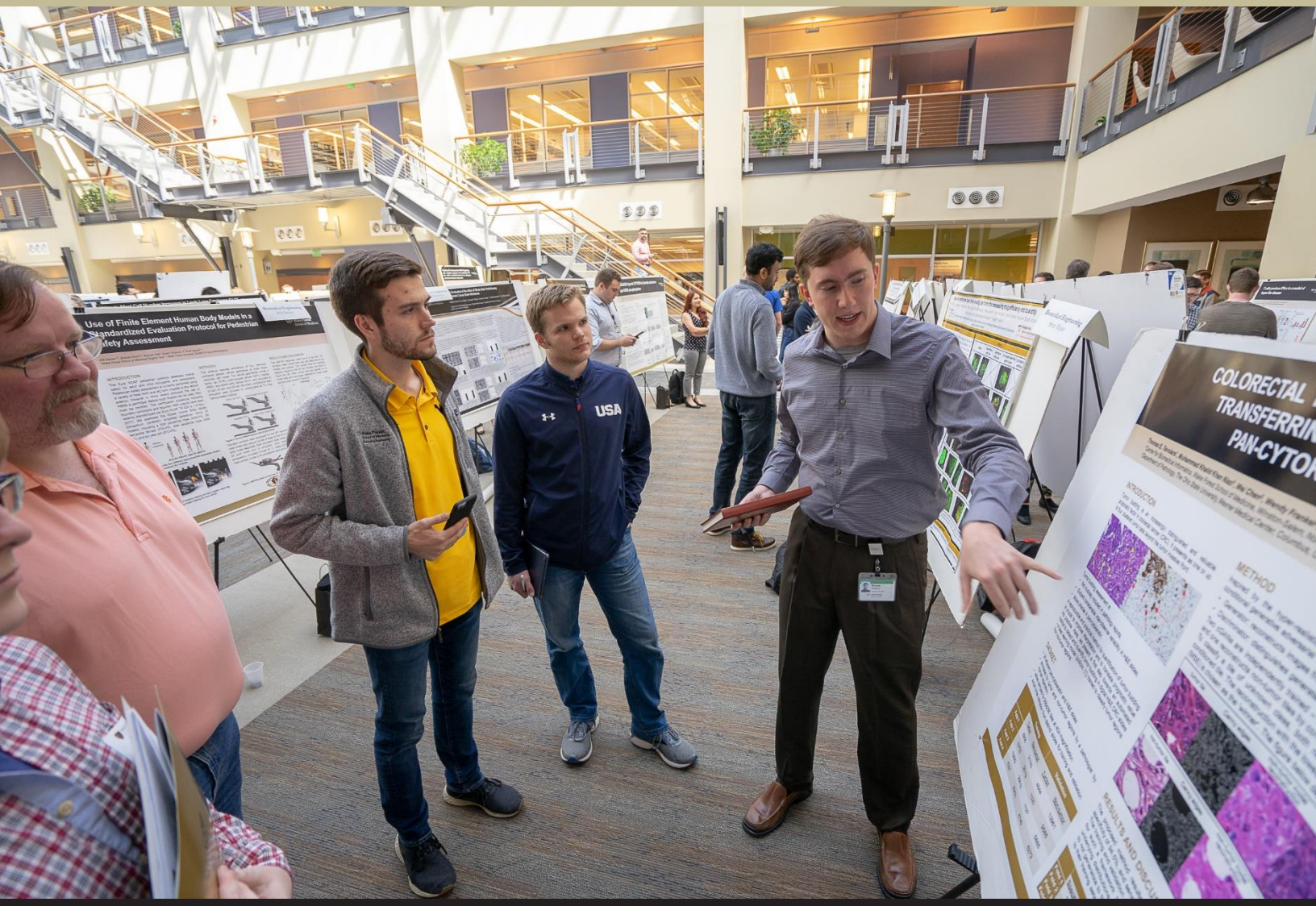
The Graduate School of Arts and Sciences

Biomedical Programs

2021 – 2022



The Graduate Bulletin

For Biomedical Graduate Programs
Administered on the School of Medicine Campus

On the Cover: PhD student Thomas Tavolara (Biomedical Engineering) discusses his poster with fellow students, Tanner Filben and Stewart Pritchard, at Research Day.

