................................... 2 cr.
- **CORE 6050** Critical Thinking and Writing ................................................................. 2 cr.
- **CORE 6300** Molecular Biophysics ............................................................................. 3 cr.
- **CORE 6400** Molecular Genetics ................................................................................. 3 cr.
- **CORE 6510** Molecular Mechanisms of Human Disease ............................................ 3 cr.

#### Advanced Courses (8 credits required)

- **BMB 5350** Hormones and Cancer ............................................................................. 1 cr.
- **BMB 6000** Biological Macromolecules ..................................................................... 3 cr.
- **BMB 6030** Data Analysis and Math Modeling in Biomedical Research .................. 3 cr.
- **BMB 6040** Fractals and Chaos in Bioscience ......................................................... 2 cr.
BMB 6050 Biological Kinetics................................................................. 3 cr.
BMB 6070 Cancer Biology II: Molecular Mechanisms ........................................ 3 cr.
BMB 6075 Epigenetics of Cancer and Addiction........................................ 3 cr.
BMB 6320 Special Topics in Cancer Biology ............................................ 1 cr.
BMB 6650 Receptor Trafficking and Signaling ........................................... 2 cr.
BMB 6660 Transcription, Chromatin, and Epigenetics................................. 2 cr.
BMB 6665 Current Topics in Nucleic Acids Biochemistry............................ 3 cr.
BMB 6675 Protein Structure and Dynamics................................................... 2 cr.

Electives (7 credits required)

Any course approved for graduate credit.

Other Journal Clubs (maximum of 4 credits: 2 Advanced and 2 Intermediate)

BMB 6510 Cancer Biology Journal Club ......................................................... 1 cr./qtr.
BMB 6520 Current Topics in Aging Research ................................................ 1 cr./qtr.
BMB 6801 Concepts of Vesicular Trafficking Journal Club ............................ 1 cr./qtr.

Courses to be selected in consultation with your project advisor.

Written Qualifying Exam

The Master’s candidate must pass the BMB Written Qualifying Exam to complete the degree requirements. Students take the written qualifying exam once they have completed the core courses and have considered whether to take the other courses featured in the exam (see below). The exam is a one-day exam held at the beginning of July. The exam consists of demonstrating critical evaluation and understanding of two published primary research papers relevant to the broad field of Biochemistry and Molecular Biology as covered in the core courses CORE 6100, CORE 6150 and CORE 6250 as well as the intermediate courses, CORE 6400 and BMB 5000. Three sets of papers reflecting the three areas of emphasis of the track: BSB, CBG and CB, will be made available to the students three days before the exam, and the student then selects two papers from which a series of specific questions are answered. The questions will cover foundation of knowledge in addition to synthesis of concepts. The exam is prepared and graded by the faculty and a pass rate of 70% is required for successful completion of the exam.

Master’s Scholarly Review Article (Final Project)

As a part of the Employee Master’s, the candidate must write a critical literature review of a selected topic in biochemistry and molecular biology and associated with your area of emphasis: Biochemistry and Structural Biology; Cell Biology and Genetics or Cancer Biology. The topic for review should be selected by the candidate in consultation with a faculty member who will act as an advisor for the scholarly review article (final project). The review article (final project) should be written as a comprehensive review of a fundamental question within the field of interest and include details of practical experimental approaches employed to investigate this problem. A perspective of where the candidate sees the field now and speculation about how the field will be advanced in the immediate future should also be included. The typical length of the text of the project is 50-75 double-spaced pages, including figures (but not references).

The scholarly review article (final project) will consist of a: Title page; Contents page; Abstract (one page); Introduction to the subject; Sections discussing different aspects of the question; and a Conclusion and
Future Directions part. As in all scientific writing, the scholarly review article (final project) should be precise and concise and give a balanced view of the area of study. The review should be fully referenced (~100 references is typical) and include illustrations and tables as necessary to show data and explain difficult concepts that are better understood visually. This document must be written in close consultation with the scholarly review article (final project) advisor and must be submitted to the Employee Master’s Advisory Committee for review at least one month prior to the final scholarly review article (final project) review date.

Prior to this meeting the committee will carefully review, edit, and critique the scholarly review article (final project) and will provide any changes to the student during the meeting. Significant deficits in the scholarly review article (final project) will require the student to revise and resubmit the document to the committee within 30 days of the defense. Three of four committee members must vote to pass the student and a form signed by all committee members must be submitted to MCGSBS immediately upon completion of the defense.

**Advisory Committee**
Each student should have an advisory committee consisting of four members of the graduate faculty. This committee will be responsible for evaluating the scope and content of the Master’s scholarly review article (final project). Selection of members of this committee should be discussed with the advisor and the program director and arranged prior to beginning the Master’s scholarly review article (final project). The committee will be chaired by the advisor and meet with the student before starting the Master’s scholarly review article (final project).
Employee Master's Degree

The Employee Master’s Degree track in Biomedical Engineering and Physiology is open only to permanent employees of Mayo Clinic. Admission to the program requires an interview with the program director. A total of 38 credits with maintenance of at least a 3.0 GPA are required for graduation.

Course Requirements

Core Courses (6 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CORE 6050</td>
<td>Critical Thinking and Scientific Writing</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CORE 6300</td>
<td>Molecular Biophysics</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>

Track Requirements (27 credits required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMEP 5200</td>
<td>Mathematics in Biomedical Engineering and Physiology</td>
<td>4 cr.</td>
</tr>
<tr>
<td>BMEP 5452</td>
<td>Biomechanics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5704</td>
<td>Bio-Instrumentation and Signal Processing</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5800</td>
<td>Introduction to Medical Imaging</td>
<td>6 cr.</td>
</tr>
<tr>
<td>BMEP 6400</td>
<td>Master’s Scholarly Review Article (Final Project)</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 6650</td>
<td>Biomedical Engineering and Physiology Journal Club</td>
<td>1 cr.</td>
</tr>
<tr>
<td>BMEP 6700</td>
<td>Physiology from Cells to Organism</td>
<td>6 cr.</td>
</tr>
</tbody>
</table>

Electives (8 credits)

Thirty-eight total credits are required to complete the program. In addition to the core and track requirements, 8 elective credits should be selected after consultation between the student and the program director. A minimum GPA of 3.0 will be required for combined coursework.

Qualifying Exam and Master’s Scholarly Review Article (Final Project)

The qualifying examination for the Employee Master’s Degree in Biomedical Engineering and Physiology is comprised of a written qualifying exam. The written exam is administered at the beginning of August and will cover track-required courses. A form signed by the track program director will be submitted to MCGSBS upon successful completion of the written qualifying exam.

In consultation with the program director, the student will select a Master’s degree advisor within the first year of the program. The advisor must have graduate school privileges and must not be the employee’s direct supervisor. In consultation with the program director and the Master’s degree advisor, the student will select an Employee Master’s Advisory Committee comprised of four faculty members.
This committee must include, at a minimum, either the program director or the associate program director. This committee should meet at least every six months to assess the student’s progress and provide guidance regarding the project. A form indicating the composition of the committee must be submitted to MCGSBS.

The Master’s scholarly review article (final project) forms the central element of the Master’s degree. The student should enroll in BMEP 6400 during the final quarter of tenure in the program in order to finalize the project. In general, the project will take the form of a substantial and scholarly review of the current field related to a specific topic of interest to the student. The final form of the scholarly review article (final project) must be approved in advance by the Biomedical Engineering and Physiology Education Committee. This document must be written in close consultation with the Master’s degree advisor and the Employee Master’s Advisory Committee, and must be submitted to the Employee Master’s Advisory Committee for review at least one month prior to the final review date.

The final evaluation of the scholarly review article (final project) is the final committee meeting. Prior to this meeting the committee will carefully review, edit, and critique the scholarly review article (final project) and will provide any changes to the student during the meeting. Committee members may orally examine the student’s general and specific knowledge. Significant deficits in the scholarly review article (final project) will require the student to revise and resubmit the document to the committee within 30 days of the meeting. Three of four committee members must vote to pass the student and a form signed by all committee members must be submitted to MCGSBS immediately upon completion of the review.
IMMUNOLOGY

K. E. Hedin, Ph.D., Program Director

Employee Master’s Degree

Students must complete a minimum of 36 credits.

Course Requirements

Core Courses (4 credit minimum)

CORE 6000 Responsible Conduct of Research (required) ................................. 1 cr.
CORE 6200 Basic Graduate Immunology ............................................................. 3 cr.

Track Requirements (16 credit minimum)

IMM 6400 Master’s Scholarly Review Article (Final Project) ............................ 3 cr.
IMM 6863 *Current Topics in Immunology ......................................................... 1 cr.
IMM 6877 Tutorial in Molecular Basis of Immune Recognition ................. 2 cr.
IMM 6879 Tutorial in Cellular Activation ......................................................... 2 cr.
IMM 6880 Tutorial in Immunopathology ......................................................... 2 cr.
IMM 6882 Tutorial in Mucosal Immunity ......................................................... 2 cr.
IMM 6884 Tutorial in Tumor Immunology ....................................................... 2 cr.
IMM 6885 Tutorial in the Generation and Function of B Cells ................. 2 cr.

*Current Topics courses may be taken more than once

Students who are not currently enrolled in a degree program (including all employee master’s students) must first obtain a signature from the Immunology program director before enrolling in any IMM tutorial course.

Electives (16 credit minimum)

The remainder of the credits can be selected from any field; with no more than nine credits in seminar or journal club style courses.

Written Examination

The Master’s candidate must pass the Immunology written qualifying exam to complete the degree requirements.

Master’s Scholarly Review Article (Final Project)

Master’s degree candidates must complete a written scholarly review article (final project) under the direction of a faculty advisor. The written review article should provide an independent scholarly review
of an important topic in immunology or a scientific grant proposal consisting of a major hypothesis, background, preliminary data (if any), and outline of experimental strategies.

Advisory Committee

The Advisory committee consists of the student’s faculty advisor and three additional members with graduate faculty privileges. The committee must be approved by the program director and MCGSBS. The committee will evaluate the scope and content of the Master’s scholarly review article (final project), and three of the four members must vote to pass the student for successful completion of the Master’s review article (final project).
The requirements for the Employee Master’s Degree in Molecular Pharmacology and Experimental Therapeutics conform to the general requirements of MCGSBS in which a minimum of 36 credits are required for graduation.

### Core Courses (12 credits required)

- **CORE 6000** Responsible Conduct of Research ................................................................. 1 cr.
- **CORE 6100** Chemical Principles of Biological Systems ..................................................... 3 cr.
- **CORE 6150** Genome Biology ................................................................................................. 3 cr.
- **CORE 6250** Molecular Cell Biology ...................................................................................... 3 cr.
- **CORE 6450** Molecular Pharmacology and Receptor Signaling........................................ 2 cr.

### Track Requirements (10 credits required)

- **MPET 5808** Introduction to Molecular Pharmacology....................................................... 4 cr.
- **MPET 6100** Master’s Scholarly Review Article (Final Project) .......................................... 3 cr.
- **MPET 6800** Research Seminars in Pharmacology .............................................................. 1 cr.
- **MPET 6805** Drug Metabolism and Pharmacogenomics.................................................... 2 cr.

### Track Tutorials (6 credits required, 3 tutorials required)

- **MPET 6000** Essentials in Patch Clamp Techniques ........................................................... 2 cr.
- **MPET 6400** Introduction to Principles of Pharmacokinetics .............................................. 2 cr.
- **MPET 6655** Mechanisms of Cell Growth and Death ......................................................... 2 cr.
- **MPET 6812** Tutorial in Receptor Biology............................................................................. 2 cr.
- **MPET 6814** Cellular Pharmacology of Agents that Target Cancer ................................. 2 cr.
- **MPET 6815** Neurobehavioral Pharmacology ................................................................. 2 cr.

### Electives (8 credits required)

Any courses approved for graduate credit; select in consultation with your project advisor.

### Written Examination

The Master’s candidate must pass the MPET Written Qualifying Exam to complete the degree requirements.
Master’s Scholarly Review Article (Final Project)

Master’s degree candidates must complete a written scholarly review article (final project) under the direction of a faculty advisor with graduate faculty privileges. The written scholarly review article (final project) should provide an independent scholarly review of an important topic in pharmacology, propose an important question related to the topic, and outline an experimental strategy to address the question.

Advisory Committee

Advisory committees shall consist of the student’s faculty advisor and three additional members with graduate faculty privileges. The committee must be approved by the program director and MCGSBS. The committee will evaluate the scope and content of the Master’s scholarly review article (final project) during an oral defense of the project. Three of the four members must vote to pass the student for a successful defense.
Employee Master's Degree

The Employee Master’s Degree track in Neurobiology of Disease is only open to permanent employees of Mayo Clinic. Admission to the program requires an interview with the program director and the completion of 6 or more credits in MCGSBS core coursework with maintenance of at least a 3.0 GPA.

Course Requirements

Core Courses (12 credits required)
CORE 6000 Responsible Conduct of Research ....................................................... 1 cr.
CORE 6050 Critical Thinking and Scientific Writing .............................................. 2 cr.
CORE 6100 Chemical Principles of Biological Systems ....................................... 3 cr.
CORE 6150 Genome Biology ................................................................................. 3 cr.
CORE 6250 Molecular Cell Biology ...................................................................... 3 cr.

Track Requirements (21 credits required)
CTSC 5600 Statistics in Clinical and Translational Research ........................... 2 cr.
NBD 6210 Neurobiology of Disease ..................................................................... 3 cr.
NBD 6401 Practical Neuroanatomy ................................................................. 2 cr.
NBD 6600 Neuroscience Journal Club (1 cr./yr.)* ................................................ 2 cr.
NBD 6650 Works in Progress (1 cr./yr.)* ............................................................... 2 cr.
NBD 6852 Topics in Neuroscience Research ......................................................... 1 cr.
NBD 6854 Basic Neuroscience ........................................................................... 5 cr.
NBD 6860 Advanced Topics in Neurobiology .................................................... 2 cr.
NBD 6100 Master’s Scholarly Review Article (Final Project) ............................. 3 cr.
* Two credits maximum

Suggested Electives (3 credits required)
NBD 5600 Behavioral Neurology ........................................................................... 2 cr.
NBD 6855 Concepts of Cell Growth and Regeneration ....................................... 2 cr.
BMEP 6300 Tutorial in Neurophysiology ............................................................ 3 cr.
CORE 6200 Basic Graduate Immunology ............................................................. 3 cr.
CORE 6400 Molecular Genetics ........................................................................ 3 cr.
CORE 6450 Molecular Pharmacology ................................................................. 2 cr.
Qualifying Exam and Master’s Scholarly Review Article (Final Project)

The qualifying examination for the Employee Master’s Degree in the Neurobiology of Disease Track is a written qualifying exam in the same format as the PhD written qualifying exam. There will be a single written qualifying exam composed of knowledge-based and research-based questions based on assigned research articles. A form signed by the track program director will be submitted to MCGSBS upon successful completion of the written qualifying exam.

In consultation with the program director, the student will select a Master’s project advisor within the first year of the program. The advisor must have MCGSBS faculty privileges and must not be the employee’s direct supervisor. In consultation with the program director and the Master’s project advisor, the student will select an Employee Master’s Advisory Committee comprised of four faculty members. This committee must include, at a minimum, either the track program director or the associate program directors. This committee should meet yearly to assess the student’s progress and to provide guidance regarding the Master’s scholarly review article (final project). A form indicating the composition of the committee must be submitted to MCGSBS.

The project forms the central element of the Master’s degree. The student should enroll in NBD 6100, Master’s Scholarly Review Article (Final Project) during the final quarter of tenure in the program in order to finalize the scholarly review article (final project). In general, the project will take the form of a substantial and scholarly review of the current field related to a specific topic of interest to the student. While the final form of the scholarly review article (final project) is at the discretion of the Employee Master’s Advisory Committee, a 50-100 page, double-spaced document comprised of text, figures, and tables as appropriate, is recommended. This document must be written in close consultation with the Master’s project advisor and must be submitted to the Employee Master’s Advisory Committee for review at least one month prior to the final scholarly review article (final project) defense date. Upon successful completion of the defense and careful editing of the document, the track will pay to have 3 copies bound (one for the Master’s project advisor, one for the track, and one for the student). Binding should be coordinated with the program director or associate program directors.

The scholarly review article (final project) defense is the final committee meeting. Prior to this meeting the committee will carefully review, edit, and critique the scholarly review article (final project) and will provide any changes to the student during the meeting. Committee members may orally examine the student’s general and specific knowledge. Significant deficits in the project will require the student to revise and resubmit the document to the committee within 30 days of the defense. Three of four committee members must vote to pass the student and a form signed by all committee members must be submitted to MCGSBS immediately upon completion of the defense.
DESCRIPTION OF CLINICAL MASTER’S DEGREE PROGRAM AND TRACK REQUIREMENTS
MASTER OF SCIENCE PROGRAM IN BIOMEDICAL SCIENCES CLINICAL SPECIALTIES

The primary purpose of the degree program is to enhance the scholarly dimension of the education of physicians and dentists who have an interest in academic medicine. Training in research is emphasized. The degree program provides a structure for development of a plan to address a research problem, an orderly approach to the project, assurance of the credentials of the advisor, appropriate supervision, and a suitable approach to the analysis and presentation of the results.

Courses in basic biomedical sciences are required to provide the student with the knowledge to address a research problem, conduct the research and evaluate the results. Courses in the track are required in addition to provide special skills, techniques or knowledge related to the specialty track. General program requirements and specialty track descriptions are outlined on the following pages. Degree candidates must be enrolled in the program at least one year prior to graduation.

ELIGIBILITY

This program is designed for Mayo residents who hold appointments to the clinical programs of Mayo School of Graduate Medical Education. Potential candidates for the degree must hold appointments of sufficient duration to complete degree program requirements.

TUITION

Tuition may be covered by a MCGSBS scholarship for Mayo graduate courses taken to meet Master’s degree requirements. Mayo will not reimburse other costs that may be associated with the degree program.

APPLICATION

Candidates must complete an Application for Graduate Training Master’s Program in Biomedical Sciences-Clinical Specialties form. The application must be approved by the track program director and MCGSBS. This form is available from the MCGSBS office.

TIME REQUIREMENT

All requirements must be satisfied within 30 days of the thesis defense.

REGISTRATION REQUIREMENT

At least 75% of the coursework for the Master’s degree must be completed in MCGSBS. Enrollment in the degree program for a minimum of one year is required. It is expected that a minimum of six months will be devoted to research.

MINIMUM CREDIT REQUIREMENTS

Students must complete a minimum of 12 credits in basic biomedical sciences and 12 additional credits in the track (credits may vary depending on the chosen track but the minimum MCGSBS credit requirement must be met). Six of the 12 credits in the track must be didactic credits. It is expected that a minimum of
six months will be devoted to research. Students are not admitted to a specialty track unless there is reasonable assurance that course work required for completion of degree requirements is available.

TRANSFER CREDITS

A total of 6 didactic credits may be transferred into the Clinical Master’s Program.

Core Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a Mayo core course must contact the Mayo course director and their program director. To substitute or to waive core course credits, the student is required to prove competence by taking an exam dictated by the course director on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo core course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Track Required Course Policy
Students who wish to transfer graduate credits to substitute or to waive credits for a track required course must contact the Mayo course director and their program director. To substitute or to waive track required course credits, at the Mayo course director’s and the program director’s discretion the student is required to prove competence by taking an exam on the subject. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the track required course, the student may request the transfer or waived credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

Elective Course Policy
Students who wish to transfer graduate credits to substitute for a Mayo elective course must contact the Mayo course director and their program director. If the course director and the program director determine that a student has the knowledge equivalent to satisfactory performance in the Mayo course, the student may request the transfer credits. A letter from the course director and the program director must be sent to the MCGSBS office to document the knowledge.

External Courses Policy
Students who wish to transfer credits not in substitution for a Mayo course(s) may request credit for graduate courses taken at another institution if they received a grade of A or B. The request must have the approval of the student’s program director and MCGSBS. A description of the course from the course catalog or a course outline must accompany the request. The time interval since the credits were earned is a consideration in such decisions. Credits must normally have been earned within the previous five years, as determined by the program director.

ADVISOR

A Master’s degree advisor must have MCGSBS full or Master’s graduate faculty privileges.
A List of Faculty with Privileges can be found on the MCGSBS intranet site.
OFFICIAL DEGREE PROGRAM FORM

Students are expected to submit their Degree Program Form to MCGSBS before the end of the first year of registration. The form must include the minimum number of courses/credits necessary to fulfill degree requirements (credits may vary depending on the chosen track but the minimum MCGSBS credit requirement must be met) and be approved by the track program director. Fifty percent of the credits on the degree program must be graded on the A-F grading system. The Degree Program Form is available on the MCGSBS intranet site.

CHANGES IN APPROVED PROGRAM

The approved degree program must be fulfilled in every detail to meet graduation requirements. Alterations in the program must be requested in writing and approved by the track program director, the student’s advisor, and MCGSBS.

MINIMUM GRADE REQUIREMENTS

Students are expected to maintain a grade point average of 3.0 in didactic course work. Students whose performance falls below this standard in a given quarter will be placed on academic probation, as described in the Deficiencies and Unsatisfactory Progress and Warning, Probation and Dismissal policies outlined on the MCGSBS intranet Policies and Procedures webpage.

EXAMINATIONS

Written Examination: A comprehensive written examination must be taken before completion of the training program. MCGSBS must be informed of the date of the examination three weeks in advance so that the Master’s Written Examination Report form can be sent to the track program director. The written examination may be taken no more than twice. If it is not passed on the first attempt, it must be retaken by the end of the quarter following the quarter in which it was first taken. Failing the examination twice will result in dismissal. The written examination must be passed before the final oral examination may be scheduled.

Final Oral Examination: Candidates for the Master’s degree are expected to pass the final oral examination before completion of the Mayo residency or fellowship training program. The final oral examination may be taken after: 1) the written examination has been passed, 2) all course work shown on the Degree Program form has been completed, and 3) the thesis is reviewed. MCGSBS must be informed of the date of the examination three weeks in advance so that the Master’s Final Oral Examination Report form can be sent to the Thesis Advisory Committee chair.

The student’s advisor must sign a form indicating that he/she has read the thesis and that it is ready for defense prior to distribution to the Thesis Advisory Committee members. The Verification that the Thesis is Ready to Defend form can be accessed on the MCGSBS intranet site. A copy of the title page of the thesis and the form must be submitted to the MCGSBS office. The thesis must be submitted to the Thesis Advisory Committee at least three weeks before the final oral examination.
Voting members of the Thesis Advisory Committee must be present in real time via physical presence or video- or teleconferencing at the final oral examination. Only one dissenting vote will be allowed for a “Pass.” Passage of the final oral examination requires a minimum of three passing votes; otherwise a determination of “Fail” must be made. Thus, no more than one Thesis Advisory Committee member may be absent for the final oral examination. The final oral examination may be taken no more than twice. If it is not passed on the first attempt, it must be retaken by the end of the quarter following the quarter in which the exam was first taken. Failing the examination twice will result in dismissal.

THESIS

Thesis Protocol: The protocol must be submitted to MCGSBS no later than six months after admission to the program. This protocol must clearly define the candidate’s role in the project and must have sufficient detail to permit review by an advisory committee. An Outline for the Master’s Thesis Protocol is available on the MCGSBS intranet site. The protocol must be submitted with the form, Recommended Action on Thesis Protocol for Clinical Master’s Degree, also available on the intranet site.

The Mayo Institutional Review Board must review all protocols for research involving the use of human subjects. It is the candidate’s responsibility to secure approval of any such protocols before the research is undertaken.

Thesis Advisory Committee: With the thesis protocol, students must submit the Master’s Thesis Advisory Committee form recommending the members of their thesis advisory/ final oral examining committee and the Degree Program form. All members must have graduate faculty privileges and the chair must have a minimum of Master’s graduate faculty privileges. The examining committee must consist of four members, one of whom is the student’s advisor, who serves as chair of the committee. Any additional Thesis Advisory Committee members beyond four will be designated as “ex officio” and will not vote at the final defense. No member other than the chair may be from among a student’s research advisors. No more than two members of the committee may have teaching/examining privileges. The recommended committee must be approved by the track program director and MCGSBS.

Progress Meetings: The Master’s Thesis Advisory Committee must meet every six months from the date of committee approval. Documentation of student progress, signed by all members of the Thesis Advisory Committee, should be submitted to MCGSBS after each of these meetings.

Preparation of Thesis: The thesis is the most important document that the Master’s candidate will prepare during the course of graduate study and is a record of the scientific accomplishments that justify the awarding of the degree. The thesis is archival. Consequently, MCGSBS has developed a standard for its format and style, which should be closely followed. Guidelines for Master’s thesis are available on the MCGSBS intranet site at For Students/General Forms/Resources.

Final Thesis Corrections: After the student has passed the final oral examination, the chair of the Thesis Advisory Committee must sign a form indicating he/she is satisfied that the final corrections to the thesis have been made. The chair must sign before the student will be cleared for graduation. MCGSBS will not certify completion of degree requirements until the final thesis has been submitted.

GRADUATION

Students are granted degrees four times a year: February, May, August, and November. Students must have all requirements completed by the first working day of the month prior to the graduation month.
Students are allowed no more than 30 days to complete M.S. degree requirements after a successful thesis defense. This policy was effective November 1, 2014. If a student does not meet this deadline, he/she will be required to re-defend his/her thesis.

<table>
<thead>
<tr>
<th>To graduate in:</th>
<th>Requirements must be completed by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>February</td>
<td>January 1</td>
</tr>
<tr>
<td>May</td>
<td>April 1</td>
</tr>
<tr>
<td>August</td>
<td>July 1</td>
</tr>
<tr>
<td>November</td>
<td>October 1</td>
</tr>
</tbody>
</table>
DENTISTRY – ORTHODONTICS

J. E. Volz, D.D.S., Program Director

Clinical Master’s Degree

In addition to the following courses, successful completion of the requirements for the Certificate in Orthodontics is required.

Biomedical Sciences Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6852</td>
<td>Surgical Anatomy of the Head and Neck</td>
<td>3 cr.</td>
</tr>
<tr>
<td>BMEP 5453</td>
<td>Fundamental Concepts in Biomechanics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>DERM 6870</td>
<td>Mucous Membrane Course</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ODON 6857</td>
<td>Research in Selected Problems</td>
<td>8 cr.</td>
</tr>
</tbody>
</table>

(1 cr./qtr. – 8 qtrs. required)

Orthodontic Didactic Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODON 6806</td>
<td>Orthodontic Seminar: Technique</td>
<td>2 cr.</td>
</tr>
<tr>
<td></td>
<td>(1 cr./qtr. - 2 qtrs. required)</td>
<td></td>
</tr>
<tr>
<td>ODON 6807</td>
<td>Orthodontic Seminar: Literature Review</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ODON 6808</td>
<td>Orthodontic Seminar: Case Presentation</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ODON 6809</td>
<td>Surgical Orthodontic Seminar</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ODON 6810</td>
<td>Clinical Oro-Facial Pathology and Developmental Disorders</td>
<td>1 cr.</td>
</tr>
<tr>
<td>FDON 6884</td>
<td>Periodontics/Orthodontics Seminar</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Orthodontic Clinical Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ODON 6804</td>
<td>Clinical Orthodontics</td>
<td>6 cr.</td>
</tr>
<tr>
<td>ODON 6805</td>
<td>Advanced Clinical Orthodontics</td>
<td>6 cr.</td>
</tr>
</tbody>
</table>
DENTISTRY – PERIODONTICS

R. L. Vidal Gonzalez, D.D.S., Program Director

Clinical Master’s Degree

Biomedical Sciences Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6852</td>
<td>Surgical Anatomy of Head and Neck</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5300</td>
<td>Introduction to Clinical Epidemiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>DERM 6870</td>
<td>Mucous Membrane Course</td>
<td>1 cr.</td>
</tr>
<tr>
<td>PDON 6857</td>
<td>Research in Selected Problems</td>
<td>12 cr.</td>
</tr>
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</table>

Periodontics Didactic Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDON 6883</td>
<td>Periodontal Seminar/Current Literature</td>
<td>3 cr.</td>
</tr>
<tr>
<td>PDON 6884</td>
<td>Periodontics/Orthodontics Seminar</td>
<td>1 cr.</td>
</tr>
<tr>
<td>PDON 6886</td>
<td>Classic Literature in Periodontics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>PROS 6870</td>
<td>Occlusion</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Periodontics Clinical Courses (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDON 6880</td>
<td>Clinical Periodontics</td>
<td>6 cr.</td>
</tr>
</tbody>
</table>

(2 cr./qtr. - 6 qtrs. required)

(1 cr./qtr. - 3 qtrs. required)

(6 cr./qtr. - 1 qtr. required)
DENTISTRY – PROSTHODONTICS

T. J. Salinas, D.D.S., Program Director

Clinical Master’s Degree

Biomedical Sciences Courses (all required)

ANAT 6852 Surgical Anatomy of Head and Neck .............................................................. 3 cr.
CORE 6000 Responsible Conduct of Research...................................................................... 1 cr.
CTSC 5600 Statistics in Clinical and Translational Research............................................. 2 cr.
CTSC 5601 Utilizing Statistics in Clinical Research............................................................ 1 cr.
DERM 6870 Mucous Membrane Course ................................................................................ 1 cr.
PROS 6857 Research in Selected Problems (2 cr./qtr. - 6 qtrs. required).......................... 12 cr.
(Master’s application must be accepted by MCGSBS to enroll in this course.)

Prosthodontic Didactic Courses (all required)

PROS 6841 Prosthodontic Seminar (Complete Dentures)............................................... 2 cr.
(1 cr./qtr. - 2 qtrs. required)
PROS 6843 Prosthodontic Seminar (Partial Dentures)....................................................... 1 cr.
PROS 6845 Prosthodontic Seminar (Fixed)............................................................................ 1 cr.
PROS 6847 Seminar: Maxillofacial Prosthetics–Advanced Prosthodontics..................... 1 cr.
PROS 6848 Seminar: Current Literature............................................................................... 1 cr.
PROS 6849 Seminar: Maxillofacial Prosthetics (Extraoral) and Advanced Prosthodontics.......................... 1 cr.
PROS 6850 Seminar: Implant Prosthodontics ..................................................................... 1 cr.
PROS 6859 Periodontal and Prosthodontic Considerations in Dentistry ....................... 1 cr.
PROS 6862 Dental Materials ............................................................................................. 1 cr.
PROS 6870 Occlusion........................................................................................................... 1 cr.
PROS 6871 Physiology, Pharmacology and Pre-Prosthetic Surgery ......................... 1 cr.
PROS 6873 Cranio-mandibular Disorders and Facial Pain ............................................. 1 cr.
PROS 6874 Prosthodontic Management of the Geriatric Patient ..................................... 1 cr.

Prosthodontic Clinical Courses (all required)

PROS 6840 Clinical Prosthodontics: Complete Dentures.............................................. 12 cr.
(6 cr./qtr. - 2 qtrs. required)
PROS 6842 Clinical Prosthodontics: Partial Dentures..................................................... 24 cr.
(6 cr./qtr. - 4 qtrs. required)
PROS 6851 Dental Roentgenology .................................................................................. 1 cr.
PROS 6852 Oral Diagnosis and Treatment of Cranio-mandibular Disorders ............... 2 cr.
PROS 6854 Implant Prosthodontics ................................................................................... 18 cr.
(6 cr./qtr. - 3 qtrs. required)
PROS 6880 Dental Laboratory Technology ...................................................................... 6 cr.

Prosthodontic Elective Courses (Student must obtain approval from program director)

PROS 6856 Oral and Maxillofacial Surgery........................................................................ 1 cr
PROS 6875 Dental Implant Procedures.......................................................................... 1 cr
PROS 6877 Dentofacial Esthetics..................................................................................... 1 cr
OBSTETRICS & GYNECOLOGY –

FEMALE PELVIC MEDICINE/ RECONSTRUCTIVE SURGERY

J. A. Occhino, M.D., Program Director

Clinical Master's Degree

Biomedical Sciences Courses Didactic (all required)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5010</td>
<td>Clinical Research Protocol Development</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5300</td>
<td>Introduction to Clinical Epidemiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5310</td>
<td>Clinical Epidemiology II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5610</td>
<td>Introductory Statistical Methods II</td>
<td>3 cr.</td>
</tr>
<tr>
<td>OBG 6840</td>
<td>Research in Obstetrics-Gynecology (6 cr./qtr. – 4 qtrs. required)</td>
<td>24 cr.</td>
</tr>
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</table>

Master’s program application must be accepted by MCBSBS to enroll in this course.

Additional elective courses may be taken after discussion and approval by the program director.
Courses available but are not limited to:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CTSC 5390</td>
<td>Advanced Applied Epidemiologic Methods</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5640</td>
<td>Logistic Regression</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5650</td>
<td>Survival Analysis</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5720</td>
<td>Clinical Trials Design and Conduct</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5740</td>
<td>Systematic Reviews and Meta-Analysis</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5761</td>
<td>Evidence-Based Medicine for Clinical Researchers</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5820</td>
<td>Introduction to Survey Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5910</td>
<td>Economic Evaluation in Health Care</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Workshops are to be taken during first year of fellowship (research rotation)

- Writing for Biomedical Publication
- Write Winning Grants

Urogynecology/Reconstructive Pelvic Surgery Didactic Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6000</td>
<td>Anatomy of the Pelvis-Perineum</td>
<td>2 cr./yr</td>
</tr>
<tr>
<td></td>
<td>Register winter quarter; attendance required winter and spring quarters</td>
<td></td>
</tr>
<tr>
<td>OBG 5803</td>
<td>Introduction to Surgical Gynecology (1 cr./qtr. - 4 qtrs. required)</td>
<td>4 cr.</td>
</tr>
<tr>
<td></td>
<td>Begin summer quarter of first year of fellowship; student must register for 4 consecutive quarters.</td>
<td></td>
</tr>
</tbody>
</table>

Urogynecology/Reconstructive Pelvic Surgery Clinical Courses

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBG 6870</td>
<td>Advanced Urogynecologic Operative Surgery</td>
<td>24 cr.</td>
</tr>
<tr>
<td></td>
<td>(6 cr./qtr. - 4 qtrs. required) Begin summer quarter of second year of fellowship.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Student must register for 4 consecutive quarters.</td>
<td></td>
</tr>
</tbody>
</table>
OBSTETRICS & GYNECOLOGY– GYNECOLOGIC ONCOLOGY

W. A. Cliby, M.D., Program Director

Clinical Master’s Degree

Biomedical Sciences Courses
Didactic (All Required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMB 5000</td>
<td>Cancer Biology I</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5610</td>
<td>Introductory Statistical Methods II</td>
<td>3 cr.</td>
</tr>
<tr>
<td>OBG 6840</td>
<td>Research in Obstetrics-Gynecology</td>
<td>24 cr. (6 cr./qtr. – 4 qtrs. required)</td>
</tr>
</tbody>
</table>

Master’s program application must be accepted by MCBSBS to enroll in this course.

*Students in this master’s program will complete their thesis research and thesis document, and defend their thesis prior to completion of all required course work and the written examination.

Additional elective courses may be taken after discussion and approval by the program director.

Courses available but are not limited to:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5300</td>
<td>Introduction to Clinical Epidemiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5310</td>
<td>Clinical Epidemiology II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5640</td>
<td>Logistic Regression</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5650</td>
<td>Survival Analysis</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Workshops below to be taken during first year of fellowship

Writing for Biomedical Publication
Writing Winning Grants

Gynecologic Oncology Didactic Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6000</td>
<td>Anatomy of the Pelvis-Perineum</td>
<td>2 cr./yr.</td>
</tr>
<tr>
<td>OBG 5803</td>
<td>Introduction to Surgical Gynecology</td>
<td>4 cr. (1 cr./qtr. – 4 qtrs. required)</td>
</tr>
</tbody>
</table>

Begin summer quarter of first year of fellowship; student must register for 4 consecutive quarters.

Gynecologic Oncology Clinical Courses

*OBG 6857 | Gynecologic Oncology | 30 cr. (6 cr./qtr. - 5 qtrs. required) |

Begin summer quarter of second year of fellowship. Student must register for 5 consecutive quarters.
OBSTETRICS & GYNECOLOGY – MATERNAL FETAL MEDICINE

C. H. Rose, M.D., Program Director

Clinical Master’s Degree

Biomedical Sciences Courses Didactic (all required)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5010</td>
<td>Clinical Research Protocol Development</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5300</td>
<td>Introduction to Clinical Epidemiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5310</td>
<td>Clinical Epidemiology II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5610</td>
<td>Introductory Statistical Methods II</td>
<td>3 cr.</td>
</tr>
<tr>
<td>OBG 6840</td>
<td>Research in Obstetrics-Gynecology</td>
<td>24 cr.</td>
</tr>
</tbody>
</table>

Master’s program application must be accepted by MCBSBS to enroll in this course.

Elective Courses (2 elective credits required) available but not limited to:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTSC 5390</td>
<td>Advanced Applied Epidemiologic Methods</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5640</td>
<td>Logistic Regression</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5650</td>
<td>Survival Analysis</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5760</td>
<td>Medical Decision Making</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5820</td>
<td>Introduction to Survey Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5910</td>
<td>Economic Evaluation in Health Care</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

Workshops

Writing for Biomedical Publication Write Winning Grants

Maternal Fetal Medicine Didactic Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBG 5804</td>
<td>Introduction to Maternal Fetal Medicine</td>
<td>4 cr.</td>
</tr>
</tbody>
</table>

(1 cr./qtr. - 4 qtrs. required)

Begin summer quarter of first year of fellowship. Student must register for 4 consecutive quarters.

Maternal Fetal Medicine Clinical Courses

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBG 6875</td>
<td>Maternal Fetal Medicine</td>
<td>24 cr.</td>
</tr>
</tbody>
</table>

(6 cr./qtr. - 4 qtrs. required)
OBSTETRICS & GYNECOLOGY –
REPRODUCTIVE ENDOCRINOLOGY AND INFERTILITY

E. A. Stewart, M.D., Program Director

Clinical Master's Degree

**Biomedical Sciences Courses Didactic (all required)**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5300</td>
<td>Introduction to Clinical Epidemiology</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5600</td>
<td>Statistics in Clinical and Translational Research</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5601</td>
<td>Utilizing Statistics in Clinical Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>OBG 6840</td>
<td>Research in Obstetrics-Gynecology</td>
<td>24 cr.</td>
</tr>
<tr>
<td></td>
<td>(6 cr./qtr. – 4 qtrs. required)</td>
<td></td>
</tr>
</tbody>
</table>

Master’s program application must be accepted by MCBSBS to enroll in this course.

Must choose one of the following basic science courses:

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORE 6150</td>
<td>Genome Biology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6250</td>
<td>Molecular Cell Biology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CORE 6400</td>
<td>Molecular Genetics</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>

Additional elective courses may be taken after discussion and approval by the program director.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMB 6660</td>
<td>Transcription, Chromatin, and Epigenetics</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5010</td>
<td>Clinical Research Protocol Development</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5310</td>
<td>Clinical Epidemiology II</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5390</td>
<td>Advanced Applied Epidemiologic Methods</td>
<td>2 cr.</td>
</tr>
<tr>
<td>CTSC 5610</td>
<td>Introductory Statistical Methods II</td>
<td>3 cr.</td>
</tr>
<tr>
<td>CTSC 5640</td>
<td>Logistic Regression</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5650</td>
<td>Survival Analysis</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5760</td>
<td>Medical Decision Making</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5820</td>
<td>Introduction to Survey Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>CTSC 5910</td>
<td>Economic Evaluation in Health Care</td>
<td>1 cr.</td>
</tr>
</tbody>
</table>

**Workshops - Recommended but not required**

- Writing for Biomedical Publication
- Write Winning Grants

**Reproductive Endocrinology & Infertility Didactic Courses**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6000</td>
<td>Anatomy of the Pelvis-Perineum</td>
<td>2 cr./yr.</td>
</tr>
<tr>
<td></td>
<td>Register winter quarter; attendance required winter and spring quarters</td>
<td></td>
</tr>
<tr>
<td>OBG 5805</td>
<td>Introduction to Reproductive Endocrinology and Infertility</td>
<td>5 cr.</td>
</tr>
<tr>
<td></td>
<td>(1 cr./qtr. - 5 qtrs. required)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Begin summer quarter of first year of fellowship; register for 5 consecutive quarters.</td>
<td></td>
</tr>
</tbody>
</table>
Reproductive Endocrinology and Infertility Clinical Courses

OGB 6865  Reproductive Endocrinology and Infertility ................................................... 30 cr.
(6 cr./qtr. - 5 qtrs. required)
Begin summer quarter of first year of fellowship; register for 5 consecutive quarters.
## ORTHOPEDICS

M. P. Abdel, M.D., *Program Director*

### Clinical Master’s Degree

#### Biomedical Sciences Courses (all required)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANAT 6855</td>
<td>Orthopedic Anatomy</td>
<td>4 cr.</td>
</tr>
<tr>
<td>CORE 6000</td>
<td>Responsible Conduct of Research</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ORS 6890</td>
<td>Research in Orthopedics</td>
<td>24 cr.</td>
</tr>
</tbody>
</table>

#### Orthopedics Didactic Courses (all required)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORS 5803</td>
<td>Prosthetics for Orthopedics</td>
<td>1 cr.</td>
</tr>
<tr>
<td>ORS 6550</td>
<td>Microvascular Surgery Skills</td>
<td>2 cr.</td>
</tr>
<tr>
<td>ORS 6860</td>
<td>Basic Knowledge and Motor Skills of Orthopedic Specialties</td>
<td>4 cr.</td>
</tr>
</tbody>
</table>

#### Orthopedics Clinical Courses (all required)

<table>
<thead>
<tr>
<th>Code</th>
<th>Course</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ORS 6852</td>
<td>Adult Reconstruction</td>
<td>3 cr.</td>
</tr>
<tr>
<td>ORS 6853</td>
<td>Surgery of the Hand</td>
<td>3 cr.</td>
</tr>
<tr>
<td>ORS 6854</td>
<td>Pediatric Orthopedics</td>
<td>3 cr.</td>
</tr>
<tr>
<td>ORS 6855</td>
<td>Orthopedic Oncology</td>
<td>3 cr.</td>
</tr>
<tr>
<td>ORS 6856</td>
<td>Fractures and Related Injuries</td>
<td>3 cr.</td>
</tr>
</tbody>
</table>
Course Listings
Course Listings – Symbols and Explanations

The following symbols are used throughout the course descriptions in lieu of page footnotes:

A-F Standard Letter Grading Scale
S-N Pass / Fail Grading Scale
f,w,sp,su Following course number indicates fall, winter, spring, or summer quarters respectively.
i Following course number indicates instructor approval required.