WAKE FOREST
UNIVERSITY

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WAKE FOREST UNIVERSITY
GRADUATE SCHOOL of ARTS & SCIENCES

2021-2022 Academic Calendar

SUMMER TERM 2021

May	20	New Student Orientation
May	24	Classes Begin
May	31	MEMORIAL DAY HOLIDAY
June	**4**	**Deadline: Statement of Intent form to Grad School for Sept graduates**
June	14	Last day to add/drop a course
July	5	JULY 4TH HOLIDAY
July	6	Course Registration for the next term opens
August	**10**	**Deadline: Last day to defend for September graduates**
August	17	Classes End
August	**17**	**Deadline: ETD Student Advisor Agreement, final copy of thesis/ dissertation, exit survey completions for September graduates**
August	18-21	Examinations
August	30	Grades Due
September	7	Graduation (Degrees Conferred)

FALL TERM 2021

August	25	New Student Orientation
August	27	Ethics RCR Bootcamp (GRAD 713)
August	30	Classes Begin
September	6	LABOR DAY HOLIDAY
September	**17**	**Deadline: Statement of Intent form to Grad School for Jan graduates**
September	20	Last day to enroll/add a course
November	8	Course Registration for the next term opens
November	24 – 26	THANKSGIVING HOLIDAY
December	**14**	**Deadline: Last day to defend for January graduates**
December	16	Classes End
December	17-21	Examinations
December	**20**	**Deadline: ETD Student Advisor Agreement, final copy of thesis/ dissertation, exit survey completions for January graduates**
January	7	Grades Due
January	14	Graduation (Degrees Conferred)

SPRING TERM 2022

January	6	New Student Orientation
January	10	Classes begin
January	17	MARTIN LUTHER KING JR. HOLIDAY
January	**21**	**Deadline: Statement of Intent form to Grad School for May graduates**
February	1	Last day to enroll/add a course
March	7 – 11	SPRING BREAK
March	21	Course Registration for the next term opens
April	15	GOOD FRIDAY HOLIDAY
April	**21**	**Deadline: Last day to defend for May graduates**
April	28	Classes end
April 29 – May 3		Examinations
May	**3**	**Deadline: ETD Student Advisor Agreement, final copy of thesis/ dissertation, exit survey completions for May graduates**
May	9	Grades Due
May	14	Hooding and Awards Ceremony
May	16	Commencement

Programs of Study

The Graduate School administers programs on the Wake Forest School of Medicine campus and the Reynolda campus, home of the undergraduate college and their associated graduate programs.

On the School of Medicine campus, the Graduate School offers 8 PhD programs in the biomedical sciences, MS programs in 11 disciplines, and graduate certificates in 3 disciplines. **All programs of study, joint degree programs, certificates, and concentrations subject to this Graduate Bulletin are noted in bold below.** All other programs, including the PhD programs in biology, chemistry, and physics, and Master's programs in 22 disciplines, are administered by the Graduate School office based on the Reynolda campus and covered by a separate Graduate Bulletin. The Graduate School also offers 15 joint degree programs in conjunction with the Wake Forest School of Medicine, School of Business, School of Divinity, and School of Law; as well as 13 certificate programs. Contact information on all programs and certificates of study may be found on our website at http://graduate.wfu.edu.

Doctoral Programs of Study

Biology (PhD)
Biomedical Engineering (PhD)
Chemistry (PhD)
Integrative Physiology and Pharmacology (PhD)
Molecular & Cellular Biosciences
(a non-degree granting admissions pathway to the following degree granting programs)

- **Biochemistry and Molecular Biology (PhD)**
- **Cancer Biology (PhD)**
- **Microbiology and Immunology (PhD)**
- **Molecular Genetics and Genomics (PhD)**
- **Molecular Medicine and Translational Science (PhD)**

Neuroscience (PhD)
Physics (PhD)

Master's Programs of Study

Addiction Research and Clinical Health (MS)
Bioethics (MA)
Biology (MS)
Biomedical Engineering (MS)
Biomedical Science (MS)
Chemistry (MS)
Clinical Research Management (MS - online)
Communication (MA)

Comparative Medicine (MS)
Computer Science (MS)
Counseling (MA)
Counseling (MA - online)
Counseling - Human Services (MAHS - online)
Documentary Film (MA/MFA)
Education (MAEd)
English (MA)
Genetic Counseling (MS)
Health and Exercise Science (MS)
Healthcare Leadership (MHL - online)
Health Disparities in Neuroscience-related Disorders (MS)
Interpreting and Translation Studies (MA):