Anatomy


ANAT 6852sp. SURGICAL ANATOMY OF HEAD AND NECK. (3 cr.; A-F; offered even years) Pawlina, Price – Cadaver dissection and lecture demonstration. Laboratory participation required for credits. Primarily intended for residents and fellows in Otorhinolaryngology.

ANAT 6855f,w,sp,su. ORTHOPEDIC ANATOMY. (2 cr.; S-N) Morrey – Lectures, prosections and demonstrations of gross anatomy of the musculoskeletal system with special emphasis on relationships and surgical approaches.

*Only Anatomy courses which are required for degree completion in clinical programs are listed.

Biochemistry and Molecular Biology

Biochemistry and Structural Biology; Cell Biology and Genetics; Cancer Biology Subtracks

BMB 5000f. CANCER BIOLOGY I: INTRODUCTION TO CANCER BIOLOGY; MOLECULAR, CELLULAR AND GENETIC BASIS OF CANCER. (3 cr.; A-F) Fernandez-Zapico, Hawse – This course will provide an introductory foundation for understanding cancer biology through the discussion of normal and abnormal tissue pathology, and the molecular, cellular and genetic mechanisms that contribute to tumorigenesis. Topics that will be covered in the course include: the histopathology of cancer, tumor initiation and promotion, oncogenes and tumor suppressors, cell cycle control, cell migration and angiogenesis. In addition, several lectures will focus on the cellular, molecular and genetic approaches to study cancer in vitro and in animal models.

BMB 5200f. BMB WORKS IN PROGRESS. (1 cr; S-N) Hawse, Katzmann – Works-in-Progress presentations on experimental research projects, given by graduate students in the Biochemistry
and Molecular Biology tracks. Register in fall quarter only (1 cr./yr.). Attendance required fall, winter and spring. At least 70% attendance is required. Students present annually after year 1.

**BMB 5350sp. HORMONES AND CANCER.** (1 cr.; S-N; offered odd years) Hawse – This course is a didactic class design to give the student an overview of hormonal carcinogenesis. The malignancies to be covered include breast cancer, prostate cancer, endometrial cancer, ovarian cancer, and thyroid cancer. The course will review epidemiology, signaling pathways, the role of hormones, and novel therapeutic approaches of the mentioned cancers.


**BMB 5660f,w,sp. EPIGENOMICS JOURNAL CLUB.** (1 cr.; S-N) Robertson, Ordog – Epigenetics, and its genome-wide applications, are rapidly emerging disciplines, seeking to define how genomes are regulated to give rise to distinct normal and diseased phenotypes. Students will gain a better understanding of Epigenomics concepts and methodologies through discussions of relevant reviews and original articles. The course covers scientific advances in DNA methylation, histone modifications, chromatin dynamics, and regulatory RNA molecules.

**BMB 6000f,w,sp,su. BIOLOGICAL MACROMOLECULES.** (3 cr.; S-N; Req. CORE 6100 or CORE 6300 or equiv.) Ramirez-Alvarado – Please contact Dr. Ramirez-Alvarado if you are planning to take this course, as this is a single student class with a waiting list. Learn to problem solve, design, and interpret the experimental results involving your favorite macromolecule. This class is tailored to each student and covers the physical principles that govern molecular structure, intermolecular interactions, the principles behind spectroscopic methods such as fluorescence, hydrodynamic methods such as electrophoresis and chromatography, and high resolution structural methods such as X-ray crystallography, nuclear magnetic resonance and cryo-Electron microscopy. This class is heavily based on the student’s research interests and case studies.

**BMB 6030f. DATA ANALYSIS AND MATHEMATICAL MODELING IN BIOMEDICAL RESEARCH.** (3 cr.; A-F; pre-req. linear algebra, calculus, basic computer skills or consent of instructor) Bajzer – An introduction to the art of mathematical modeling and to methods for data fitting with applications to biomedical sciences. Theoretical knowledge along with data reduction practice are offered to provide sufficient skills in using data fitting procedures. Students are encouraged to apply acquired knowledge to their own research projects.

**BMB 6040sp. FRACTALS AND CHAOS IN BIOSCIENCES.** (2 cr.; A-F; pre-req. college calculus) Peters, J. – An overview of applications of fractals and chaos in biosciences. The emphasis is on general understanding of basic concepts (self-similarity, scaling, dimension, sensitivity to initial conditions, bifurcations, chaotic data, control of chaos, etc.) and their applications (protein backbone, neurons, ion channel kinetics, glycolysis, allosteric enzymes, pulmonary hypertension, tumor growth, etc.). Mathematical aspects and technical details are reduced to a minimum.
BMB 6050f. BIOLOGICAL KINETICS. (3 cr.; S-N; pre-req. college level biochemistry or biophysics, college calculus, college chemistry, basic computer skills) Bajzer, Caride – An overview of applications of kinetic analysis to various biological problems including complex steady-state and pre-steady-state enzyme kinetics, kinetics of protein folding, ion pumps, calcium signaling, oscillatory biochemical reactions, neurotransmitter release and tumor growth. Experimental, theoretical and practical aspects are covered in sufficient detail to allow participants to approach their kinetic problems with an adequate background.

BMB 6070w. CANCER BIOLOGY II: MOLECULAR MECHANISMS OF CANCER: SIGNAL TRANSDUCTION PATHWAYS AND NETWORKS. (3 cr.; A-F; offered even years; pre-req. BMB 5000) Billadeau, Fernandez- Zapico – This course will provide a basic CORE of information on the molecular mechanisms through which cells receive and respond to external signals in the normal state, while highlighting how dysregulation of these signaling pathways contributes to tumorigenesis. Emphasis will be on the principles of cell signaling through specific cell surface receptors or within specific signaling networks. In addition, the molecular, genetic and biochemical strategies by which cell signaling pathways are being elucidated will be discussed. Topics to be covered include: the regulation of cell signaling pathways through cell surface receptors and hormone receptors, intracellular kinases and GTP-binding proteins, NF-κB, apoptosis, and DNA damage signaling.

BMB 6075sp. EPIGENETICS OF CANCER AND ADDICTION. (3 cr.; A-F; offered even years; pre-req. CORE 6150) Ekker – This course is designed to provide the student with an understanding of how epigenetics plays a central role in cancer but is also involved in a range of other disease states, such as addiction.

BMB 6300f,w,sp,su. MASTER’S SCHOLARLY REVIEW ARTICLE (FINAL PROJECT). (3 cr.; S-N) Staff – Critical review article of an area of biochemistry and molecular biology submitted as Employee Master’s project. Topic is chosen by student in consultation with the advisor and an advisory committee. May be taken only once for credit. Register in the quarter in which you present your final project to the advisory committee; and register with your advisor as course director.

BMB 6320sp. SPECIAL TOPICS IN CANCER BIOLOGY. (1 cr.; S-N; offered even years) Salisbury – This course will present a comprehensive discussion of the origin and maintenance of embryonic, adult (somatic) and cancer stem cells; stem cell self-renewal vs. asymmetric division and differentiation; genes that determine stemness; cancer stem cells and the origin of tumor cell heterogeneity and cancer progression; epigenetics and the cancer stem cell niche; and cancer stem cells as therapeutic targets in cancer treatment.

BMB 6390f,w,sp,su. INDEPENDENT STUDY IN BIOCHEMISTRY AND MOLECULAR BIOLOGY. (1-2 cr.; A-F) Staff – Tutorials arranged on an individual basis in selected advanced topics in biochemistry and molecular biology. Students are expected to define a topic and specific reading list in consultation with a member of the faculty. Mastery of the subject matter is assessed by examination or by submission of a formal review of the subject area.

BMB 6500f,w,sp. BMB JOURNAL CLUB. (1 cr.; S-N) Hawse – Students of the Biochemistry and Molecular Biology program present a peer review article relevant to BMB, in some cases associated with the research of the seminar speaker coming the following week. Register in fall quarter only (1 cr./yr.; total of 4 cr.). Attendance required fall, winter and spring at the journal
club and the associated BMB Seminar. At least 70% attendance is required at both the journal club and seminar.

**BMB 6510f,w. CANCER BIOLOGY JOURNAL CLUB.** (1 cr./qt.; S-N) Fernandez-Zapico, Hawse – This journal club will discuss current primary literature covering all aspects of cancer biology. The journal club will meet once per week and be conducted under the open discussion format with directed student and faculty presentations. During the fall quarter, journal articles of fundamental and historic interest in the area of cancer biology will be read and discussed. Topics to be covered include: cell cycle, oncogenes, tumor suppressors, growth factors, signal transduction, metastasis, DNA tumor viruses, and retroviruses. Register in fall quarter only. Attendance required fall and winter quarters.

**BMB 6515f,w,sp. MUSCULOSKELETAL JOURNAL CLUB.** (1 cr/yr.; S-N) Westendorf – Graduate students, postdoctoral fellows and residents present peer-reviewed articles that describe new and high impact work in musculoskeletal research fields. MCBSBS students from any track or program are welcome to attend and lead discussions in this interdisciplinary forum that spans molecular and cellular biology, biomechanics, endocrinology, orthopedics, osteoimmunology, physiology, and other disciplines. This is a shared course with the Biomedical Engineering and Physiology and track. Register in fall quarter only. Attendance required in consecutive fall, winter and spring quarters. Students must present and lead one discussion during one of the quarters and attend 75% of meetings over all three quarters to earn credit.

**BMB 6520f,w,sp. CURRENT TOPICS IN AGING RESEARCH.** (1 cr./yr.; S-N; register in fall quarter only; attendance required fall, winter, and spring) LeBrasseur, J. Miller – Current topics in aging research utilizes the Kogod Center’s “Aging Mondays” to expose students to a range of topics related to the basic biology of aging presented in four concurrent series: journal club, works-in-progress, NERDs and seminars presented by an international group of seminar speakers. Each series meets at noon on a different Monday of the month. There are no course prerequisites, but attendance requires preapproval by the course director. Presentation at the Aging JC or WIP during the quarter is required for credit.

**BMB 6650sp. RECEPTOR TRAFFICKING AND SIGNALING TUTORIAL.** (2 cr.; A-F; offered odd years; pre-req. CORE courses 6100, 6150 and 6250) Katzmann, Horazdovsky – This tutorial focuses on understanding the molecular basis of receptor traffic and signaling in eukaryotic cells. Special attention is directed toward contributions by the cytoskeleton and vesicular transport machinery during endocytosis and secretion. Students prepare oral presentations describing a synthesis of appropriate topics.

**BMB 6660f. TRANSCRIPTION, CHROMATIN, AND EPIGENETICS.** (2 cr.; A-F; offered even years; pre-req. CORE courses 6100, 6150 and 6250) Lomberk, Urrutia – This course will cover in depth mechanisms of transcriptional regulation within a modern conceptual framework focused on epigenetics. Topics will include chromatin structure and dynamics, nuclear structure and nuclear domains, and chromosomal territories. The application of epigenetics to human development and diseases will be discussed.

**BMB 6665w. CURRENT TOPICS IN NUCLEIC ACIDS BIOCHEMISTRY.** (3 cr.; A-F; offered even years; pre-req. CORE courses: CORE 6100, CORE 6150, and CORE 6250 or consent of instructor) Maher – The three objectives of this tutorial are 1) to familiarize advanced graduate students with
biochemical and biophysical principles of nucleic acids and their interactions with proteins; 2) to introduce molecular viewing tools to facilitate atomic-level understanding of macromolecular structure, and 3) to apply these principles and tools to current biological problems and processes involving nucleic acids.

BMB  6675w. PROTEIN STRUCTURE AND DYNAMICS. (2 cr.; A-F; offered odd years; pre-req. CORE courses 6100 and 6150 or consent of instructor) Mer, Thompson – This tutorial discusses various models of protein folding including the experimental approaches and computational methods for predicting and determining structure. Examples from the current literature highlight protein structure, proteomics and functional proteomics.

BMB  6680f. NMR SPECTROSCOPY, MICROSCOPY, AND METABOLOMICS. (1cr; S -N; offered odd years) Macura, Vuckovic – NMR methods can roughly be divided in spectroscopy (structure and dynamics of molecules), microscopy (imaging of and dynamics in organs and organisms) and metabolomics (identification and quantitation of metabolites in body fluids and tissues/cellular extracts). In this course the basic principles of these methods will be described and explained with emphasis on the experiment design and data interpretation.

BMB  6801f,w,sp. CONCEPTS OF VESICULAR TRAFFICKING JOURNAL CLUB. (1 cr. /qt.; S-N; pre-req. CORE 6250) McNiven – Study of the basic mechanisms by which cells package, process, and transport synthesized and/or endocytosed proteins.

BMB  6900f,w,sp,s,su. BMB THESIS PROPOSAL. (2 cr.; S-N) Katzmann – Thesis proposal: The written thesis proposal matches the new format of NIH R01 grants and, hence, is limited to 14 pages, including illustrations but not including references. In the student’s own words, the proposal should outline the rationale for the proposed project and how it is to be executed. The proposal is subdivided into the following sections:

**Abstract:** Summary of your project (1 page).

**Specific Aims:** Describe briefly the aims of your project and hypotheses (1 page).

**Significance:** Put your project into context with what is known about this area of biology and show the importance of the questions you are asking (2-3 pages).

**Innovation:** How is the project you are proposing novel and groundbreaking (~1 page).

**Approach:** Describe what you plan to do and how you plan to do it. Include preliminary data for each aim that sets the scene and supports your hypotheses (8-10 pages).

Register for course credit the quarter AFTER you have prepared your proposal and taken the oral exam. Submit note signed by your committee to the course director indicating that your thesis proposal was satisfactory.

Research

BMB  6890f,w,s,su. RESEARCH IN BIOCHEMISTRY AND MOLECULAR BIOLOGY. (S-N) Staff – Graduate thesis research for Ph.D. students under supervision of staff.
Biomedical Engineering and Physiology

BMB 6515f,w,sp. MUSCULOSKELETAL JOURNAL CLUB. (1 cr./yr.; S-N) Westendorf, Oursler – Graduate students, postdoctoral fellows and residents present peer-reviewed articles that describe new and high impact work in musculoskeletal research fields. MCBSBS students from any track or program are welcome to attend and lead discussions in this interdisciplinary forum that spans molecular and cellular biology, biomechanics, endocrinology, orthopedics, osteoimmunology, physiology, and other disciplines. This is a shared course with the Biochemistry and Molecular Biology track. Register in fall quarter only. Attendance required in consecutive fall, winter and spring quarters. Students must present and lead one discussion during one of the quarters and attend 75% of meetings over all three quarters to earn credit.

BMEP 5100f. RADIOLOGICAL HEALTH. (2 cr.; S-N; offered odd years; consent of instructor required prior to registration) Sturchio – An introduction to concepts of radiological health, philosophy and principles of radiation protection, interpretation of standards and regulations, and planning of facilities and activities.

BMEP 5160sp. INTRODUCTION TO RADIATION PHYSICS. (3 cr.; A-F; offered even years, pre-req. calculus, atomic or modern physics) McGee – This is an introductory graduate course designed for those interested in the radiation sciences. The course will introduce the student to the basic concepts and physical principles that underlie modern radiation physics including atomic structure, radiation, interactions of radiation with matter, introduction to cavity theory, biological effects of radiation (dose), x-ray production and dosimetry techniques.

BMEP 5200f,su. MATHEMATICS IN BIOMEDICAL ENGINEERING & PHYSIOLOGY. (4 cr., 2 per quarter; A-F) Manduca, Bajzer – This course will introduce mathematical topics used in biomedical engineering and quantitative physiological applications including a brief review of trigonometry and calculus, then covering linear algebra, vector analysis, complex variables and functions, Fourier series and transforms, dimensional analysis, ordinary differential equations, and basic concepts in probability. A basic introduction to MATLAB and mathematical modeling is included.

BMEP 5250w. ANATOMY FOR BIOMEDICAL ENGINEERS. (2 cr.; S-N; offered odd years) Pawlina – Students dissect selected regions of the human body and learn correct names and locations of associated anatomical structures. Each student then gives a detailed presentation to the class of the region studied.

BMEP 5450f. LABORATORY METHODS IN BIOMEDICAL IMAGE PROCESSING. (3 cr.; A-F) STAFF – An introduction to important concepts in applied biomedical imaging, including digital processing of images, image signal characteristics, histogram analysis, domain processing, digital filters, image compression, reconstruction from projections, discussions of image composition, interactive 3D display, image processing and segmentation, registration and quantitative analysis. Practical applications in basic science and medicine are discussed. Students will use ANALYZE biomedical imaging software developed at Mayo to investigate these topics.

BMEP 5452w. BIOMECHANICS. (3 cr.; A-F) Hewett, Tschumperlin, K. Zhao – This course provides an overview of the mechanical properties and structural behavior of biological tissues. Specific
course topics include cell matrix level mechanics, structure and function relationships in tissues and organs, analysis of forces in human function and movement, and application of stress and strain analysis to biological tissues.

BMEP 5453w. FUNDAMENTAL CONCEPTS IN BIOMECHANICS. (3 cr.; A-F) Kaufman – This course is an introduction to biomechanics and addresses the fundamental topics of kinematics and kinetics.

BMEP 5460f. FINITE ELEMENT METHODS. (3 cr.; A-F; offered odd years; contact the program director prior to registering for this course) Staff – This course introduces the fundamental concepts of the finite element methods and its major applications in biomechanics research.

BMEP 5550sp. IMAGE GUIDED PROCEDURES IN BIOMEDICAL APPLICATIONS. (4 cr.; A-F; pre-req. BMEP 5450 or equivalent) Holmes – An introduction to the concepts, methods and applications of image guided technology and interventions, including device tracking, advanced visualizations, workflow emulation and virtual reality simulations in biomedical research and clinical procedures.

BMEP 5704sp. BIOINSTRUMENTATION AND SIGNAL PROCESSING. (3 cr.; A-F). Holmes – This course will provide an introduction to basic principles of bioinstrumentation and related signal processing. The course will begin with discussion of the basics of sensing and theoretical treatment of signals, with an emphasis on bioinstrumentation applications. The remaining portion of the course will focus on analog and digital signal processing, involving both theoretical analysis and practical implementation.

BMEP 5740f. MAGNETIC RESONANCE IMAGING SYSTEMS. (3 cr.; A-F; offered odd years; pre-req. advanced calculus, Fourier analysis, and a course in modern physics) Riederer – An introduction to physics and engineering aspects of modern diagnostic magnetic resonance imaging (MRI).

BMEP 5800f,w,sp. INTRODUCTION TO MEDICAL IMAGING. (6 cr., 2 cr. Per quarter; A-F). McCollough, Leng – An introduction to the fundamental principles of medical image acquisition and analysis. Diagnostic imaging modalities to be covered include radiographic imaging, x-ray computed tomography, digital radiography, nuclear medicine, ultrasound and magnetic resonance imaging. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information.

BMEP 5802sp. ADVANCED PRINCIPLES OF BIOMECHANICS. (3 cr.; A-F; pre-req. BMEP 5453) An, C. Zhao – Advanced concepts of orthopedic biomechanics, including kinematics and kinetics, mechanics of deformable bodies, stress analysis, tissue engineering and fluid mechanics.

BMEP 6000i. TUTORIAL IN EXERCISE PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Joyner – This course is designed for selected physiology graduate students who seek a broad overview in integrative physiology. The focus will be on presenting broad biological concepts related to integration, regulation, homeostasis, and the multitude of organ systems and how they adapt to various environmental and physical stresses. The course meets once a week for 1½ to 2 hours. It is taught using a collegial problem-solving approach.
solving approach. Students take a major role in where the course goes. The course runs one full academic year.

BMEP 6100sp. MEDICAL HEALTH PHYSICS. (2 cr.; A-F; pre-req. BMEP 5100 or equivalent, or consent of instructor) Sturchio – Radiation protection philosophy and principles as applied to the medical environment: protection of patients, public, and employees; procedures for obtaining Nuclear Regulatory Commission license. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information.

BMEP 6151w. RADIATION ONCOLOGY PHYSICS. (3 cr.; A-F; pre-req. BMEP 5160) Beltran, Herman, Remmes – Physics principles of the application of ionizing radiation in radiation therapy, including radiation characteristics, dose calculation, treatment planning/dosimetry, brachytherapy and quality assurance. This course has been accredited by the Commission on Accreditation of Medical Physics Education Programs (CAMPEP); please contact the instructor for further information.

BMEP 6300sp. TUTORIAL IN NEUROPHYSIOLOGY. (3 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Sieck – This course will provide an understanding of the basic concepts in cell and neurophysiology. The application of current experimental methods and techniques will be emphasized. Classic papers from the literature will be assigned and discussed. Laboratory demonstrations and computer modeling will be included if class size permits.

BMEP 6302i. TUTORIAL IN ULTRASONIC IMAGING. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Fatemi – Principles of ultrasound physics and interaction of ultrasound with biological tissues; principles and methods of tissue imaging using ultrasound; evaluating mechanical properties of tissue by ultrasound; measuring blood flow and tissue motion by Doppler method; artifacts in ultrasound imaging and in Doppler techniques; overview of recent and advanced techniques in medical ultrasound clinical applications of ultrasound.

BMEP 6304i. TUTORIAL IN PHYSIOLOGICAL IMAGING. (2 cr.; A-F; consent of instructor required prior to registration) Ritman – Imaging of physiological function of in-situ organs, the limitations of those data and models needed to analyze such image data.

BMEP 6305w. SEMINARS IN MACHINE LEARNING. (1 cr.; S-N) Erickson – This is a seminar course on machine learning, with particular focus on applications in medical imaging. The course will include discussions of seminal as well as more recent publications that are of interest to the field. There will also be discussion of challenges of practical application of methods, as well as potential pitfalls.

BMEP 6350sp. ADVANCED CONCEPTS IN MOLECULAR BIOPHYSICS. (4 cr.; A-F; offered even years) Sine – This course focuses on the biophysics of ion channels, solute transporters, molecular motors, elastic proteins, molecular recognition, protein dynamics and enzyme kinetics. A set of technical lectures will cover patch clamp recording, single channel kinetic analysis, x-ray crystallography, mass spectrometry and fluorescence spectroscopy. Didactic lectures are complemented by student presentations of a corresponding scientific paper.
BMEP 6400f,w,sp,su. MASTER’S SCHOLARLY REVIEW ARTICLE (FINAL PROJECT). (3 cr.; S-N) Staff – Requires paper or equivalent in the area of Biomedical Engineering and Physiology submitted as Employee’s Master’s Project. Topic is chosen by the student with guidance from the advisor. May be taken only once for credit.

BMEP 6420sp. WAVE PROPAGATIONS AND BIOMEDICAL APPLICATIONS. (2 cr.; A-F; pre-req. college physics) Fatemi – Wave propagation is a fundamental phenomenon of acoustics, electromagnetics, and optics. This course will emphasize the wave propagation of ultrasound and their applications to medical imaging and tissue property identification. In addition to linear wave propagation, nonlinear wave propagation and their potential medical applications will be studied.

BMEP 6470f. TWO-DIMENSIONAL DIGITAL SIGNAL PROCESSING. (4 cr.; A-F; pre-req. BMEP 6704 or working knowledge of linear system theory and one-dimensional digital signal processing) Ottesen – Fundamentals of 2-D digital signal processing, including 2D discrete Fourier and Z-transforms, 2D discrete cosine transforms, and 2D linear and nonlinear Finite Impulse Response filters. Other topics covered are histogram equalization, edge-detection methods, morphology, compression routines and fuzzy logic filters. This class is a foundation for image processing. There will be homework and class projects.

BMEP 6490sp. ADVANCED TOPICS IN BIOMEDICAL IMAGE PROCESSING. (3 cr.; A-F; offered even years; pre-req. BMEP 5450 or BMEP 6700 equivalent experience or coursework) Manduca – An in-depth study of difficult problems in imaging science as they relate to biomedical images. Areas of study include image segmentation, image registration, texture analysis, shape description and matching, deconvolution, multispectral analysis and denoising.

BMEP 6500i. SPECIAL TOPICS IN IMAGING SCIENCE. (2 cr.; A-F; pre-req. BMEP 5450, BMEP 6700; consent of instructor required prior to registration) Staff – Special topics in the imaging sciences applied to biomedical problems and data; including 3-D imaging, volume rendering, surface rendering, image segmentation, image registration and fusion, shape description and analysis, multi-spectral analysis and classification, virtual reality visualization, image modeling.

BMEP 6600i. PHYSIOLOGY & BIOMEDICAL ENGINEERING SEMINARS. (1 cr.; S-N; consent of instructor required prior to registration) Tschumperlin, Matveyenko, Urban – Presentations of research topics related to physiology and biomedical engineering. All BMEP students are required to attend seminars. In addition to attendance, students are required to give two short (30 min) presentations related to their own research projects, one prior to the start of winter quarter in their third year and the second in their fifth year. Students should register in the quarter in which they give their second presentation.

BMEP 6650i. BIOMEDICAL ENGINEERING & PHYSIOLOGY JOURNAL CLUB. (1 cr.; S-N) Holmes, Haider – The Biomedical Engineering Journal Club provides a forum for discussion of recent advances in biomedical engineering and physiology. Development of critical reading and writing skills will be incorporated as they apply to manuscript and grant reviewing and writing. Each student is expected to present at least one paper per year. Faculty will be invited to participate as appropriate. Students are required to attend for 3 consecutive quarters in a given year - fall, winter and spring (register for course in spring).
BMEP 6700f,w,su. PHYSIOLOGY FROM CELLS TO ORGANISM. (6 cr.; 2 cr. per quarter; A-F) J. Miller, Linden – The goal of this course will be an emphasis on the importance of integrative physiology in the evolving area of functional genomics. Laboratory demonstrations will provide exposure to state-of-the-art physiological techniques with applications from cell physiology to human disease.

BMEP 6704sp. DIGITAL SIGNAL PROCESSING I. (4 cr.; A-F, offered annually) Ottesen – First of a two-part series starts with one-dimensional (1D) discrete time signals and systems, and the effects of sampling. It moves into the areas of 1D Discrete Fourier Transforms (DFT), Z-transforms, linear and circular convolutions and signal flow-graphs. Various methods for design of common analog filters and their conversion to 1D digital Infinite Impulse Response (IIR) digital filters. Also covered are 1D digital Finite Impulse Response (FIR) filters with linear phase characteristics. There will be homework, class projects, and an in-class final exam.

BMEP 6705f. DIGITAL SIGNAL PROCESSING II. (4 cr.; A-F; offered 2014; pre-req. BMEP 6704 or consent of instructor) Ottesen – Topics covered are special 1D analog filters and their conversion to 1D digital equivalent filters; Advanced designs and structures of optimal FIR digital filters; spectral and cepstral analysis, and parametric and non-parametric estimation of signals; the effects and filtering techniques for different types of noise and introduction to discrete 1D ordered-statistic, homomorphic, Wiener, Golay-Savitzky and fuzzy logic filters. There will be homework, case studies and class projects.

BMEP 6710w. NUMERICAL METHODS IN BIOMEDICAL RESEARCH. (3 cr.; A-F) Bajzer, Manduca – This course provides an overview of advanced mathematical and numerical methods commonly used in biomedical research including: theory and solution of ordinary and partial differential equations, common transforms, function fitting, interpolation and extrapolation, optimization and search algorithms, and filtering and time series analysis.

BMEP 6730w. LABORATORY METHODS IN MAGNETIC RESONANCE IMAGING. (2 cr.; S-N; offered even years; pre-req. BMEP 5740, previous or concurrent registration) Edmonson – Introduction to MRI laboratory methods. Firsthand experience in basic and advanced MR image acquisition strategies, experimental tradeoffs, image reconstruction, and data interpretation.

BMEP 6740w. ADVANCED TOPICS IN MAGNETIC RESONANCE IMAGING SYSTEMS. (3 cr.; S-N; offered even years; pre-req. BMEP 5740) Riederer – A technical study of advanced topics in contemporary magnetic resonance imaging (MRI). Topics to be discussed include vascular imaging and flow assessment, motion effects and compensation, echo-planar imaging, parallel acquisition, cardiac imaging, and diffusion.

BMEP 6745f. ADVANCED MEDICAL IMAGE RECONSTRUCTION: THEORY AND APPLICATIONS. (3 cr.; A-F; prereqs BMEP 5200 and BMEP 5800 or equivalent coursework) Trzasko – The objective of this course is to provide imaging students in-depth training in the theory and applications of advanced signal processing techniques for medical image reconstruction (all modalities), including statistical and iterative techniques for limited data and quantitative imaging applications.
BMEP 6750f,sp. MAGNETIC RESONANCE TECHNICAL SEMINAR. (1 cr.; S-N; offered odd years; consent of instructor required prior to registration) Riederer – Seminar held weekly consisting of a presentation of some contemporary technical research topic in magnetic resonance.

BMEP 6755f. X-RAY COMPUTED TOMOGRAPHY. (3 cr; A-F; offered even years; prereq BMEP 5800) Yu, Leng, McCollough – The objective of this course is to give students in-depth training in X-ray computed tomography, including analytical and iterative reconstruction; dose measurement, management and reduction; cardiac and multi-energy CT; current clinical applications; and emerging techniques. Hands-on lab work and programming will be required as part of this course.

BMEP 6770f. FUZZY LOGIC THEORY AND APPLICATIONS. (4 cr.; A-F; prereq a knowledge of Matlab and an interest in intelligent systems, like decision making, pattern recognition, classification and control) Ottesen – This course is intended for students and practicing scientists and engineers. It covers the applied concepts of fuzzy logic to several application areas. Fuzzy logic allows for the programming human experience into the computer. The reasoning used in fuzzy logic is similar to that of human reasoning. It allows for approximate values and inferences as well as incomplete or ambiguous data (fuzzy data) as opposed to only relying on crisp data (binary yes/no choices). Fuzzy logic is able to process incomplete data and provide approximate solutions to nonlinear problems that cannot be modeled in traditional ways. There will be homework, case studies and class projects.

BMEP 6830w. LABORATORY METHODS IN PHYSIOLOGY. (2 cr.; A-F) Blanco – This course provides instruction and hands-on experience in the use of common methods and techniques in physiology. It will acquaint students with regulations, information sources, and ethical considerations of responsible animal use in research. Lab directors will teach students techniques such as appropriate handling, sampling, anesthesia, and surgery of animal subjects, with an emphasis on rodents, including transgenic methods and rodent models.

BMEP 6840f. LABORATORY METHODS IN BIOMECHANICS. (2 cr.; A-F) Kaufman – This course is an introduction to biomechanics laboratory methods, covering techniques spanning from the in-vitro tissue level to in-vivo joint biomechanics. The course will include hands-on experience in material testing, motion tracking, force measurement, EMG measurement, device accuracy testing, and data processing. Students will also become familiar with IRB and IACUC study requirements.

BMEP 6853i. READINGS IN BIOMEDICAL ENGINEERING. (2 cr.; S-N; consent of instructor required prior to registration) Staff – Review of contemporary topics in Biomedical Engineering literature to be arranged with individual staff members.

BMEP 6855i. TUTORIAL IN CARDIOVASCULAR PHYSIOLOGY. (3 cr.; A-F; offered only once per year with consent of instructor required prior to registration) V. Miller – Students will be exposed to advanced topics in cardiovascular physiology with an emphasis on Integrative control mechanisms in health and disease, structure and function, sex-based medicine and translational approaches to investigations. Students will be required to critically evaluate current literature, provide a historical overview of a specific topic and to write a review article on a topic of mutual interest to the group.
BMEP 6856i. TUTORIAL IN RESPIRATORY PHYSIOLOGY. (3 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Sieck – The goal of this course is to provide an in-depth account of the functional components of the respiratory system and their integration in health and disease.

BMEP 6857i. TUTORIAL IN CELLULAR MECHANICS. (2 cr.; A-F; consent of instructor required prior to registration) Tschumperlin – Detailed review of cellular structure and function relationships, diffusion, micro-mechanics, mechano-chemical signal transduction.

BMEP 6858i. TUTORIAL IN SMOOTH MUSCLE PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Prakash – Students will be exposed to advanced topics related to smooth muscle signaling pathways, intracellular calcium regulation, pharmaco-mechanical coupling, etc.

BMEP 6859i. TUTORIAL IN RENAL PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Romero – Renal hemodynamics, glomerular function, mechanisms and regulation of electrolyte transport.

BMEP 6860i. TUTORIAL IN ENDOCRINE PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Eberhardt – This course focuses on several aspects of endocrine physiology, including mechanisms of hormone action, calcium homeostasis, glucose, and fatty acid metabolism, pituitary, thyroid and adrenal physiology, immunologic aspects of endocrinology, and endocrine effects on bone biology.

BMEP 6861i. TUTORIAL IN SKELETAL MUSCLE PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Sieck – The goal of this course is to explore muscle physiology from the protein-protein interactions that establish the molecular basis of muscle contraction to the biomechanics of movement.

BMEP 6862i. TUTORIAL IN NEUROMOTOR CONTROL PHYSIOLOGY. (2 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Sieck – The goal of this course is to explore modeling and analysis of complex physiological systems: respiratory control, sleep apnea, and locomotion. A laboratory session and journal reviews are also planned to prove some of the above concepts and their applications.

BMEP 6863f. TUTORIAL IN NEURAL ENGINEERING. (2 cr.; A-F; offered odd years; prereq: BMEP 6700, BMEP 5704, BMEP 5200) Sieck, Worrell – Course offered at the discretion of the instructors, or Fall term if the first option is not possible. This course is designed to explore the engineering applications in neuroscience. Included topics are the fundamental physical principles governing neural interface systems, relevant anatomy and physiology of the nervous system, and the conceptual design, optimization and implementation of neural interface technology. The course focuses mainly on neural interfaces and prosthetics.

BMEP 6864i. NEURAL ENGINEERING TUTORIAL. (2 cr; A-F; offered odd years; prereq: BMEP 6704. BMEP 6700, BMEP 5704, BMEP 5200) Sieck, Worrell – This course is designed to explore the engineering applications in neuroscience. Included topics are the fundamental physical principles governing neural interface systems, relevant anatomy and physiology of the nervous system, and
the conceptual design, optimization and implementation of neural interface technology. This course focuses mainly on neural interfaces and prosthetics.

**BMEP 6870f. SYSTEMS PHYSIOLOGY I.** (3 cr.; A-F) Romero – In Systems Physiology I; The Cell as a Complex Biological System – the students will obtain a broader view of traditional “Cellular Physiology.” All systems are made up of components which must communicate and respond. This course will focus on the fundamental organization that exists at the molecular, cellular, tissue, organism and population levels.

**BMEP 6871w. SYSTEMS PHYSIOLOGY II.** (3 cr.; A-F) Sieck – Development, Growth and Regeneration – concepts of intracellular communications as taught in Systems Physiology I will be reinforced, and the concept of intercellular communication will be introduced as they relate to the development, growth, and regeneration of issues. Roles of stem and progenitor cells along with contributions from various model systems will be incorporated.

**BMEP 6872sp. SYSTEMS PHYSIOLOGY III.** (3 cr.; A-F) Ordog – The students will focus on the role of biological oscillators in cellular and higher-order physiological functions including cell cycle, circadian rhythms, neuroendocrine control of reproduction and metabolism, reproduction and germ cell development, as well as gastrointestinal and urogenital motor physiology. Topics discussed will include the role of transcriptional and epigenetic regulators, metabolic factors, and cellular signaling pathways in rhythm generations at the molecular and cellular level, interactions between oscillators to control complex organ and organismal functions, and mathematical models. This course builds on, reinforces, and extends concepts of intra- and intercellular communication discussed in the preceding Systems Physiology courses.

**BMEP 6876w. ADAPTIVE AND NONLINEAR PHYSIOLOGICAL SYSTEMS.** (3 cr.; A-F; pre-req. BMEP 6875) Staff – The course covers the modeling and analysis of the following complex physiological systems: Respiratory Control, Cardiac Dysrhythmias, Sleep Apnea, Neutrophil Density Regulation, Cardiovascular Variability, and Circadian Rhythms. Adaptive and nonlinear control concepts are explained and applied to these physiological systems, and where Matlab and Simulink are used for simulation. A laboratory session and journal reviews are also planned to prove some of the above concepts and their applications.

**BMEP 6878i. TUTORIAL IN BONE PHYSIOLOGY.** (3 cr.; A-F; offered only once per year with consent of instructor required prior to registration) Oursler – Lectures and discussions in physiology of both normal and abnormal bone. Classes are a combination of lectures and current topical literature. Topics will vary, depending on the interest of enrolled students.

**Research**

**BMEP 6890f,w,sp,su. RESEARCH IN BIOMEDICAL ENGINEERING AND PHYSIOLOGY.** (S-N) Staff – Opportunities in research for Ph.D. students to be arranged with individual staff members. Must enroll every quarter once a thesis laboratory is selected.

**Core**

**CORE 6000w,su. RESPONSIBLE CONDUCT OF RESEARCH.** (1 cr.; S-N) Sharp – A series of presentations on various aspects of biomedical ethics.
CORE 6001 RESPONSIBLE CONDUCT OF RESEARCH REFRESHER COURSE. (0 cr.; prereq CORE 6000) Sharp – The NIH requires Responsible Conduct of Research (RCR) instruction at least once during each career stage, and at a frequency of no less than once every four years. The RCR Refresher Course consists of three hours of face-to-face instruction and case-based discussion using interactive video. Ph.D. and M.D., Ph.D. students will be notified by MCGSBS when they are required to take the refresher course.

CORE 6050sp. CRITICAL THINKING AND SCIENTIFIC WRITING. (2 cr.; S-N; pre-req. enrollment in a degree-granting program of the Mayo Clinic College of Medicine or consent of instructors) Bieber, Hedin – This course is intended for first year graduate students across all tracks. The course will involve two components. The first will be a didactic element that introduces the scientific method, techniques and tools for searching and organizing the scientific literature, practical bioinformatics approaches, applied biostatistical analysis, scientific manuscript writing, and grant preparation. In parallel, students will choose a topic of interest and will prepare an NIH-style small grant proposal (e.g. 6-12 page R01 format) that will be critiqued by the course directors, the instructors, and by the other students in the class in a “study section” setting. Via a series of weekly roundtable forums discussing the merits and faults of each proposal throughout the writing process, the students will learn to craft a coherent and well-reasoned grant.

CORE 6100f. CHEMICAL PRINCIPLES OF BIOLOGICAL SYSTEMS. (3 cr.; A-F; pre-req. calculus, organic chemistry, quantitative analytical chemistry, or consent of instructor) Maher – An introduction to the fundamental principles of biomacromolecular structure and function, including nucleic acids, proteins, and biomembranes. The course also provides a survey of methods of structure determination and analysis, principles of catalysis, kinetics and bioenergetics.

CORE 6150su. GENOME BIOLOGY. (3 cr.; A-F) Horazdovsky – This course will explore the organization and function of the genome, with an emphasis on the features that are critical for the regulation of gene expression in mammalian systems. Topics to be examined include genome packaging and replication, as well as transcription, RNA processing, translation, and protein processing.

CORE 6200f. BASIC GRADUATE IMMUNOLOGY. (3 cr.; A-F) A. Johnson – Structure, genetics, and function of immunoglobulins; biosynthesis of antibody; cellular regulation of immune response; tumor and transplantation immunology; immune response to infectious agents; autoimmunity and immune deficiencies.

CORE 6250w. MOLECULAR CELL BIOLOGY. (3 cr.; A-F) Radisky (Derek), Salisbury – Class is designed to convey the central principles of how eukaryotic cells function at the structural and biochemical level. Emphasis of topics is on: the cytoskeleton, extracellular matrix and cell-cell interactions, protein transport in the secretory and endocytic pathways, and cell cycle, mitosis, programmed cell death. Course format utilizes didactic lectures combined with student presentations and interactive problem sets.

CORE 6300sp. MOLECULAR BIOPHYSICS. (3 cr.; A-F) Burghardt, Sine – This course is an introduction to the molecular organization, dynamics and intermolecular interactions of biologically important macro-molecules with emphasis on proteins. Introductory courses in organic chemistry, biochemistry and calculus are recommended prerequisites.
CORE 6400w. MOLECULAR GENETICS. (3 cr.; A-F) Harris, Xu – Overview of topics in genetics of general importance to biomedical research with emphasis on molecular aspects.

CORE 6450sp. MOLECULAR PHARMACOLOGY AND RECEPTOR SIGNALING. (2 cr.; A-F) Brimijoin – A chief aim of modern life science is to understand the biological mechanisms of living systems and to apply this knowledge in discovering cures for disease. This course will provide a comprehensive introduction to receptors and downstream signaling pathways important in disease and the science underlying the use of chemical agents, proteins, nucleic acids, and genes to influence these pathways and biological outcomes. The course will also survey computer-aided drug discovery, gene therapy, pharmacogenomics, and the basic principles of modern molecular pharmacology. Carefully constructed problem sets will enable students to master practical issues in designing and interpreting experiments on drug-receptor interactions.