- Interpreting and Translation Studies
- Intercultural Services in Healthcare
- Teaching of Interpreting

Liberal Arts Studies (MA)
Mathematics & Statistics (MA)
Molecular Medicine and Translational Science (MS)
Neuroscience (MS)
Physics (MS)
Psychology (MA)
Religious Studies (MA)
Sustainability (MA)
Translational & Health System Science (MS)

Joint Degree Programs

MS & BS/A (Bioethics)
MS & BS/A (Computer Science)
MS & BS/A (Neuroscience)
MA/JD (Bioethics)
MA/JD (Religious Studies)
MA/JD (Sustainability)
MA/MD (Bioethics)
MS/MD (Translational and Health System Science)
PhD/MD
MA/MDiv (Bioethics)
MA/MDiv (Counseling)
MAEd/MDiv (Education)
MA/MDiv (Sustainability)
PhD/MMS (MMTS & PA)
PhD/MBA

Graduate Certificates

Bioethics:

- Bioethics
- Biomedical Research Ethics
- Clinical Bioethics

Clinical and Translational Investigation
Curriculum, Instruction, and Assessment
Interpreting and Translation Studies:

- Intercultural Services in Healthcare
- Interpreting Studies
- Teaching of Interpreting (Postgraduate)
- Translation Studies

Learning Health System Science
Medieval and Early Modern Studies
Structural and Computational Biophysics
Sustainability

Concentrations

Antimicrobial Stewardship & Infection Prevention
Cancer Biology
Integrative Physiology and Pharmacology
Neuroscience
Regenerative Medicine
Religion and Public Engagement
Women's Gender, and Sexuality Studies

The University

Wake Forest University is characterized by its devotion to liberal learning and professional preparation for men and women, its strong sense of community and fellowship, and its encouragement of free inquiry and expression.

Wake Forest Institute was founded in 1834 by the Baptist State Convention of North Carolina. The school opened its doors on February 3 with Samuel Wait as principal. Classes were first held in a farmhouse on the Calvin Jones plantation in Wake County, North Carolina, near which the village of Wake Forest later developed.

Rechartered in 1838 as Wake Forest College, Wake Forest is one of the oldest institutions of higher learning in the state. The School of Law was established in 1894, followed by a two-year medical school in 1902. Wake Forest was exclusively a college for men until World War II, when women were admitted for the first time.

In 1941 the medical school moved to Winston-Salem to become affiliated with North Carolina Baptist Hospital and was renamed the Bowman Gray School of Medicine. In 1946 the trustees of Wake Forest and the Baptist State Convention of North Carolina accepted a proposal by the Z. Smith Reynolds Foundation to relocate the College to Winston-Salem.

The late Charles and Mary Reynolds Babcock donated much of the R.J. Reynolds family estate as the site for the campus and building funds were received from many sources. From 1952 to 1956, the first fourteen buildings were constructed in Georgian style on the new campus. The move to Winston-Salem took place in the summer of 1956; the original, or "old" campus, is now home to Southeastern Baptist Theological Seminary.

Following the move, Wake Forest grew considerably in enrollment, programs, and stature and became a University in 1967. The School of Business Administration, first established in 1948, was named the Charles H. Babcock School of Business Administration in 1969 and admitted its first graduate students in 1971. In 1972 the school enrolled only graduate students and the name was changed to the Charles H. Babcock Graduate School of Management; departments of business and accountancy and economics were established in the College. In 1980 the Department of Business and Accountancy was reconstituted as the School of Business and Accountancy; the name was changed to the Wayne Calloway School of Business and Accountancy in 1995. On July 1, 2009, the Wayne Calloway School of Business and Accountancy and the Charles H. Babcock Graduate School of Management officially merged under the name Wake Forest University Schools of Business.

The Division of Graduate Studies, established in 1961, is now organized as the Graduate School and encompasses advanced work in the arts and sciences on both the Reynolda and Bowman Gray campuses. In 1997 the medical school was renamed the Wake Forest School of Medicine; its campus is now known as the Bowman Gray Campus. The School of Divinity was established in 1999.

Wake Forest honors its Baptist heritage in word and deed. The University will fulfill the opportunities for service arising out of that heritage. Governance is by an

independent Board of Trustees; there are advisory boards of visitors for the College and each professional school. A joint board of University trustees and trustees of the North Carolina Baptist Hospital is responsible for Wake Forest University Baptist Medical Center, which includes the hospital and the medical school.