CORE 6510sp. MOLECULAR MECHANISMS OF HUMAN DISEASE. (3 cr.; A-F), Mukhopadhyay, Windebank – This course is designed to introduce students to the basic organization, histology, and function of major organ systems and provide an appreciation for pathophysiological conditions leading to disease and therapeutic intervention. Lecture topics will focus on a new system each week. Systems discussed include skin, bone, hematopoiesis, vascular, cardiac, pulmonary, gastroenterology, kidney, and metabolic. This course is intended for students with no medical training.

CORE 6770w. VIROLOGY AND GENE THERAPY. (3 cr.; A-F) Cattaneo – The Virology and Gene Therapy core course is the sum of three one-credit courses that will be held consecutively during the spring quarter: Molecular Virology, From Viruses to Vectors, and Gene Therapy.

Clinical and Translational Science

Clinical Trials

CTSC 5010f,sp. CLINICAL RESEARCH PROTOCOL DEVELOPMENT. (2 cr.; S-N; pre-req., CTSC 5300, CTSC 5310 (either prior or concurrent registration), CTSC 5600; limited to students admitted to CTS programs and T32 trainees with faculty approval) A. Rule – The goal of this course is to systematically teach the process by which one takes a conceptual idea for a clinical research project and converts it into a research proposal or grant application. It is expected that students will already have begun to formulate their research question and refine their research project. Students will use their own research question to build a proposal for a research project that they intend to conduct in the future. By the end of the course, students will have a proposal for an important, valid, feasible research project that can serve as the foundation for a Certificate or Master’s thesis research project or a grant application.

CTSC 5020f. REGULATORY ISSUES IN CLINICAL RESEARCH. (1 cr.; S-N) N. Staff, Greenberg – This online course is designed to introduce students to regulatory issues pertaining to clinical research. Topics will expose students to the various external and internal regulatory agencies, including the Institutional Animal Care and Use Committees (IACUC), U.S. Food and Drug Agency (FDA) and Mayo Clinic’s Institutional Review Board (IRB), and how they affect investigator’s research responsibilities. Students will view lectures by content experts and engage in activities that include, but are not limited to, analyzing an actual IRB protocol, attending a full
IRB meeting, researching on Mayo Clinic’s Research Knowledge Base (RKB), and reviewing regulatory documents. Evaluation will be based on completion of online modules, assessments and participation of one IRB meeting.

CTSC 5025su. INTRODUCTION TO REGULATORY SCIENCE. (1 cr.; A-F) Greenberg - In this in-person course, participants will learn about critical areas of regulatory science, as defined by the FDA’s “Advancing Regulatory Science” report. This will include: the role of bioethics in regulation; toxicology and product safety; innovations in the science and conduct of clinical trials; product manufacturing and quality; evaluating emerging technologies; using informatics to improve health outcomes; and understanding regulatory processes, including the role of advisory committees and meetings.

CTSC 5190sp. COMPLEMENTARY AND ALTERNATIVE MEDICINE RESEARCH. (1 cr.; A-F) Sood – This course is designed to provide a broad overview of complementary and alternative medicine (CAM) research and introduce participants to unique aspects of CAM practice. Students will learn summary information on evidence base for incorporating CAM treatments in practice. Critical requirements needed to successfully compete for CAM research grants at the NIH will be presented and experts from the Mayo CAM clinic will discuss pertinent aspects of CAM practice and answer clinical and research questions. In addition, participants will write a brief research proposal that will be critiqued by the course faculty.

CTSC 5240w. PRINCIPLES AND PRACTICES OF PEDIATRIC RESEARCH. (2 cr.; A-F; class extends over two quarters) Jacobson – This course addresses the special concerns and challenges faced by clinical investigators when conducting clinical research involving infants, children, or teenagers. The course will address the principles and practice of pediatric research as it applies to epidemiological, observational, and experimental studies. Topics include ethics, regulation, parental permission, assent, funding, recruitment, retention, remuneration, data collection, and analysis.

CTSC 5260su. METHODS AND FOUNDATIONS IN BIOMEDICAL ETHICS. (1 cr.; A-F) Sharp, Tilburt – The methods of biomedical ethics provide a rigorous analytic framework for engaging ethical challenges in medicine and translational research. The aim of this workshop-based course is to prepare participants to develop research studies that examine topics in bioethics, develop their scholarly interest in biomedical ethics, and identify ethical issues in their work. Individual sessions will examine how to develop a research topic, how to identify and critically assess relevant literature, how to design robust empirical research studies in bioethics, and how to select among potential research methods. Specific case studies will be used to illustrate exemplary bioethics research.

CTSC 5261f. BIOMEDICAL ETHICS II. (1 cr.; A-F) Hook – The goal of the course is to provide the learner with an understanding of key events and cases that have influenced the development of biomedical ethics, along with a reflection of the presuppositions and thinking of those involved at the time. In addition to the historical review of the medical, legal, philosophical, ethical and, where appropriate, theological aspects of past cases, the learner will also be challenged to reassess contemporary views, presuppositions and practices from the perspective of criticisms that might arise from future generations of patients, physicians scientists and jurists.
CTSC 5262w. BIOMEDICAL ETHICS III. (1 cr.; A-F) Hook – The goal of the course is to provide the learner with an understanding of key events and cases that have influenced the development of biomedical ethics, along with a reflection of the presuppositions and thinking of those involved at the time. In addition to the historical review of the medical, legal, philosophical, ethical and, where appropriate, theological aspects of past cases, the learner will also be challenged to reassess contemporary views, presuppositions and practices from the perspective of criticisms that might arise from future generations of patients, physicians scientists and jurists.

CTSC 5720w. CLINICAL TRIALS: DESIGN AND CONDUCT. (1 cr.; A-F; pre-req. CTSC 5600 or equivalent) Sloan – This course will focus on the statistical considerations and practical issues involved in the design and conduct of clinical trials. The foundation and practical considerations involved in drug development for humans will be presented. The Phase I-III paradigm for clinical trials will be discussed including issues about aims, endpoints, statistical power, early stopping rules, and analytic techniques. There will be a focus on several case studies of clinical trials. Issues about subject selection, study design, masking treatment assignment, outcome measures, goals, and post hoc analyses will be reviewed.

Community-Engaged and Health Disparities Research

CTSC 5070su. WHAT RESEARCHERS NEED TO KNOW ABOUT COMMUNITY-ENGAGED RESEARCH. (1 cr.; A-F) Balls-Berry – Community-engaged research consists of a variety of research methods and tools that explore the bi-directional relationships of community members, patients, community leaders, and researchers. This introductory course will use didactic and interactive lectures to provide learners with a foundation in community engaged research principles. Learners will expand their knowledge base on community engaged research techniques and will be introduced to the methodological approaches of participatory research, Active Community Engagement Continuum, rapid assessment methods, deliberative democracy, and community-based participatory research. Learners will interact with investigators and staff who conduct community engaged research and will participate in the Cross Cultural Communication for Researchers Workshop.

CTSC 5080f. WHAT RESEARCHERS NEED TO KNOW ABOUT ELIMINATING HEALTH DISPARITIES. (1 cr.; A-F) Balls-Berry – The major purpose is to create a heightened awareness amongst clinical researchers and investigators (active and prospective) that the racial, ethical, ethnic, cultural, and socioeconomic dimensions of clinical research are important metrics that should be considered in all phases of clinical research study design, development, execution, analysis and reporting. Successful grant funding includes the ability to write proposals that will address these disparities.

Translation

CTSC 5140f. EPIGENETICS AND EPIGENOMICS: IMPACT ON TRANSLATIONAL RESEARCH AND FUTURE MEDICAL PRACTICE. (2 cr.; A-F; offered odd years) Ordog, Robertson – This introductory course is designed to introduce students to Epigenetics and Epigenomics, which are promising to become an important foundation of modern medicine, including individualized health care delivery. Of great interest to translational medicine, emerging data demonstrate that epigenetic changes are often amenable to therapeutic intervention. In this course, students will discuss molecular mechanisms underlying epigenetic events, the tools for the design and execution of research in this discipline, how to generate and analyze data and the application of Epigenomics to diagnostic and therapeutic treatments. The course will consist of didactic
evidence-based lectures and class discussions, writing exercises and critical research literature which aim at gaining a deeper insight on the impact of Epigenomics to human health.

CTSC 5202f,w,sp,su. INDEPENDENT STUDY OF LABORATORY METHODS. (1-2 cr.; S-N; approval by CTSA Curriculum Committee required prior to registration; limited to students admitted to CTS programs) Cook – The purpose of this course is to provide hands-on experience in specific laboratory methods and techniques for MD and non-research students funded by Career Development Awards in concert with the student’s career development and research plan. The independent study must fill an important gap in the student’s training that cannot be met through existing courses. Students are expected to define their objectives and specific techniques/skills to be learned in consultation with a faculty member. Application for Independent Study must be made 6-8 weeks before start of quarter. Contact CCaTS curriculum specialist for application.

CTSC 5270su. HEPATOBILIARY PATHOBIOLOGY. (1 cr.; A-F; offered even years) Malhi – The purpose of this course is to teach hepatobiliary pathobiology through a series of 12 interactive lectures covering a broad range of topics within the field. The course will emphasize basic hepatobiliary pathophysiology including a strong emphasis on research methodology. Areas of research approaches will include state of the art cellular and molecular biology methods. Principles and methodologies of cancer genetics and genetics of complex disease relevant to liver disorders will be presented. An array of experimental approaches and concepts from in vitro, to in vivo, to animal models are incorporated in the presentations.

CTSC 5271su. PATHOPHYSIOLOGY OF DIGESTIVE DISEASE. (1 cr.; A-F; offered odd years) Kashyap – The purpose of this course is to teach gastrointestinal/hepatobiliary physiology and discourse through a series of 12 interactive lectures covering a broad range of topics within the field. The course will emphasize basic cellular and molecular concepts with clinical and clinical research correlations whenever possible.

CTSC 5280f. APPLIED ENTERIC NEUROSCIENCES IN HEALTH AND DISEASE. (1 cr.; A-F; offered odd years) Camilleri – This course provides information of the mechanisms, diagnosis, and management of gastrointestinal diseases that affect motor and sensory functions of the digestive tract. Topics covered will include genetic and molecular basis of motility disorders, antroduodenal manometry, sensitivity testing, gastroduodenal motility disorders, diabetes and the gut, colonic motility testing and management of constipation, dyspepsia, irritable bowel syndrome, current and emerging therapies for IBS, motility disorders, and pharmacogenomics. Evaluation will be based on class participation and a final exam.

MPET 6820sp. REGENERATIVE MEDICINE PRINCIPLES TO PRACTICE. (2 cr.; A-F) Terzic, Windebank – This course is designed to introduce students to principles of stem cell biology, and provide an appreciation for applications in regenerative medicine and surgery. Presenters will stress fundamental principles. Applied topics will include lectures on core principles of regenerative medicine with examples of stem cell use in regenerative pharmacology and cell replacement therapy, diagnostics, toxicology or as vehicle for gene therapy, prospects for clinical therapy, stem cell banking, tissue engineering, ethical and regulatory affairs, intellectual property rights and patenting issues. The course will follow a discovery-translation-application curriculum. Attendance and participation in each class is required. By course end, students should become proficient in the comprehension of fundamental concepts underlying stem cell
platforms as well as obtain insight in new therapeutic/diagnostic opportunities. This course is in collaboration with Karolinska Institute.

CTSC 6110f,w,sp. CTS WORKS IN PROGRESS (1 cr.; S-N; registration limited to CTS PhD students only) Ekker – CTS Works in Progress provides a forum for CTS predoctoral students to present their research to and have their presentations evaluated by a group of their peers. This course is open to predoctoral students in the CTS track only. Attendance is required for CTS PhD students Fall, Winter and Spring. CTS students register only for the quarter in which they present (1cr./yr.).

CTSC 6120w. CASE STUDIES IN TRANSLATION. (2 cr.; A-F) Windebank, Greenberg – This course will explore the process by which the fundamental discoveries move from the first demonstration of an experimental observation to widespread use in medicine and public health. Examples will be chosen to represent the different classes of discovery that lead to improved health.

CTSC 6130f,w,sp. CTS JOURNAL CLUB. (1 cr.; S-N; registration limited to CTS PhD students only) Ekker – CTS journal club provides a forum for CTS predoctoral students to select, present and lead a discussion on an original clinical and/or translational research article chosen by the student and their mentor. This course is open to predoctoral students in the CTS track only. Attendance is required for CTS PhD students fall, winter and spring. CTS PhD students register only in the quarter in which they present (1 cr./yr.).

CTSC 6150f,sp CASE STUDIES IN ENTREPRENEURIALISM (1 cr.; A-F) Ekker, K. Campbell - The entrepreneurial world is exemplified by strong leaders of highly focused teams tackling major problems in the world today. In this course, we will use case-method, small-group and experiential learning approaches to learn about entrepreneurialism in general, look at exemplar scenarios and finish with visits of novel active team environments with a focus on life sciences. We will follow six key topics for deep analysis then follow with two immersions to visit startups formed around the Mayo Clinic and University of Minnesota.

CTSC 6160w CASE STUDIES IN PRECISION MEDICINE (2 cr., A-F; pre-req. CTSC 5020; PhD students pre-req. also include CORE 6510) Klee, Schimmenti - In this course, students will experience an electronic laboratory environment focusing on unsolved medical odyssey cases. These are typically individuals with undiagnosed or rare diseases where current testing has failed to provide an informed assessment of their medical condition. Currently, the standard practice is whole exome sequencing of the patient and, ideally, an unaffected sibling and parent(s). Under direction of key scientists from the Center for Individualized Medicine, students will explore these unsolved cases using modern informatics tools while also delving deeper into both the medical history as well as the published literature. Initially, exemplar cases will be used to provide examples cases, followed by the full laboratory analyses. Each session, student genomic sleuths will present their cases to the class, for group analysis and assessment. For cases where the analysis is considered strongly positive, the results will be transferred to CIM for subsequent implementation in the Clinic.

Clinical Epidemiology

CTSC 5290f. GI POPULATION SCIENCES. (1 cr.; A-F) Kane, Saito-Loftus – The purpose of this course is to teach clinical epidemiology and methodology as applied to, or specific to, gastrointestinal diseases. The course will show what has been learned from epidemiology in GI diseases from
gastrointestinal research and contributed to our clinical understanding of gastrointestinal diseases. During 12 interactive sessions with pre-assigned reading, this course will cover current knowledge and approaches to studying the epidemiology of a wide span of gastrointestinal disorders. Broadly, course topics will be divided into those with a clinical focus and those with a methodological focus. Topics will include the clinical epidemiology of esophageal reflux and Barrett’s esophagus, inflammatory bowel disease, functional gastrointestinal disorders, celiac disease, pancreatic cancer, and chronic liver disease as well as study questionnaire selection and development, health economics/decision analysis, conducting clinical trials, molecular epidemiology, and genetic epidemiology as related to the field of GI.

CTSC 5300w,su. INTRODUCTION TO CLINICAL EPIDEMIOLOGY. (1 cr.; A-F) J. Olson, Wennberg – This online course is the first in a series of three epidemiology methods courses. This first course presents an overview of epidemiology; the second gives students the opportunity to plan five studies of various designs; and the third concentrates on the application of these methods based on published epidemiologic studies. Thus, the three courses together equate a typical 4-credit introductory epidemiology course. As the first in this series, this course addresses basic terminology and methodological concepts in epidemiology from a clinical perspective. Topics will include issues related to measurement (reliability, validity), testing (sensitivity, specificity), prevalence, incidence, causation, study design (ecologic studies, cohort studies, case-control studies, clinical trials, cross-sectional studies), bias, and confounding.

CTSC 5310f,w,su. CLINICAL EPIDEMIOLOGY II. (1 cr.; A-F; pre-req. CTSC 5300) J. Olson, Wennberg – This online course is the second in a series of three epidemiology methods courses. The goal of this course is to guide students through the thought processes necessary to design methodologically sound studies. Course is highly collaborative with students who will work together in assigned online groups to design five different studies. Each will include elements of hypothesis specification, study design, study populations, measurement of important study variables, quality assurance/quality control, and internal and external validity. The final assignment will be completed independently and involve a peer review of other students’ work. The case studies in this course are designed to be similar to Part II of the Comprehensive Master’s Exam.

CTSC 5390w. ADVANCED APPLIED EPIDEMIOLOGIC METHODS. (2 cr.; A-F; pre-req. CTSC 5300, CTSC 5310, CTSC 5600) Rocca, Chamberlain – This course is the third and final in the series of epidemiology methods classes and is designed to increase the ability of students to interpret and criticize research articles in the medical literature. One or more articles for each of the following major types of epidemiological studies will be discussed: 1) prevalence study, 2) incidence study, 3) case-control study, 4) cohort study, and 5) clinical trial. For each type of study, the instructor will explain the general terminology and give guidelines on how to read the articles in the first session. The students will then be assigned to read an article (or two articles) and to write a summary report for each article following a standardized format (article abstracting form). The instructor and the students will jointly interpret and discuss each article in the following session. All students are expected to participate in the discussion. Three additional lectures will be an introduction, a discussion of bias, and a discussion of confounding and interaction.

CTSC 5500sp. GENETIC EPIDEMIOLOGY: ASSOCIATION STUDIES. (1 cr.; A-F; offered odd years; pre-req. CTSC 5300, CTSC 5310, CTSC 5600, CTSC 5610) Slager – To provide in depth discussion of study design, data collection, basic data analysis, and quality assurance/quality control of
genetic association studies. The knowledge gained from this class will be integrated with the knowledge gained from the clinical epidemiology and biostatistics classes. Upon completion, students will be able to critically appraise articles from the current genetic epidemiology literature.

**Quantitative and Qualitative Methods**

**CTSC 5600w,su. STATISTICS IN CLINICAL AND TRANSLATIONAL RESEARCH. (2 cr.; A-F)** Enders – This online course introduces basic statistical methods used in a variety of clinical study designs. Course materials use published or ongoing clinical research studies and emphasize statistical reasoning and concepts. General concepts covered are exploratory data analysis, descriptive statistics, estimation, and inference. Statistical techniques covered are those for comparing counts/proportions, for comparing means, and for comparing diagnostic tests. Coverage of each statistical technique includes identifying what research questions it can address, verifying that assumptions are adequately met, and identifying limitations of the conclusions. Course material is presented through online interactive lectures. Evaluation includes individual homework assignments, group assignments, and midterm and final examinations.

**CTSC 5601sp,su. UTILIZING STATISTICS IN CLINICAL RESEARCH. (1 cr.; A-F; pre-req. CTSC 5600 taken concurrently or prior) Enders** – This course introduces statistical software for introductory statistical methods including descriptive statistics, estimation, and inference; students also participate in in-person discussion of the pros and cons of methods used in the literature. The focus of the course is on determining the correct statistical method for a given situation, introducing the corresponding method in the JMP statistical software, and correctly interpreting the results of the JMP analysis. (This is also available as an accelerated 4-week course CTSC 5601 Section ACC in spring and summer.)

**CTSC 5610f. INTRODUCTORY STATISTICAL METHODS II. (3 cr.; A-F; pre-req. CTSC 5600 and CTSC 5601) Enders** – This course provides an introduction to methods for statistical modeling. Specific topics covered include simple linear regression and multiple linear regression and introduces some extensions of these methods such as logistic regression and Cox regression. General concepts taught include graphical methods, descriptive statistics, and statistical inference. Particular attention is given to verification of model assumptions, interpretation, and generalization of results. The course is a combination of lectures and computer labs; assignments require the use of statistical software (JMP). Evaluation includes homework assignments and midterm and final examinations.

**CTSC 5640w. LOGISTIC REGRESSION. (1 cr.; A-F; pre-req. CTS C 5600, CTSC 5610) Winham** – Logistic regression is often used as an analytic tool for medical studies with binary endpoints. The goals of this course are to: 1) recognize appropriate occasions to use logistic regression; 2) understand how logistic regression may be used to estimate the magnitude of association for a predictor versus a binary outcome variable using an odds ratio; 3) interpret odds ratios for binary, categorical, and continuous predictor variables; 4) describe how the odds ratio may be influenced by confounding variables and/or interactions among variables, and how logistic regression may be used to adjust for the presence of confounders and to test for the presence of interaction; 5) explore the assessment of statistical significance, model building, and model assessment strategies in the presence of several risk variables; and 6) apply the use of logistic regression in score development and validation with the associated receiver-operator characteristic (ROC) curve. From this course, students will learn how to use statistical software (JMP) to perform
logistic regression and select appropriate models depending on research questions. Evaluation will include computer laboratory sessions, individual homework, and a final exam.

CTSC 5641sp. PROPENSITY SCORING METHODS. (1 cr.; A-F; pre-req. CTSC 5640, CTSC 5600, CTSC 5610) Borah – Propensity score methods are a set of potent tools that an empirical researcher can apply to mimic a randomized control trial retrospectively using an observational database and have emerged as some of the most widely used methods for estimating treatment effects in observational studies. Although RCTs are considered the “gold standard,” they may not always be feasible for a variety of reasons. As an alternative, propensity scoring methods have emerged as some of the most widely used methods for estimating treatment effects in observational studies. At the end of this class, students will be able to describe the uses and limitations of propensity score methods including the assumptions that underlie propensity score methods, distinguish between different methods and implement propensity score methods available in statistical software.

CTSC 5650sp. SURVIVAL ANALYSIS. (1 cr.; A-F; pre-req. CTSC 5600, CTSC 5601, CTSC 5610) Yin – This course will introduce students to methods for summarizing and analyzing time-to-event data, which commonly occur in clinical trials and epidemiological studies. Basic quantities (e.g., survival function, hazard function) and their relationships will be introduced. Non-parametric approaches (such as the Kaplan-Meier method) and parametric approaches (e.g., Weibull) for estimating these quantities for a given data set of event times will be covered. Associated tests (such as the log-rank test) to compare event times originating from multiple groups will be discussed. The widely-used semi-parametric Cox proportional hazards regression model will be introduced and related topics including variable selection, assumption testing, and model building will be covered. Power and sample size calculations for planning studies with survival (time-to-event) outcome data will be discussed. Software packages demonstrated will include JMP and R, while other web-based resources and topics may be included as dictated by students’ interests and the availability of sufficient time.

CTSC 5690w,su. CRITICAL APPRAISAL OF STATISTICAL METHODS IN THE MEDICAL LITERATURE. (1 cr.; A-F; pre-req. CTSC 5600, CTSC 5610) Enders – This course will be concerned with reading and reviewing articles in the medical literature with an emphasis on analyzing and understanding the statistical aspects. Prior to each class session students will be required to read the assigned manuscript and prepare a written review. Evaluation will be based on participation, completion of homework (written reviews), and the final exam.

CTSC 5710f. PRACTICAL DATA COLLECTION. (1 cr.; A-F; prerequisite CTSC 5600 and CTSC 5601 or equivalent) Ou – This course introduces the general principles and practical exercises of data management and presenting in medical research, including laboratory experiments, cohort observational studies, and clinical trials. Data management portion will cover design of data collection system (case report forms/surveys, electronic databases, and data entry interface) and data quality control and monitoring. Data presentation portion will introduce sound practical data presentations by graphs and tables which are aimed to deliver the appropriate inferences regarding data in an efficient yet objective manner. This course will heavily focus on hands-on practices by introducing REDCap for data collection and management, and statistical software for plots and tables. Evaluation will be based on in-class short quizzes, in-class exercises, and take home assignments.
CTSC 5715f. PUBLICATION QUALITY TABLES AND FIGURES. (1cr.; A-F) Enders, Larson, J. – This course introduces sound practical data presentations by tables and graphs which are aimed to deliver the appropriate inferences regarding data in an efficient yet objective manner. This course will utilize software to generate summary statistics and figures. Evaluation will be based on in-class assignments and take home assignments.

CTSC 5810sp. QUALITATIVE RESEARCH DESIGN, METHODS, AND ANALYSIS. (1 cr.; A-F) Kumbamu – This course provides an overview and comparative analysis of selected qualitative research methods and analytic strategies. In this class, students will be introduced to the theoretical foundations and explore the strengths and limitations of a variety of qualitative methods, such as focus groups, interviewing, observational analysis, and document analysis. Students will learn about various computer programs used for analyzing qualitative data and develop skills for performing qualitative research by engaging in hands-on experiences.

CTSC 5820sp. INTRODUCTION TO SURVEY RESEARCH. (1 cr.; A-F; pre-req. CTSC 5600) Yost – This course provides an overview of survey research. It is intended to familiarize students with the theory and application of survey research in data collection. The overall goal of this course is to provide students with a foundation that will allow them to conduct a survey or be aware of the issues to consider in the design and implementation of a survey. Specific topics covered are question writing, questionnaire design, scale development, reliability and validity, sampling, sample size estimation, survey types, statistical analysis and presentation of results. No prior survey research experience is required or expected.

Health Services and Comparative Effectiveness Research

CTSC 5201f,w,sp,su. INDEPENDENT STUDY FOR CLINICAL PRACTICE ISSUES. (1-2 cr.; S-N; approval by course director required prior to registration; limited to students admitted to CTS programs) Cook – The purpose of this course is to provide needed training in clinical practice for non-MD/non-biology students funded by Career Development Award programs in concert with the student’s career development and research plan. The independent study must fill an important gap in the student’s training that cannot be met through existing courses. Tutorials are arranged on an individual basis in selected advanced topics in clinical practice. Students are expected to define an objective and specific reading list in consultation with a faculty member. Application for Independent Study must be made 6-8 weeks before start of quarter. Contact CCaTS curriculum specialist for application.

CTSC 5740w. SYSTEMATIC REVIEWS AND META-ANALYSES. (2 cr.; A-F; pre-req. CTSC 5600, CTSC 5300, CTSC 5310; limited to students admitted to CTS program w/priority to MS students; approval of the selected topic with course faculty is required prior approved admission) Montori, Murad, West – By the end of this problem-based course, the learner will be comfortable with the methods of evidence synthesis and will have completed a systematic review/meta-analysis, from protocol to journal-ready manuscript, in a topic of their choice. The course will consist of 11 weekly two-hour small group tutorials with expert faculty to discuss key concepts and troubleshoot the students’ reviews in progress. Each session will represent a step in conducting a systematic review. A series of selected readings for each session will help students prepare to participate in discussions. There will be two practical sessions: one for developing thorough and systematic search strategies, in coordination with Mayo Library; the other for learning how to use meta-analysis software. Evaluation will be based on the methodological quality of the final systematic review/meta-analysis.
CTSC 5760w. MEDICAL DECISION MAKING. (1 cr.; A-F) Bundrick, Liebow – This course is intended to provide a sound, thorough introduction to the principles of clinical decision making in the areas of basic medical decision psychology and quantitative decision analysis. Evaluation will be based on two written exams, mostly centered on analyzing the approach of clinicians to realistic cases, on a realistic clinical dilemma, and on utilizing the formal techniques of decision/cost-effectiveness analysis and a written critique of a cost-effectiveness article in the medical literature.

CTSC 5761sp. EVIDENCE-BASED MEDICINE FOR CLINICAL RESEARCHERS. (1 cr.; A-F; pre-req. CTSC 5600, CTSC 5300, CTSC 5310) Montori, Murad – This course addresses a critical need of clinical researchers seeking an easier translation of their research findings into improved quality of care and patient outcomes. That is, an understanding of how the users of research need to know to translate clinical research evidence into practice. Students will benefit the most from this course if they have conducted research and have completed the design of one or more studies.

CTSC 5770sp. DIAGNOSTIC TESTING STRATEGIES. (1 cr.; A-F; pre-req. CTSC 5600 or equivalent, CTSC 5760 highly recommended) West – This course is designed to enable students to become skilled in the formulation and revision of diagnostic testing strategies for common medical problems, within a Bayesian framework (e.g., pre-test probabilities, test operating characteristics/likelihood ratios and post-test probabilities). The first five sessions will introduce material in a discussion format. Subsequent sessions will be organized around student presentations on clinical topics selected from a pool of over 50 which have been formally analyzed in the text. Students will review the relevant background for the clinical problem, the prevalence of the disease in question, the operating characteristics (sensitivity/specificity, etc.) of the pertinent history and exam components and diagnostic tests, and the range of post-test probabilities that might be expected to result from the application of various diagnostic strategies. Discussion will be initiated by presenting a hypothetical case and requesting input as to suggested plans for diagnostic testing. The instructor will provide a brief summary of learning points at the end of each session.

CTSC 5860f. BEHAVIORAL INTERVENTIONS IN CLINICAL RESEARCH. (1 cr.; A-F) Ehlers, Gudenkauf – This course will focus on techniques for operationalizing, implementing, and monitoring the fidelity of behavioral interventions in clinical trials. Topics will include treatment development, assessing feasibility and acceptability of treatments, study design, recruitment and retention, rationale and techniques for assessing treatment fidelity, participant adherence, and dissemination of results. The course will also examine successes and pitfalls in implementing clinical trials involving behavioral interventions.

CTSC 5870sp. SOCIAL AND BEHAVIORAL FOUNDATIONS OF HEALTH IN HEALTH SCIENCES RESEARCH. (1 cr.; A-F) Eton, Radecki Breitkopf – This course is designed to help students develop a basic understanding of the role of social constructs and behavioral processes in health and interaction with the healthcare system. The course is intended to provide insight into concepts and theories of social and health behavior. The underlying framework of the course is the biopsychosocial model of health. In this perspective, health is influenced by biologic, social, behavioral, and environmental factors that frequently interact with each other to a greater or lesser extent.
CTSC 5880sp. HEALTH COMMUNICATION THEORY AND INNOVATION (1 CR.; A-F)
Agunwamba – This course is designed to give an overview of critical health communication topics and to provide key principals in effective communicating whether during clinical encounters or on national television. The course will cover health communication functions, mechanisms, and methods to impact behavior change throughout populations, including patient-physician communication, mass media communication, health education and health literacy, and finally, technology and eMedicine. There will be a strong emphasis on the importance of theory and methods in developing health messages. The primary theories and methods used in this course will draw upon social epidemiological and population health approaches. We will aim to apply communication strategies using research methods and messaging theory, and cover health journalism and media.

CTSC 5910f. ECONOMIC EVALUATION IN HEALTH CARE. (1 cr.; A-F; pre-req. CTSC 5600, CTSC 5610 previously or concurrently, offered odd years) Borah – In a world of rising health care costs and fixed budgets, economic evaluation plays an increasingly important role in technology assessment and payment decisions. This course will present basic concepts, theory, and methods associated with economic evaluation in health care. Specific topics include: cost-effectiveness analysis, cost-utility analysis, issues related to study design (trial-based, model-based, and observational administrative claims-based economic evaluation), outcomes measurement and analysis (clinical outcomes, costs, patient-reported outcomes), guidelines and reference standards, and the use of economic data in decision-making. This course will be presented in the form of lectures supported by presentation of case studies demonstrating these methods applied to specific clinical topics.

CTSC 5940f. SECONDARY DATA ANALYSIS. (1 cr.; A-F; pre-req. CTSC 5600 or equivalent as approved by the instructor) Habermann – Secondary data analysis takes advantage of data originally collected for other purposes to answer distinct health services research questions. There are many secondary data sources readily available, yet they are typically underutilized. As such they provide a rich opportunity for empirical investigation and subsequent publication. This course provides the student an introduction to secondary data analysis using publicly available data sources. Data sources covered in this class include survey data (individual, household and provider surveys), administrative data (hospital, outpatient and administrative claims), and cancer and clinical registry data.

Biomedical Informatics
CTSC 5960w,su. INTRODUCTION TO MEDICAL INFORMATICS. (2 cr.; A-F) Herasevich, Pickering – This course is intended to provide an introduction to the principles of informatics in the context of clinical research utilizing clinical data. Information science (IS) is now playing a major role in many clinical research studies, from managing vast volumes of genomic and clinical data to integration of data, information, and knowledge, and finally, to executing complex and reproducible analyses. Information Technology (IT) infrastructure, guided by appropriate principles and expertise, could determine the success or failure of a study. This course will provide a general background for investigators and clinical researchers working with clinical data and to enable them to interact with IS and IT professionals effectively.

CTSC 5961f,sp. HEALTH INFORMATION TECHNOLOGY EVALUATION: CLINICAL INFORMATICS METHODS. (1 cr; A-F; pre-req. CTSC 5600, CTSC 5300, CTSC 5010 (all previously or concurrently) Herasevich, Pickering – This course will present basic concepts, theory, and methods associated with health information technology evaluation. Specific topics
include: structure of studies, measurement fundamentals, design of demonstration studies, analyzing results of evaluation, proposing and communication results of evaluation studies, guidelines and reference standards. Students will design and develop a protocol for health information technology studies.

Research
CTSC 6890f,w,sp,su. RESEARCH IN CLINICAL AND TRANSLATIONAL SCIENCE. (S-N) Program Mentor – Graduate thesis research for Ph.D. students under supervision of staff.

DENTISTRY – ORTHODONTICS

Orthodontics Didactic
ODON 6806f,w,sp,su. ORTHODONTIC SEMINAR: TECHNIQUE. (1 cr; A-F) Staff Seminar on technical orthodontic procedures.

ODON 6807f,w,sp,su. ORTHODONTIC SEMINAR: LITERATURE REVIEW. (1cr; A-F) Staff Classical orthodontic literature as well as current literature review.

ODON 6808f,w,sp,su. ORTHODONTIC SEMINAR: CASE PRESENTATION. (1 cr; A-F) Staff Cases with complete records reviewed and new patient treatment plans discussed.

ODON 6809f,w,sp. SURGICAL ORTHODONTIC SEMINAR. (1 cr; A-F) Viozzi - Case presentation, illustration, diagnostic and treatment procedures that encompass the various dental specialties.

ODON 6810sp. CLINICAL ORO-FACIAL PATHOLOGY AND DEVELOPMENTAL DISORDERS. (1 cr; A-F; prerequisite D.D.S., D.M.D., M.D. or equivalent required) Staff - A review of the clinical presentations of many congenital and acquired pathological disorders, developmental deficiencies, and malformations important to the dental specialist.

Research
ODON 6857f,w,sp,su. RESEARCH IN SELECTED PROBLEMS. (1 cr/qtr; A-F) Staff - Arrangements for research in selected areas related to minor.

Clinical
ODON 6800f,w,sp,su. ADVANCED ORTHODONTIC TECHNIQUES. (3 cr; A-F) Staff - Initial technical procedures in preparation for clinical patient care. Technical procedures on the typodont, model preparation, photography, metallurgy, and cephalometrics.

ODON 6802f,w,sp,su. ORTHODONTIC CASE ANALYSIS. (6 cr; A-F) Staff - First phase involves complete review of previously treated cases. Second phase is application of basic analytic principles to clinical patients.

ODON 6803f,w,sp,su. ORTHODONTIC TREATMENT PLANNING. (6 cr; A-F) Staff - Mechanical principles coordinated with case analyses to provide the treatment plan. Force analysis and biomechanics of tooth movement.
ODON 6804f,w,sp,su. CLINICAL ORTHODONTICS. (6 cr; A-F) Staff - Individual treatment care and clinical observation. Treatment care coordinated with other services in selected instances in the hospital.

ODON 6805f,w,sp,su. ADVANCED CLINICAL ORTHODONTICS. (6 cr; A-F) Staff - Final treatment care of individual patients.

DENTISTRY – PERIODONTICS

Periodontics Didactic
PDON 6883f,w,sp,su. PERIODONTIC SEMINAR. (1 cr; A-F) Sheridan, Assad Literature review and discussion.

PDON 6884su. PERIODONTOLOGY/ORTHODONTICS SEMINAR. (1 cr; A-F; offered odd years) Volz - Histopathology of periodontal disease. Oral mucous membrane; calcified tissues. Interdisciplinary case reviews.

PDON 6886f,w,sp,su. CLASSIC LITERATURE IN PERIODONTICS. (2 cr/qtr; A-F); Sheridan, Assad - Review of 55 years of classic literature from the Journal of Periodontology. Two one-hour sessions per week x 26 weeks.

Research
PDON 6857f,w,sp,su. RESEARCH IN SELECTED PROBLEMS. (2 cr; A-F) Assad

Clinical
PDON 6880f,w,sp,su. CLINICAL PERIODONTICS. (6 cr; A-F) Sheridan, Assad - Etiology, diagnosis, and treatment of periodontal disease.

DENTISTRY – PROSTHODONTICS

Prosthodontics Didactic
PROS 6841f,w,sp. COMPLETE DENTURE PROSTHODONTIC SEMINAR. (1 cr; A-F) Carr - Literature review and discussion of past and current concepts and practices of complete denture prosthesis.

PROS 6843f,w,sp. REMOVABLE PARTIAL PROSTHODONTIC SEMINAR. (1 cr; A-F) Carr - Literature review and discussion of past and current concepts and practices of removable partial denture prosthesis.

PROS 6845f,w,sp. FIXED PROSTHODONTIC SEMINAR. (1 cr; A-F) Salinas - Principles, practices, and concepts related to clinical and laboratory phases of fixed prosthodontics.

PROS 6847f,w,sp,su. SEMINAR: MAXILLOFACIAL PROSTHETICS (INTRAORAL) ADVANCED PROSTHODONTICS. (1 cr; A-F) Salinas - Literature review and discussion of past and current concepts and practices of implant prosthodontics and maxillofacial prosthetics.

PROS 6848f,w,sp. SEMINAR: CURRENT LITERATURE. (1 cr; A-F) Carr, Salinas - Review and discussion of practical, clinical, or laboratory applications of current literature in prosthodontics and related fields, with an emphasis on evidence-based appraisal of the literature.
PROS 6849f,w,sp. SEMINAR: MAXILLOFACIAL PROSTHETICS (EXTRAORAL) ADVANCED PROSTHODONTICS. (1 cr; A-F) Salinas - Literature review and discussions on clinical and laboratory procedures involved in fabrication of extraoral prostheses.

PROS 6850f,w,sp. IMPLANT PROSTHODONTICS. (1 cr; A-F) Salinas - Literature review and discussion of past and present concepts and practices of implant prosthodontics.

PROS 6859f,w,sp. PERIODONTAL AND PROSTHODONTIC CONSIDERATIONS IN DENTISTRY. (1 cr; A-F) Salinas - This course is designed to promote in-depth discussions of subjects of interest in the areas of orthodontics, periodontology and prosthodontics. The interrelationship of the three fields is stressed.

PROS 6862f,w,sp. DENTAL MATERIALS. (1 cr; A-F) Salinas - Discussion of physical properties, mechanical properties, technical procedures and the interrelationship of these with clinical procedures related to dental materials most commonly used in prosthodontics.

PROS 6870f,w,sp. OCCLUSION. (1 cr; A-F) Salinas - A series of detailed discussions of the principles, practices, and concepts of occlusion.

PROS 6871f,w,sp. PHYSIOLOGY, PHARMACOLOGY AND PRE-PROSTHETIC SURGERY. (1 cr; A-F) Salinas - Discussion of physiology of major organ systems in conjunction with pharmacologic management of disorders of these systems. Pre-prosthetic surgery is discussed and reviewed through an evaluation of the literature.

PROS 6873f,w,sp. CRANIO-MANDIBULAR DISORDERS AND FACIAL PAIN. (1 cr; A-F; prerequisite Pros 6870) Reid - Literature review and discussion of past and current concepts and practices in the management of patients with cranio-mandibular disorders including myofacial pain dysfunction, temporomandibular disorders and atypical face pain.

PROS 6874f,w,sp. PROSTHODONTIC MANAGEMENT OF THE GERIATRIC PATIENT. (1 cr; A-F) Salinas - Literature review and discussion of medical complications found in the geriatric patient with emphasis placed on special considerations made during prosthodontic treatment.

Clinical

PROS 6840f,w,sp,su. CLINICAL PROSTHODONTICS: COMPLETE DENTURES. (6 cr; A-F) Carr, Salinas - Orientation and introduction to clinical and laboratory phases of prosthodontics in the medical center with emphasis on principles, concepts, and practices related to complete denture prosthesis.

PROS 6842f,w,sp,su. CLINICAL PROSTHODONTICS: PARTIAL DENTURES. (6 cr; A-F) Carr, Salinas - Orientation and introduction to clinical and laboratory phases of prosthodontics in the medical center with emphasis on principles, concepts, and practices related to removable and fixed partial denture prosthesis.

PROS 6851f,w,sp,su. DENTAL ROENTGENOLOGY. (1 cr; A-F) Reid - X ray diagnosis and technique.
PROS 6852f,w,sp,su. ORAL DIAGNOSIS AND TREATMENT OF CRANIO-MANDIBULAR DISORDERS. (2 cr; A-F) Salinas - Clinical diagnosis and treatment related to dental problems, including craniomandibular disorders and facial pain.

PROS 6854f,w,sp,su. IMPLANT PROSTHODONTICS. (6 cr; A-F) Carr, Salinas - Clinical and laboratory procedures involved in the management of patients who receive prostheses supported and retained by endosseous implants.

PROS 6880f. DENTAL LABORATORY TECHNOLOGY. (6 cr; A-F) Salinas - A full time clinical assignment to familiarize the resident with all aspects of laboratory technology used in the fabrication of removable and fixed partial and maxillofacial prostheses.

Electives

PROS 6856f,w,sp,su. ORAL AND MAXILLOFACIAL SURGERY. (1cr; A-F) Arce, Viozzi, Van Ess - Residents will work with the practitioners in the area of Oral and Maxillofacial Surgery to evaluate and treat patients who require surgical treatment of oral disease, elective treatment of partial and complete edentulism and maxillofacial defects. Residents will learn the diagnostic testing media for use with these patients. This will include standard intraoral, panoramic and cephalometric radiography along with lateral hypocycloidal tomography, computerized tomography and magnetic resonance imaging of teeth, jaws, temporomandibular joints and facial structures. Residents will learn techniques for treatment, especially in a multispecialty health care environment.