The College, School of Business, School of Law, and the School of Divinity are located on the Reynolda Campus in northwest Winston-Salem and the Morrocroft Campus in Charlotte, NC. The Wake Forest School of Medicine is about five miles away, with locations in the city's downtown area and in the Baptist Medical Center. The Graduate School maintains operations on both the Reynolda and School of Medicine campuses depending on the program of study. The University also offers instruction regularly at Casa Artom in Venice, at Worrell House in London, at Flow House in Vienna, and in other places around the world.

The College offers courses in more than forty fields of study leading to the baccalaureate degree. The School of Divinity offers the Master of Divinity degree. The Wake Forest School of Business offers a four-year bachelor of science degree, with majors in accountancy, business and enterprise management, finance, and mathematical business (offered jointly with the Department of Mathematics); and three graduate degree programs, Master of Science in Accountancy (MSA), Master of Arts in Management (MA), and Master of Business Administration (MBA).

The School of Law offers the Juris Doctor and Master of Laws in American law degrees. The school also offers a joint JD/MBA degree with the Schools of Business. The Wake Forest School of Medicine offers the Doctor of Medicine degree (MD) as well as the Master of Medical Science (MMS) through the Physician Assistant program, and the Master of Science (MS) in Nurse Anesthesia, and the Doctor of Nursing Practice (DNP degree). The School of Medicine and the Schools of Business offer a joint MD/MBA program.

The Graduate School confers the Master of Arts, Master of Arts in Education, Master of Arts in Human Services, Master of Arts in Liberal Studies, Master of Fine Arts, Master of Healthcare Leadership, and Master of Science degrees in the arts and sciences and biomedical science, and the Doctor of Philosophy degree. The Graduate School also offers an MD/MS, MD/PhD, PhD/MMS, as well as an MD/MA in bioethics jointly with the School of Medicine, and a PhD/MBA program jointly with the School of Business. In addition, the Graduate School offers an MDiv/MA in bioethics, counseling, or sustainability as well as an MDiv/MAED jointly with the School of Divinity; and a JD/MA in bioethics, religious studies or sustainability jointly with the School of Law. Certificates are offered in Bioethics, Clinical and Translational Investigation, Learning Health System Science, Interpreting and Translation Studies, Structural and Computational Biophysics, and Sustainability.

Statement of Purpose of the University

Following is the official statement of the purposes and objectives of the University: *Wake Forest is a University dedicated to the pursuit of excellence in the liberal arts and in graduate and professional education. Its distinctiveness in its pursuit of its mission derives from its private, coeducational, and residential character; its size and*

location; and its Baptist affiliation. Each of these factors constitutes a significant aspect of the unique character of the institution. The University is comprised of Wake Forest College, the Graduate School, the School of Law, the School of Medicine, the School of Divinity and the School of Business. It seeks to honor the ideals of liberal learning, which entail commitment to transmission of cultural heritages; teaching the modes of learning in the basic disciplines of human knowledge; developing the critical appreciation of moral, aesthetic, and religious values; advancing the frontiers of knowledge through in-depth study and research; and applying and using knowledge in the service of humanity.

Wake Forest has been dedicated to the liberal arts for over a century and a half; this means education in the fundamental fields of human knowledge and achievement, as distinguished from education that is technical or narrowly vocational. It seeks to encourage habits of mind that ask "why," that evaluate evidence, that are open to new ideas, that attempt to understand and appreciate the perspectives of others, that accept complexity and grapple with it, that admit error, and that pursue truth. Wake Forest College has by far the largest student body in the University, and its function is central to the University's larger life. The College and the Graduate School are most singularly focused on learning for its own sake; they, therefore, serve as exemplars of specific academic values in the life of the University.

Beginning as early as 1894, Wake Forest accepted an obligation to provide professional training in a number of fields as a complement to its primary mission of liberal arts education. This responsibility is fulfilled in the conviction that the humane values embodied in the liberal arts are also centrally relevant to the professions. Professional education at Wake Forest is characterized by a commitment to ethical and other professional ideals that transcend technical skills. Like the Graduate School, the professional schools are dedicated to the advancement of learning in their fields. In addition, they are specifically committed to the application of knowledge to solving concrete problems of human beings. They are strengthened by values and goals which they share with the College and Graduate School, and the professional schools enhance the work of these schools and the University as a whole by serving as models of service to humanity.