PROS 6875f,w,sp,su. DENTAL IMPLANT PROCEDURES. (1cr; A-F) Salinas, Vidal - Provide an in depth knowledge of standard methods for the comprehensive approach to using dental implant for comprehensive patient treatment. Additional understanding is introduced of advanced pain control measures, preprosthetic surgery, infection control and sterile technique, dental implant treatment planning, dental implant surgery, dental implant restorative procedures, complication management, and maintenance. Understanding of the indications and benefits for nitrous oxide sedation is provided along with a familiarity with other methods of pain control such as intravenous sedation and general anesthesia. These axioms are taught alongside surgical residents to exchange mutually supportive care between surgery and prosthodontics to allow an in depth experience with this level of care.

PROS 6877f,w,sp,su. DENTOFACIAL ESTHETICS. (1cr; A-F) Salinas – Topics covered in formal instruction: Residents are instructed formally with the analysis from photographs, radiographs, and diagnostic casts to utilize for treatment of patients with prosthodontic needs. The resident will start with a critical analysis of facial esthetics and what is considered referenced normal and that of which is achieved through specific objectives. The resident will understand their use of analytic skills at the chairside to perform a thorough clinical assessment of that of facial esthetics and how it correlates to intraoral dental esthetics. After a specific litany of factor recording, the resident will augment their photographic skills with a standardized esthetic display format for mapping the esthetic continuum for patient esthetic dentofacial analysis. Digital Smile design is also introduced to the resident to augment their skills in evaluating these factors for prosthodontic treatment.

Research
PROS 6857f,w,sp,su. RESEARCH IN SELECTED PROBLEMS. (2 cr; A-F; offered 6 quarters during program, including all of final year) Carr, Salinas

DERMATOLOGY*

DERM 6870f. MUCOUS MEMBRANE COURSE. (1 cr; S-N; Oral - even years; Genital - odd years) Bruce, Torgerson - This course provides knowledge of inflammatory, allergic, premalignant, and malignant conditions affecting the oral mucosa and other mucosal surfaces as well as the skin. Diagnosis utilizing clinical and pathologic tools will be emphasized. Treatment will be discussed.
* Only Dermatology courses which are required for degree completion in clinical programs are listed.

Immunology

IMM 6400f,w,sp,su. MASTER'S SCHOLARLY REVIEW ARTICLE (FINAL PROJECT). (3 cr.; A-F) Staff – The Employee Master’s project will consist of a scholarly written review of an important area of immunology. Topics will be chosen by the student in consultation with the advisor and the student’s advisory committee. The written review will describe the current state of understanding in the area, identify outstanding questions and controversies, and describe potential future directions for research that will address these questions. The final document and an oral defense of the document must be of sufficient merit to satisfy all members of a four-member advisory committee, to be selected and approved by the Immunology program director prior to beginning work on the Employee Master’s project. Register in the quarter in which you present your final project to the advisory committee; and register with your advisor as course director.

IMM 6862w,sp. CURRENT TOPICS IN CELL ACTIVATION AND SIGNALING. (1 cr.; S-N) Hedin, Billadeau– Weekly discussions of recent scientific literature on topics related to receptors, transmembrane signaling mechanisms, and gene expression.

IMM 6863f,w,sp. CURRENT TOPICS IN IMMUNOLOGY. (1 cr.; S-N; prerequisite CORE 6200 or equivalent) H. Dong – Current literature on important areas of immunology. Critical review of methods, results and findings. Register in the quarter you present (1 cr./yr.). Attendance required fall, winter and spring.

IMM 6867f,w. CURRENT TOPICS IN CLINICAL AND TRANSLATIONAL IMMUNOLOGY. (1 cr.; A-F) Kita – This is a series of journal clubs on a broad area of clinical and translational immunology. The topics include: hypersensitivity responses, innate immunity, mucosal immunology, and mechanisms and treatment of immune-mediated diseases.

IMM 6877w. TUTORIAL IN MOLECULAR BASIS OF IMMUNE RECOGNITION. (2 cr.; A-F; offered odd years; pre-req. CORE 6200 or equivalent) Pease, David, Schrum, Rajagopalan, Taneja – Regulation and structure of genes and proteins that function in specific immune recognition. Genes of the MHC, T cell receptors, and immunoglobulins will be featured.

IMM 6879w. TUTORIAL IN CELLULAR ACTIVATION. (2 cr.; A-F; offered even years; pre-req. CORE 6200 or equivalent, basic knowledge of receptor pharmacology is desirable but not a requisite) Hedin, Billadeau, Medina, Gil Pages, Shapiro – This course focuses on the intracellular signaling
pathways which regulate the activation, growth, and differentiation of lymphoid cells. Additional emphasis is placed on molecular mechanism of immunosuppression by cyclosporine, FK506, and related compounds.

**IMM 6880sp. TUTORIAL IN IMMUNOPATHOLOGY.** (2 cr.; A-F; offered odd years) Barry, Johnson, Weaver, Pavelko – Concepts in the immunopathology of virus and bacterial infection, autoimmunity, tumor immunology, and transplantation. Emphasis will be on immune mechanisms that the host uses to respond against pathologic agents, how disregulation of these responses lead to autoimmunity, and adaptive strategies infectious agents use to evade immunity.

**IMM 6882w. TUTORIAL IN MUCOSAL IMMUNITY.** (2 cr.; A-F; offered odd years; pre-req. CORE 6200) Khazaie, Kita, Wettstein, Faubion, Linden, Matveyenko, Mangalam, Murray, Chia, J. Lee – The course will review aspects of mucosal immunology and sterile inflammation. This will include microbiota and their interaction with host, innate immunity, including innate lymphoid cells, NK cells, gdT-cells, dendritic and other myeloid cells, adaptive immunity with emphasis on intraepithelial lymphocytes, Tr1 cells, regulatory T-cells and immune regulation, the current knowledge of the receptors and molecules that are used by immune cells to recognize stress and microorganisms, organ specific immunity, the enteric nervous system and brain-gut axis, circadian rhythm.

**IMM 6884w. TUTORIAL IN TUMOR IMMUNOLOGY.** (2 cr; A-F; offered even years; pre-req. CORE 6200 or equivalent) Dong, Khazaie, Markovic, Pavelko, Parney, Vile – Concepts in tumor immunology. This course is based on the current literature with heavy emphasis on student/faculty discussion.

**IMM 6885sp. TUTORIAL IN THE GENERATION AND FUNCTION OF B CELLS.** (2 cr.; A-F; offered even years; pre-req. CORE 6200 or equivalent) Medina, Jelinek, Novak, Shapiro, Taneja, Abraham – This course is designed to provide an in depth understanding of the generation and function of B lymphocytes in health and disease. The prerequisites are successful completion of Immunology CORE 6200 or Mayo Medical School, Block V, Normal Function, Immunology course. The final grade will be based, class participation, and the grade achieved on the comprehensive final exam.

**Research**

**IMM 6890f,w,sp,su. RESEARCH IN IMMUNOLOGY.** (S-N) Staff – Graduate thesis research for Ph.D. students under supervision of staff.

**M.D.-Ph.D.**

**MDPH 5000f,w,sp,su. LABORATORY ROTATIONS FOR M.D.-Ph.D. STUDENTS.** (1 cr.; S-N) Staff – Graduate thesis research (4 weeks) under supervision of staff. Three one-month rotations required.

**MDPH 5150f. MEDICAL SCIENTIST SURVIVAL SKILLS I.** (1 cr.; S-N; offered even years) Isaya – This two-week colloquium will cover grant writing. Working in small groups, students will be required to produce a complete grant application (F30 format). Students will receive written critiques and a score for their work. Limited to 18 M.D.-Ph.D. students.
MDPH 5200f. MEDICAL SCIENTIST SURVIVAL SKILLS II. (1 cr.; S-N; offered odd years) Kaufmann – This two-week colloquium is designed to enhance critical reading skills. The first week will involve large group discussion of recent literature articles, emphasizing best practices in data presentation and interpretation. The second week will involve student presentation of paired articles, specifically articles that reach mutually incompatible conclusions. In addition, students will individually prepare brief written critiques of a recent article. Limited to 18 M.D.-Ph.D. students.

MDPH 5300f. WEEKLY MD-PhD CONFERENCE. (1 cr.; S-N) Isaya, Kaufmann – Weekly MD-PhD Conference includes journal clubs (article presentation by students), clinical pathologic correlations (clinical cases presented by students) and career development talks. MD-PhD students in the PhD phase must present one article per year and one clinical pathologic correlations case every other year. Attendance required: 70% of scheduled conferences (confirmed by card swipe only). Registration limited to M.D.-Ph.D students in the PhD phase of the MD-PhD program. Register in fall quarter only (1 cr./yr.).

Mayo Clinic Graduate School of Biomedical Sciences

MGS 5100su. SURF ROTATION AND SEMINAR SERIES. (2 cr.; S-N) Staff – During this 10-week fellowship students will attend a weekly SURF seminar, other seminars and journal clubs within MCGSBS and present at an end-of-the-year event hosted by their program. Students will receive hands-on research training during the 10-week full-time fellowship.

MGS 5102f,w,sp,su. Ph.D. LABORATORY ROTATION. (2 cr.; S-N) Staff – Graduate thesis research (8 weeks) under supervision of staff.

MGS 5104w,sp,su,f PREP (Post-Baccalaureate) ROTATION (2 cr. S-N) Staff – One-year intense mentored research experience in basic science or translational research, only for students selected to join the Mayo Clinic PREP. Special seminars and selected graduate-level courses to expand each student’s knowledge base and apply basic science knowledge to biomedical research. Mentoring and guidance to assist with successful continuation into a Ph.D. or an M.D.-Ph.D. program to succeed in a basic or translational biomedical research career.

MGS 5153w,su. KAROLINSKA INSTITUTET ONLINE COURSE. (1 cr.; S-N) Dr. David Herron, Karolinska – This course is 100% online with no physical meetings and runs over an 8-week period. Students will need approximately 10 hours per week for study; the course is paced with deadlines. For the writing modules, students write and revise a grant application, write a popular science summary of their research, and shorten an abstract. For the other modules, the students work entirely from the perspective of their own research project. By invitation only.

Molecular Pharmacology and Experimental Therapeutics

MPET 5808f. INTRODUCTION TO MOLECULAR PHARMACOLOGY. (4 cr.; A-F) Sun-Hee Lee – This course covers the effects of drugs and other therapeutic agents on biological systems, with particular emphasis on how drugs interact with their receptors, are metabolized by humans, affect the functions of organ systems, and are used to treat diseases.
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<th>Course Code</th>
<th>Course Title</th>
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<tr>
<td>MPET 6000w</td>
<td>ESSENTIALS IN PATCH CLAMP TECHNIQUE. (2 cr.; S-N) Reyes Ramirez, Terzic – An introduction to patch clamp electronics and ion channel measurements. A limited number of students pursuing research with patch clamp techniques will be accepted.</td>
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<td>MPET 6100f,w,sp,su</td>
<td>MASTER'S SCHOLARLY REVIEW ARTICLE (FINAL PROJECT). (3 cr.; S-N) Staff – The Employee Master’s project will consist of a scholarly written review of a topical area in pharmacology. The review will describe the current state of understanding of the topic, identify an important question related to the topic, and describe potential future directions and experimental strategies to address the question. The topic will be chosen by the student in consultation with a faculty advisor with full or associate graduate privileges and the student’s Advisory Committee. The student’s committee will evaluate the scope and content of the Employee Master’s Project. Register in the quarter in which you present your final project to the advisory committee; and register with your advisor as course director.</td>
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<td>MPET 6205f</td>
<td>CLINICAL PHARMACOLOGY JOURNAL CLUB. (1 cr.; S-N) Weinshilboum – This journal club meets once monthly. At each meeting, one participant chooses, along with his/her mentor, an original research article and leads the discussion. Articles deal with any aspect of the interactions between xenobiotics and man, spanning articles of fundamental laboratory-based science to clinical trials. This journal club will be of interest to graduate students in pharmacology, post-doctoral students in pharmacology, and trainees in clinical pharmacology. Register in fall quarter only (1 cr./yr.). Attendance required fall, winter and spring.</td>
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<td>MPET 6400sp</td>
<td>INTRODUCTION TO PRINCIPLES OF PHARMACOKINETICS. (2 cr.; A-F) Reid – This 12-week course will focus on the qualitative and quantitative description of the kinetics of drug absorption, distribution and elimination. Learners will gain a basic and practical understanding of the physiological factors that influence these processes and will develop the skills necessary to fine tune dosing regimens for the purpose of optimizing drug levels. Rigorous mathematical derivation of important concepts will be minimized. This course will prepare learners to work in the pharmaceutical industry or take the board examination in clinical pharmacology.</td>
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<td>MPET 6655f</td>
<td>MECHANISMS OF CELL GROWTH AND DEATH. (2 cr.; A-F; offered even years; pre-req. CORE 6100, 6150 and 6250 or consent of instructor) Karnitz, Kaufmann – This tutorial provides in-depth coverage of a series of cellular signaling pathways including those activated by receptor tyrosine kinases, cell death receptors, and DNA damage. Specific topics include receptor tyrosine kinases and the Ras and phosphatidylinositol 3-kinase pathways, cell death receptors and caspase activation, and the ATM/ATR-dependent signaling pathways. Alterations in the signaling pathways in disease states are discussed.</td>
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<td>MPET 6700f</td>
<td>APOPTOSIS JOURNAL CLUB. (1 cr.; S-N) Kaufmann – The course is a journal club reviewing recent articles on the cellular mechanisms of apoptosis. An emphasis is placed on reviewing articles describing new, universal molecular and biochemical pathways of apoptosis. The course meets monthly throughout the year. No prerequisites are required. Register in fall quarter only (1 cr./yr.). Attendance required fall, winter and spring.</td>
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<td>MPET 6800f</td>
<td>RESEARCH SEMINARS IN PHARMACOLOGY. (1 cr.; S-N) Machida – The purpose of this course is to provide a forum for development of graduate speaking skills in a seminar setting. Students prepare talks presented to students, faculty, fellows, and research technicians. Register in fall quarter only (1 cr./yr.) Attendance required fall, winter and spring.</td>
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MPET 6805w. DRUG METABOLISM AND PHARMACOCENOMICS. (2 cr.; A-F) Weinshilboum – Principles of disposition of drugs in biological systems. Lectures on absorption, distribution, excretion, and metabolic transformation of drugs; descriptions of enzyme systems and factors affecting them.

MPET 6811w. TUTORIAL IN CARDIOVASCULAR PHARMACOLOGY. (2 cr.; A-F; offered even years) Landry, Behfar – Advances in physiology, pharmacology, genomics and regenerative medicine are in the process of creating new therapeutic opportunities in cardiovascular medicine. The present course will examine recent literature to explore advanced topics related to understanding innovative pharmacological approaches to treating cardiovascular disease. Previous completion of the Principles of Pharmacology course in the Medical School or Graduate School is required.

MPET 6812sp. TUTORIAL IN RECEPTOR BIOLOGY. (2 cr.; S-N) Brimijoin – Student-led discussions and presentations on current topics in receptor biology (runs concurrently with CORE 6450).

MPET 6813f. TUTORIAL IN SYSTEMS PHARMACOLOGY (2 cr.; A-F; offered odd years; pre-req. MPET 6805, MPET 5808 strongly recommended) Hu Li, Keith Robertson – Changes in biomedical research have greatly increased the opportunities for clinical impact. These new opportunities were born in large part through the emergence of large-scale genomics, transcriptomics, epigenomics, proteomics, and metabolomics research efforts that have yielded huge databases from large patient cohorts and laboratory studies. This explosion of data now necessitates use of quantitative and systems approaches more broadly and deeply than ever before in biomedicine. This course will cover how these large multi-layer datasets can be creatively analyzed and more importantly, how they can be integrated to yield new information on disease and drug response mechanisms, deregulated pathways, and biomarkers of disease and drug response. The class format will be part didactic lecture and part group discussion using recent illustrative papers that will help advanced graduate students and postdoctoral fellows learn how to generate and analyze ‘omics’ data and what the pitfalls and limitations are in this field. Students who have not taken these courses should discuss enrollment with one of the course directors first.

MPET 6814w. CELLULAR PHARMACOLOGY OF AGENTS THAT TARGET CANCER. (2 cr.; A-F; offered even years) Kaufmann – This tutorial will examine the mechanisms of action of selected pharmacological agents of the cellular and subcellular level. Drug targets to be examined during the quarter will include plasma membrane receptors, enzymes involved in signal transduction, cell cycle regulation, chromatin modification and DNA repair, selected pathways in intermediary metabolism, and/or regulators of apoptosis. Emphasis will be placed on: 1) understanding the variety of experimental approaches that are applicable to the study of drug action in different subcellular compartments and, 2) developing an ability to critically evaluate recent literature.

MPET 6815sp. NEUROBEHAVIORAL PHARMACOLOGY. (2 cr.; A-F) Choi – This course will cover the most recent neuropharmacological aspects of behavior disorders. The emphasis will be on understanding the advancement of neurogenetics, neurobiology, neuroimaging, and human genomics, which are enabling us to decipher behavioral disorders in molecular levels, and thereby to develop more precise pharmacological treatment methods.

MPET 6820sp. REGENERATIVE MEDICINE. (2 cr.; A-F) Terzic – This graduate course is designed to introduce principles and practice of stem cell biology and regenerative medicine. Particular
emphasis is placed on state-of-the-art derivation of stem cell population lineages, analysis of respective genomic, proteomic, and metabolomic traits, and applications in therapy in diagnosis. Prerequisites for this course include proficiency in fundamental cell biology, genomics, and pharmacology. This is a shared course with the Clinical and Translational Sciences track.

Research

MPET 6890f,w,sp,su. RESEARCH IN MOLECULAR PHARMACOLOGY AND EXPERIMENTAL THERAPEUTICS. (S-N) Staff – Directed research projects for Ph.D. students under the supervision of a faculty advisor.

Neurobiology of Disease

NBD 5600f. BEHAVIORAL NEUROLOGY. (2 cr.; S-N; offered odd years) Taner – Students will learn about the neuropathological, genetic, and clinical characteristics of neurodegenerative diseases such as Alzheimer’s disease. The course will feature the most current knowledge about each disease, including therapies available or ongoing research on the causes of the disorder.

NBD 6100f,w,sp,su. MASTER’S SCHOLARLY REVIEW ARTICLE (FINAL PROJECT). (3 cr.; A-F) McLean – The Employee Master’s project will consist of a written scholarly review article of an important area of molecular neuroscience. The student will identify an area of active neuroscience research, describe the current state of understanding in the area, identify fundamental outstanding questions and controversies, and describe potential future directions for research that will address these questions. The final document, and an oral defense of the document, must be of sufficient merit to satisfy all members of a four member Employee Master’s Advisory Committee, to be selected by the student and approved by the Neurobiology of Disease Program Director prior to beginning work on the Employee Master’s project. Register in the quarter in which you present your final project to the advisory committee; and register with your advisor as course director.

NBD 6210w,sp. NEUROBIOLOGY OF DISEASE. (3 cr.; A-F; odd years; pre-req. consent of course director) Fryer – This course is designed for graduate students (Ph.D. and M.S.), residents, clinical fellows, and postdoctoral fellows in neuroscience/neurology and clinical translational science training programs. It is intended to confer a detailed mechanistic understanding of the genetic, pathological and cell biological basis of important neurological diseases and syndromes. The scientific background and context for each disease will also be provided and therapeutic rationales will be discussed along with current mechanisms and modeling (cellular or model organisms). The focus will be on research-oriented students, but this course will also provide a mechanistic understanding for clinically oriented students. Basic science and clinical experts from all three Mayo campuses will provide this didactic survey course. These 90-minute lectures will be on Monday afternoons. A two-page proposal on a student-selected disease entailing a brief background, importance, and two specific aims will be due at the end of the course. This course will span two quarters (January to June).

NBD 6401f. PRACTICAL NEUROANATOMY. (2 cr.; A-F; odd years; pre-req. first year MCGSBS student or consent of course director) Scarisbrick – This course is designed to provide a fundamental understanding of neuroanatomical nomenclature and the structure and function of
the human nervous system. The emphasis is on practical application of neuroanatomical knowledge for research-oriented students. This course is appropriate for students in all tracks who want to increase their knowledge of Neuroanatomy.

Course detail:

(1) The course is laboratory based. There will be ten 3-hour lecture/laboratory sessions.
(2) Students will view at least one brain cutting session with a Mayo Neuropathologist and one Neurohistopathology review.
(3) Students will write a mini-review of an area of Neuroanatomical interest.

NBD 6600f,w,sp. NEUROSCIENCE JOURNAL CLUB. (1 cr.; S-N) Ross – This multifaceted course will address current topics in neuroscience and will emphasize dynamic interactions between students and faculty. Each quarter two to three focused topics will be covered in depth through a series of literature reviews and presentations by the students. One credit will be given per year for years 1 and 2 and every student is required to present and participate each quarter in years 1 through 4. Register for this course fall quarter only of years 1-2 (1 cr./yr.). Attendance required fall, winter, and spring all years.