Wake Forest was founded by private initiative, and ultimate decision-making authority lies in a privately appointed Board of Trustees rather than in a public body. Funded to a large extent from private sources of support, Wake Forest is determined to chart its own course in the pursuit of its goals. As a coeducational institution it seeks to "educate together" persons of both sexes and from a wide range of backgrounds—racial, ethnic, religious, geographical, socioeconomic, and cultural. Its residential features are conducive to learning and to the pursuit of a wide range of co-curricular activities. It has made a conscious choice to remain small in overall size; it takes pride in being able to function as a community rather than a conglomerate. Its location in the Triad area of North Carolina engenders an ethos that is distinctively Southern, and more specifically North Carolinian. As it seeks to broaden further its constituency and to receive national recognition, it is also finding ways to maintain the ethos associated with its regional roots.

Wake Forest is proud of its Baptist and Christian heritage. For more than a century and a half, it has provided the University an indispensable basis for its mission and purpose, enabling Wake Forest to educate thousands of ministers and lay people for enlightened leadership in their churches and communities. Far from being exclusive and parochial, this religious tradition gives the University roots that ensure its lasting identity and branches that provide a supportive environment for a wide variety of faiths. The Baptist insistence on both the separation of church and state and local autonomy has helped to protect the University from interference and domination by outside interests, whether these be commercial, governmental, or ecclesiastical. The Baptist emphasis upon revealed truth enables a strong religious critique of human reason, even as the claims of revelation are put under the scrutiny of reason. The character of intellectual life at Wake Forest encourages open and frank dialogue and provides assurance that the University will be ecumenical and not provincial in scope, and that it must encompass perspectives other than the Christian. Wake Forest thus seeks to maintain and invigorate what is noblest in its religious heritage.

LIBRARIES

The libraries of Wake Forest University support instruction and research at the undergraduate level and in the disciplines awarding graduate degrees. The libraries of the University hold membership in the American Library Association and in the Association of Southeastern Research Libraries.

The Wake Forest University libraries include the Z. Smith Reynolds (ZSR) Library, which is located on the Reynolda Campus and primarily supports the undergraduate College, the Wake Forest School of Business, the Reynolda-based programs of the Graduate School of Arts and Sciences, and the School of Divinity. The Professional Center Library, housed in the Worrell Professional Center on the Reynolda Campus, serves the School of Law. The Coy C. Carpenter Library primarily serves the Wake Forest School of Medicine and the biomedical science programs of the Graduate School of Arts and Sciences and is located on the Bowman Gray Campus.

The three library collections total over 2.4 million titles, including over 1.4 million e-books, more than 100,000 electronic journals and over 15,000 DVDs as well as streaming media and other formats. The ZSR Library serves as a congressionally designated selective federal depository. The Professional Center Library holds nearly 130,000 volumes and the Coy C. Carpenter Library holds nearly 27,000 volumes. The three libraries share an online search portal, which also provides access to books, electronic resources, journals and databases. Through interlibrary loan service, students, faculty and staff may obtain materials from other libraries at no charge.

BOWMAN GRAY CAMPUS AND INNOVATION QUARTER LIBRARY RESOURCES

All faculty, staff and students in the Wake Forest University Graduate School of Arts and Sciences and Biomedical Sciences have full and unrestricted access to the Coy C. Carpenter Library of Wake Forest School of Medicine at its main facility on the first floor of the Gray Building. The Library is centrally located within the Wake Forest-affiliated hospital (Wake Forest Baptist Medical Center), and most of the resources are

available online. The main facility of the Library is also well-stocked with print volumes covering all medical and surgical specialties, as well as the basic sciences. There is a branch of the Library located on the third floor of the Bowman Gray Center for Medical Education (BGCME) building in Innovation Quarter that is reserved mostly for students. The Carpenter Library's website, www.wakehealth.edu/library, offers access to PubMed, UpToDate, Journal Citation Reports, Micromedex, PsycINFO, and Web of Science, as well as over 70 other bibliographic and full text databases.

Graduate students receive free document delivery service for materials the Library owns and interlibrary loan service for materials from other libraries when the Library does not own or license a particular journal or book. In addition, all graduate students have unlimited copying and printing services at both locations.

The Library provides assistance to graduate students as they complete the Graduate School's requirement to archive an electronic full-text copy of their thesis or dissertation in Wake Forest University's institutional repository, WakeSpace at etd.wfu.edu.