NBD 6650f. NEUROBIOLOGY OF DISEASE WORKS IN PROGRESS. (1 cr.; S-N) Ross – Presentation of ongoing research projects by graduate students in the Neurobiology of Disease Ph.D. Program. One credit will be given per year and every student is required to present a WIP each year in years 2 – 5. Register for this course fall quarter only of years 2-3 (1 cr./yr.). Attendance required fall, winter, and spring all years.

NBD 6852w,sp. TOPICS IN NEUROSCIENCE RESEARCH. (1 cr./yr.; A-F) Bieber – It is intended that students enrolled in Basic Neuroscience (NBD 6854) will also enroll in this companion course will introduce graduate students to the primary research literature in basic neuroscience. The emphasis will be on developing the ability to read the research literature efficiently, identifying the key points in otherwise complex papers. Emphasis will also be placed on the critical evaluation of experimental data and on the basic technical approaches that are commonly used in neuroscience research.

NBD 6854w,sp. BASIC NEUROSCIENCE. (5 cr.; A-F) Benarroch – The Basic Neuroscience course consists of a series of didactic lectures and question and answer sessions covering basic molecular, cellular, neurochemical and physiological aspects of the organization of the nervous system, with an emphasis on clinical correlations. The course is intended to provide neurology and neurosurgery residents and neuroscience graduate students with basic information on the organization of the nervous system at the molecular, cellular, synaptic, and system levels. The course will also provide information that will allow clinical trainees to understand and critically analyze the increasing number of papers in the neurologic literature that address basic mechanisms of disease and therapeutic approaches. Finally, the course will provide an overview of the spectrum of neurologic disease that will allow basic science trainees to put their specific research projects in the context of potential clinical relevance.

NBD 6855sp. CONCEPTS OF CELL GROWTH AND REGENERATION. (2 cr.; Even Years; A-F; prerequisites NBD 6600 required, NBD 6850 recommended) Henley – The course will explore the processes by which developing neurons grow and establish functional connections during embryonic development, intrinsic and extrinsic growth inhibitors, and potential strategies for
enhancing neuroregeneration in the adult peripheral and central nervous systems. Papers will be chosen to represent fundamental discoveries and the most current findings.

Objectives:
At the end of the course, participants will be able to:
• Describe molecular mechanisms underlying the growth and guidance of developing neurons.
• Describe the mechanisms controlling synaptogenesis and interactions between neurons and glia.
• Describe inhibitors of neurite growth.
• Describe current methods for analyzing and enhancing neuroregeneration.
• Critically review and write a critique of scientific manuscripts submitted to peer-reviewed journals.
• Synthesize the conclusions from the different modules into a framework.
• Identify gaps in current knowledge within the framework.
• Use the framework to propose strategies for promoting neuroregeneration and potential pitfalls.

The course will consist of an introductory module, 20 papers (two/week) and a final synthesis module. For the introductory module, the course director will present an overview and class participants (two to four/group) will discuss and propose strategies for promoting regeneration in the nervous system. For the papers module, participants will be assigned (two/group) to present papers each week. For each paper, designated presenters will provide a brief synopsis of the background literature and an in depth review of a recent scientific publication. All participants are required to read, write a critical review, and discuss the papers each week. The course instructor will moderate each class and facilitate discussions. The topics and papers will be available one week before they are presented, so that each participant will have time to read and prepare a critical review. Critical reviews are due within 24 hours of the relevant paper presentation and are to be in a format requested by scientific journals for reviewers of submitted manuscripts. Presenters will be expected to extensively use electronic searching methods and published resources to provide an overview of background literature in addition to the key findings and shortcomings of the assigned papers. The presentation will be submitted to the course chair within 24 hours of the class presentation and will be distributed to course registrants via email upon request. For the final synthesis module, participants will be divided into teams (two to four/group) to develop and present a novel multi-level strategy with potential to promote regeneration in the nervous system following injury or degenerative disease. Potential pitfalls will need to be identified and discussed. The course chair will promote discussion during each class so that all participants are actively involved in the discussion.

Total Lecture Time: 2 hours/week
Evaluation: Attendance (10%) │ Paper Presentations (40%) │ Paper Critical Reviews (50%)

NBD 6860f. ADVANCED TOPICS IN NEUROBIOLOGY. (2 cr.; S-N; offered odd years; prerequisites NBD 6210 and NBD 6850; second year Neurobiology of Disease students, others only by permission of instructor) McLean – This course is intended for second year students in the NBD track and above and will be structured as a small group didactic discussion of advanced topics in neurobiology.
NBD 6900f,w,sp,su. NBD THESIS PROPOSAL. (2 cr.; S-N; prerequisite—must have completed and passed qualifying exams) McLean – Thesis proposal: The written thesis proposal matches the format of NIH F31 grants and, hence is limited to 7 pages, including figures but not references. In the student's own words, the proposal should outline the rationale for the proposed project and how it is to be executed. The proposal is subdivided into the following sections.

- Abstract: Summary of the project (1 page)
- Specific Aims: Briefly describe the aims and hypotheses of your project (1/2 page).
- Significance: Put your project into context with what is known about this area of neuroscience and demonstrate the significance of the questions you are asking (1 page)
- Innovation: How is the proposed project novel and groundbreaking (1/2 page)
- Approach: Describe what you plan to do and how you plan to do it. Include preliminary data for each aim that supports your question and hypothesis (4 pages).

Register for credit the quarter AFTER you have prepared your proposal and passed your qualifying oral exam.

Research

NBD 6890f,w,sp,su. RESEARCH IN THE NEUROBIOLOGY OF DISEASE. (S-N) Staff – Graduate thesis research for Ph.D. students under supervision of staff.

OBSTETRICS AND GYNECOLOGY

Didactic

OBG 5803f,w,sp,su. INTRODUCTION TO SURGICAL GYNECOLOGY. (1 cr; A-F) Prerequisite: must be enrolled in Gynecology Oncology Fellowship Program or Female Pelvic Medicine and Reconstructive Surgery Fellowship Program) Cliby, Occhino. Didactic sessions presented weekly. Student preparation and participation is required. Students earn MCBSBS credits for participation in fellowship didactic activities; not a formal classroom setting. Must register each of the four consecutive quarters. Begin summer quarter of first year of fellowship.

OBG 5804f,w,sp,su. INTRODUCTION TO MATERNAL FETAL MEDICINE. (4 cr; A-F) Prerequisite: must be enrolled in Maternal Fetal Medicine Fellowship Program. Borowski. Students earn MCBSBS credits for participation in fellowship didactic activities; not a formal classroom setting. Didactic sessions presented weekly. Student preparation and participation is required. Must register each of the four consecutive quarters. Begin summer quarter of first year of fellowship.

OBG 5805f,w,sp,su. INTRODUCTION TO REPRODUCTIVE ENDOCRINOLOGY AND INFERTILITY. (5 cr; A-F; as prerequisite, must be enrolled in Reproductive Endocrinology & Infertility Fellowship Program) Stewart and STAFF. Students earn MCBSBS credits for participation in fellowship didactic activities; not a formal classroom setting. Didactic sessions presented weekly. Student preparation and participation is required. Must register each of the five consecutive quarters. Begin summer quarter of first year of fellowship.

Research

OBG 6840f,w,sp,su. RESEARCH IN OBSTETRICS GYNECOLOGY. (24 cr; A-F; prerequisite: must be enrolled in the Gynecology Oncology Fellowship Program, Female Pelvic Medicine and Reconstructive Surgery Fellowship Program, Maternal Fetal Medicine Fellowship Program, Reproductive Endocrinology & Infertility Fellowship Program, or Obstetrics and Gynecology
Residency Program) Stewart. Graduate thesis research under supervision of staff. Students earn MCBSBS credits for participation in fellowship or residency research activities; not a formal classroom setting. Master’s program application must be accepted by MCBSBS to enroll in this course.

Clinical

**OBG 6857f,w,sp,su. GYNECOLOGIC ONCOLOGY.** (30 cr; A-F; As prerequisite, satisfactory completion of an obstetrical and gynecologic residency training program at an accredited institution and maintenance of satisfactory status within the Gynecologic Oncology Fellowship Program) Cliby and staff. Preoperative evaluation, surgical treatment, and postoperative management of benign and malignant gynecologic disease processes and the complications thereof arising within the female genitalia. In addition, the acquisition of theoretical and practical knowledge regarding the natural history, the diagnosis, alternatives to surgical management, prognosis, and the postoperative immediate and long-term disposition for each of the disease processes requiring surgery will be anticipated. Students earn MCBSBS credits for participation in fellowship clinical and surgical activities, not a formal classroom setting. Must register for each of the five consecutive quarters. Begin summer quarter of second year of fellowship.

**OBG 6865f,w,sp,su. REPRODUCTIVE ENDOCRINOLOGY AND INFERTILITY.** (30 cr; A-F; prerequisite satisfactory completion of an obstetrics and gynecology residency training program at an accredited institution and maintenance of satisfactory status within the Reproductive Endocrinology and Infertility Fellowship Program) Stewart and STAFF. Management of patient care under faculty supervision, developing clinical and surgical skills related to infertility, amenorrhea, abnormal uterine bleeding, neuroendocrine dysfunction, reproductive tract abnormalities (acquired and developmental), androgen disorders, recurrent abortion, and menopause. Review of patient care cases on a weekly basis to determine the best approach and plan of care. Daily discussion of the best management of patients undergoing ovulation induction or in vitro fertilization (IVF). Participation in IVF, gamete micromanipulation, assisted hatching, embryo cryopreservation, and oocyte donation. Preparation for clinical practice in reproductive endocrinology through extensive experience in sonography, sonohysterography, controlled ovarian hyperstimulation, transvaginal ultrasound-directed oocyte retrieval and embryo transfer. Application of medical and surgical treatments for male infertility, including epididymal aspiration, testicular biopsy and electroejaculation under the supervision of a urologist and medical endocrinologist. Students earn MCBSBS credits for participation in fellowship clinical and surgical activities, not a formal classroom setting. Must register for each of the five consecutive quarters. Begin summer quarter of first year of fellowship.

**OBG 6870f,w,sp,su. ADVANCED UROGYNECOLOGIC OPERATIVE SURGERY.** (24 cr; A-F; prerequisite is satisfactory completion of an obstetrics and gynecology or urology residency training program at an accredited institution and maintenance of satisfactory status within the Female Pelvic Medicine and Reconstructive Surgery Fellowship Program) Occhino and staff. The preoperative, intra operative and postoperative management of gynecological patients. Students earn MCBSBS credits for participation in fellowship clinical and surgical activities, not a formal classroom setting. Must register for each of the four consecutive quarters. Begin summer quarter of second year of fellowship.

**OBG 6875f,w,sp,su. MATERNAL FETAL MEDICINE.** (24 cr; A-F; Borowski; prerequisite is completion of an obstetrical and gynecologic residency training program at an accredited institution and
maintenance of satisfactory status with the Maternal Fetal Medicine Fellowship Program.) Direct medical management of maternal and fetal conditions during pregnancy. Clinical experience in obstetrical, genetic, medical and surgical complications of pregnancy and their effect on the mother and developing fetus through an intensive ambulatory and labor and delivery practice. Focus on the use of screening and diagnostic sonography and development of associated invasive procedural skills including chorionic villus sampling, genetic amniocentesis, in-utero stenting procedures, laser therapy for twin-twin transfusion syndrome, and percutaneous umbilical cord sampling/intrauterine blood transfusion. Students earn MCBSBS credits for participation in fellowship clinical and surgical activities, not a formal classroom setting. Must register for each of the four consecutive quarters. Begin summer quarter of first year of fellowship.

**ORTHOPEDICS**

**Didactic**

ORS 5803f,sp. PROSTHETICS FOR ORTHOPEDICS. (1 cr; A-F) Morrey. Lectures and discussions regarding upper and lower extremity Prosthetics for amputations at various levels, includes class participation in the application of immediate-type pylons.

ORS 6550f,w,sp,su. MICROVASCULAR SURGERY SKILLS. (2cr; S-N; Prerequisite is student must be involved in or have completed a training program in an approved surgical specialty or subspecialty or be involved as a research fellow, technician, etc.) Forty hours of instruction and practice, which includes the care and adjustment of the operating microscope, the basic techniques of microsurgical suture placement, and microvascular anastomosis of a rat femoral artery and rat femoral vein. Following successful completion of the above measures, the students will extend their application to end to side microvascular anastomosis, as well as epineural and fascicular nerve repair using the rat sciatic nerve model.

ORS 6860f,w,sp,su. BASIC KNOWLEDGE AND MOTOR SKILLS OF ORTHOPEDIC SPECIALTIES. (4 cr; A-F; consent of instructor is required; Morrey.) This course will cover pertinent basic knowledge and motor skills as it applies to the subspecialties of Orthopedics, including adult reconstruction/ trauma, hand and upper extremity, pediatrics, spine, and sports medicine.

**Clinical**

ORS 6852f,w,sp,su. ADULT RECONSTRUCTION. (3 cr; A-F) Turner and staff. This course covers all areas of adult reconstructive surgery, including spine, hip, knee, shoulder, elbow, ankle and foot. Course will include personal teaching on patient assessment, surgical technique, pre- and postoperative care, as well as follow-up care.

ORS 6853f,w,sp,su. SURGERY OF THE HAND. (3 cr; A-F) Turner and staff. Supervised exposure to clinical hand surgery with weekly teaching conference and monthly journal club.

ORS 6854f,w,sp,su. PEDIATRIC ORTHOPEDICS. (3 cr; A-F) Turner and staff Incidence, etiology, evaluation and treatment of congenital developmental, metabolic, and post-traumatic orthopedic conditions from birth to physiologic maturity.
ORS 6855f,w,sp,su. ORTHOPEDIC ONCOLOGY. (3 cr; A-F) Turner and staff Orthopedic oncology residents participate in evaluation and management of patients with various musculoskeletal neoplasms. The surgical experience includes modern limb salvage procedures.

ORS 6856f,w,sp,su. ORTHOPEDIC TRAUMA. (3 cr; A-F) Turner and staff Instruction in patient assessment by history, physical examination, imaging modes, laboratory tests and other adjunctive special evaluation techniques in the investigation of the musculoskeletal system and its fractures and related injuries. Included are experiences in outpatient, inpatient and operating room settings. The didactic program includes clinical conferences, lectures and journal clubs.

Research
ORS 6890f,w,sp,su. RESEARCH IN ORTHOPEDICS. (6 cr; S-N) Staff Graduate thesis research for Master’s students under supervision of staff.

Virology and Gene Therapy

VGT 5300w. GENE THERAPY LECTURE COURSE. (1 cr.; A-F) Russell – After attending this course the student will have gained an appreciation of the broad potential scope of gene therapy and should understand how to develop a gene based therapeutic from an idea to a validated product. Various gene therapy strategies will be considered in relation to a broad spectrum of human diseases illustrating how genes can be used for gene replacement, tissue engineering, destruction of unwanted tissues, or immune stimulation. Stages in the development of gene-based drugs will be studied from vector design through preclinical proof of efficacy, clinical protocol development, product manufacture, pharmacology and toxicology testing, analysis of clinical trial outcomes, regulatory affairs, patenting and partnering with industry.

VGT 5500w. FROM VIRUSES TO VECTORS LECTURE COURSE. (1 cr.; A-F) Vile – This course will cover the structure of viruses from which vectors are commonly derived and will describe the modifications made to the wild-type vectors which ensures the production of safe, efficient, targeted vectors for gene therapy.

VGT 5600w. MOLECULAR VIROLOGY LECTURE COURSE. (1 cr.; A-F) Cattaneo – We highlight unifying principles emerging from the study of animal viruses. Using selected examples we illustrate virus structure, cell entry and receptors, replication of retroviruses, DNA viruses and riboviruses, transcription and RNA processing, translation and intracellular transport, particle assembly and cell escape. We discuss which questions are still outstanding and introduce emerging viruses.

VGT 6740f. VIRUSES AND VECTORS JOURNAL CLUB. (1 cr.; A-F) Cattaneo – Discussion of recent advances in the fields of virology and gene therapy. Students, postdocs and staff will present recently published papers that are of general interest to the fields. Emphasis will be on the development of new vectors for gene delivery and on cytoreductive therapy. From 2nd year on: Register in fall quarter only (1 cr./yr.). Attendance required fall, winter and spring.

VGT 6745f. CURRENT TOPICS IN VIROLOGY AND GENE THERAPY. (1 cr.; A-F) Ikeda – This is a weekly seminar course in which visiting seminar speakers alternate with Mayo investigators. The format is a one-hour seminar in which the presenter gives a detailed account of their own
virology or gene therapy research followed by a lively question and answer session. From 2nd year on: Register in fall quarter only (1 cr./yr.). Attendance required fall, winter and spring.

VGT 6884sp. VIRAL DISEASE TUTORIAL. (2 cr.; offered odd years; A-F) Staff – Virus pathology and disease tutorial. Major viruses and their molecular biology, pathogenesis and clinical features, emerging pathogens, therapeutic strategies. Important viral infections will be covered; emphasis will also be placed on emerging viruses of strong topical or emerging interest. Structure: 11-12 sessions, meeting weekly for about two hours. Discussion will center on important papers after introduction to topic by faculty: 1) e.g., cytomegalovirus, Ebola, EBV, dengue and yellow fever, hepatitis C, HIV, herpes simplex 1 and 2, influenza, lassa and other arenaviruses, measles and mumps, RSV, papillomaviruses, rhinoviruses, smallpox, viral diagnosis; 2) e.g., avian influenza, Nipah, SARS, Sin Nombre (Hanta) virus, West Nile virus.

VGT 6886sp. MOLECULAR VIROLOGY TUTORIAL. (2 cr.; offered odd years; A-F) Ikeda – This tutorial is a companion to the Molecular Virology course. It deepens the subjects illustrated in the lectures. Publications that have contributed in shaping the field or have identified new principles will be introduced by staff members and presented by the students.

VGT 6888sp. GENE AND CELL THERAPY TUTORIAL. (2 cr.; offered even years; A-F) Dingli – The major goal of this tutorial is to develop a broad understanding of the field of clinical gene transfer and therapy. Tutorials will range from the scientific and biological aspects of gene vectors and safety to the conduct and regulatory issues of clinical gene transfer trials. A variety of instructors will discuss pertinent questions involving the development and practice of ongoing clinical trials. These trials will include those that address infectious disease, malignancies, and cardiovascular disease.

Research

VGT 6890f,w,sp,su. RESEARCH IN VIROLOGY AND GENE THERAPY. (S-N) Staff – Graduate thesis research for Ph.D. students under supervision of staff.
Academic Calendar (2017-2018) ................................................................. 4
Academic Calendar (2018-2019) ................................................................. 5
Policies ........................................................................................................... 12

Course Listings
Anatomy ........................................................................................................ 102
Biochemistry and Molecular Biology ........................................................ 102
Biomedical Engineering and Physiology ..................................................... 106
Core ............................................................................................................... 114
Clinical and Translational Science ............................................................. 116
Dentistry ....................................................................................................... 126
Immunology ................................................................................................. 130
M.D. – Ph.D. ............................................................................................... 132
MCGSBS (MGS) ........................................................................................ 132
Molecular Pharmacology and Experimental Therapeutics ....................... 133
Neurobiology of Disease ........................................................................... 135
Obstetrics and Gynecology ........................................................................ 138
Orthopedics ............................................................................................... 140
Virology and Gene Therapy ........................................................................ 141

Doctor of Philosophy Program in Biomedical Sciences .............................. 17
M.D. – Ph.D. Program .................................................................................. 28
Ph.D. Degree Programs
Biochemistry and Molecular Biology Track ............................................. 31
Biomedical Engineering and Physiology Track ......................................... 35
Clinical and Translational Sciences Track .................................................. 39
Immunology Track ..................................................................................... 44
Molecular Pharmacology and Experimental Therapeutics Track .............. 47
Neurobiology of Disease Track ................................................................. 50
Virology and Gene Therapy Track ............................................................ 54

Basic Science Master’s Degree Programs ................................................... 56
Biochemistry and Molecular Biology Track ............................................. 62
Clinical and Translational Sciences Track .................................................. 64
Immunology Track ..................................................................................... 67
Molecular Pharmacology and Experimental Therapeutics Track .............. 68

Employee Master’s Degree Programs ......................................................... 69
Biochemistry and Molecular Biology Track ............................................. 74
Biomedical Engineering and Physiology ................................................... 77
Immunology Track ..................................................................................... 79
Molecular Pharmacology and Experimental Therapeutics Track .............. 81
Neurobiology of Disease Track ................................................................. 83
Clinical Master’s Degree Programs..............................................................................................................85
Orthodontics Clinical Master’s Track........................................................................................................91
Periodontics Clinical Master’s Track ........................................................................................................92
Prosthodontics Clinical Master’s Track ....................................................................................................93
OB/GYN - Female Pelvic Medicine/Reconstructive Surgery Master’s Track ....................................94
OB/GYN - Gynecologic Oncology Master’s Track ............................................................................95
OB/GYN - Maternal Fetal Medicine Master’s Track ...........................................................................96
OB/GYN - Reproductive Endocrinology and Infertility Master’s Track ........................................97
Orthopedics.............................................................................................................................................99