Librarians also offer publication assistance, Research ID and ORCID setup, copyright guidance, instruction in NIH and other government funded public access compliance, BioSketch creation, and individual database instruction on products such as PubMed, EndNote, and more.

Reynolda Campus Library Resources

The Z. Smith Reynolds Library (ZSR) provides comprehensive reference and research services in-person and online. Research Librarians work with individual classes across the disciplines on research papers and library users can request personal research sessions with Research Librarians at all phases of their research process. Library faculty also teach elective courses in the fundamentals of research and information literacy and upper-level courses geared towards research in the disciplines and special topics in information. The Digital Initiatives & Scholarly Communication librarians and staff support and empower faculty scholarship through digital tools, methods, publication, and preservation.

Special Collections & Archives (SCA) in ZSR is the repository for the Baptist Historical Collection of North Carolina (the Ethel Taylor Crittenden Collection), Personal Collections & Manuscripts, the Rare Book Collection, and the University Archives. All are welcome to use the SCA online collections and to visit the Research Room. It is a beautiful space for researchers to delve into the collections, and where SCA hosts many events and exhibits.

The library has ten group study rooms equipped with large screen monitors that can be booked online. Publicly available Windows and Macintosh computers are available in the Scholars Commons and Reference areas, and media viewing stations are available in the Media Room. Multimedia equipment, Chromebooks, tablets, and other technology devices may be reserved for checkout. The Reference Desk and online chat are available to help library visitors to find resources and research assistance. The library has a 118-seat auditorium for use by Wake Forest community groups for programs, lectures, and film screenings. There is also the ZieSta Room, a space for students to take a break from studying to nap or rest in comfortable loungers.

ZSR houses the Information Systems Service Desk, the Teaching and Learning Collaborative, and The Writing Center. The Teaching and Learning Collaborative is a resource center for Wake Forest faculty at all stages of their careers. The Writing Center provides help to guide students through their writing process.

ZSR library is committed to creating an accessible, enriching, and welcoming community space for all. The library is open for students continuously during the fall and spring terms 24 hours a day from Sunday through Thursday, and daytime hours Friday and Saturday. Two 24-hour study rooms are located near the entrance to the library and may be accessed by keycard even when the library is closed. The study room on one side houses a coffee bar. Check out the hours and events calendar to stay up to date.

Information Technology/Academic Computing

The Office of Academic Computing is dedicated to the development and support of technology innovations in graduate education. Its mission is to provide the infrastructure for faculty and students to effectively utilize technologies to augment the lifelong learning process. A key role of the department is to facilitate basic understanding with regard to the uses of technology, not only within education but also within the workplace.

The department has developed a ubiquitous computing environment, focusing on technology standards in hardware, software, and networking. The main strategic initiative has been the development of a Web-based curriculum for the individual programs of the Graduate School. The Web-based curriculum provides an organization framework for the digitized lectures and course materials of each program, education-oriented Web sites, schedules, collaborative discussions, and links to specialty content application.

The Medical Center's Information Technology group provides contiguous technical support for faculty, staff and students 24 hours per day, each day of the year. Both hardware and software support are covered through various groups in this department. In addition to the technical support functions, the office also provides services to the faculty for the development of teaching applications and assistance with the digitization of curriculum content. Three software developers are employed for this specific purpose.

Wake Forest has a gigabit Ethernet connection to the Internet. Wake Forest is also a key member of Internet 2, which is focused on providing advanced network technologies, and the North Carolina Research and Education Network (NCREN), which provides statewide educational programs.

Recognition and Accreditation

Wake Forest University is accredited by the Southern Association of Colleges and Schools Commission on Colleges to award baccalaureate, masters, and doctorate degrees. Contact the Commission on Colleges at 1866 Southern Lane, Decatur, Georgia, 30033-4097 or call 404-679-4500 for questions about the accreditation of Wake Forest University.

The Wake Forest School of Medicine is a member of the Association of American Medical Colleges and is fully accredited by the Liaison Committee on Medical Education, the joint accrediting body of the Association of American Medical Colleges and the American Medical Association. The Wake Forest University Physician Assistant Program is accredited by the Accreditation Review Commission on Education for the Physician Assistant Inc. (ARC-PA). For more information on the accreditation status of the program, visit the ARC-PA website (https://www.arc-pa.org/Acc_Programs/acc_programs. html) or the medical school website (https://www.wakehealth.edu/Academic-Programs/Physician-Assistant-Program/Accreditation.htm). The School of Law is a member of the Association of American Law Schools, the American Bar Association, and is listed as an approved school by the Council of the Section of Legal Education and Admissions to the Bar of the American Bar Association and by the Board of Law Examiners and the Council of the North Carolina State Bar. Wake Forest University School of Business is accredited by the Association to Advance Collegiate Schools of Business. The program in counseling leading to the Master of Arts in Education degree is accredited by the Council for the Accreditation of Counseling and Related Educational Programs. The Divinity School is accredited by the Association of Theological Schools in the United States and Canada (ATS).

Wake Forest University is a member of many of the major institutional organizations and associations at the national, regional, and statewide levels, including the following: The American Council on Education, the Association of American Colleges, the National Association of Independent Colleges and Universities, the Council of Graduate Schools in the United States, the Commission on Colleges of the Southern Association of Colleges and Schools, Oak Ridge Associated Universities, Southern Universities Conference, the North Carolina Conference of Graduate Schools, the North Carolina Association of Colleges and Universities, the North Carolina Department of Public Instruction, and the North Carolina Independent Colleges and Universities. In addition, many offices of the University are members of associations which focus on particular aspects of university administration.

Oak Ridge Associated Universities

Since 1993, students and faculty of Wake Forest University have benefited from its membership in Oak Ridge Associated Universities (ORAU). ORAU is a consortium of more than one hundred colleges and universities and a contractor for the U.S. Department of Energy (DOE) located in Oak Ridge, Tennessee. ORAU works with its member institutions to help their students and faculty gain access to federal research facilities throughout the country; to keep its members informed about opportunities for fellowship, scholarship, and research appointments; and to organize research alliances among its members.

Through the Oak Ridge Institute for Science and Education (ORISE), the DOE facility that ORAU operates, undergraduates, graduates, postgraduates, as well as faculty enjoy access to a multitude of opportunities for study and research. Students can participate in programs covering a wide variety of disciplines including business, earth

sciences, epidemiology, engineering, physics, geological sciences, pharmacology, ocean sciences, biomedical sciences, nuclear chemistry, and mathematics. Appointment and program length range from one month to four years. Many of these programs are especially designed to increase the numbers of under-represented minority students pursuing degrees in science- and engineering-related disciplines. A comprehensive listing of these programs and other opportunities, their disciplines, and details on locations and benefits can be found at https://orise.orau.gov/.

ORAU's Office of Partnership Development seeks opportunities for partnerships and alliances among ORAU's members, private industry, and major federal facilities. Activities include faculty development programs, such as the Ralph E. Powe Junior Faculty Enhancement Awards, the Visiting Industrial Scholars Program, consortium research funding initiatives, faculty research, and support programs as well as services to chief research officers.

For more information about ORAU and its programs, review the ORAU website at https://www.orau.org.

THE ADMINISTRATION

The Bulletin of Wake Forest University contains a full accounting of the leadership, reflecting the leader's year of hire, their role, and their degree histories, for the university and its schools (the College, Law, Business, Divinity, and the Graduate School's Reynolda-based graduate programs of study). The full list of administrators may be reviewed at https://bulletin.wfu.edu/administration.

In addition, the Bulletin of Wake Forest University contains a full listing of all members of the university's governing and advisory boards, including the Board of Trustees and its Officers. The full list of governing and advisory board members may be reviewed at https://bulletin.wfu.edu/governing-advisory-boards/.

Owing to this Bulletin's applicability to programs administered by and hosted at the School of Medicine's campus, this document provides a list of key administrative personnel based on the School of Medicine campus. The Graduate School administration can be found after the section describing the Graduate School.

SCHOOL OF MEDICINE ADMINISTRATION

Julie A. Freischlag (2018)
CEO, Wake Forest Baptist Medical Center
Dean of Wake Forest School of Medicine
BS, University of Illinois; MD, Rush University

Modupeola Akinola (2019)
Assistant Dean of Admissions and Student Financial Aid
BS, MB, University of Ibadan Medical School - Nigeria

Evelyn (Lynn) Y. Anthony (2017)
Senior Associate Dean of Faculty Affairs
BS, University of North Carolina, Chapel Hill; MD, Duke University

Gregory L. Burke (2017)
Senior Associate Dean for Research
Professor of Public Health Sciences and Chief Science Officer
MD, MSc, University of Iowa

C. Randall Clinch (2011)
Associate Dean for MD Program Academic Affairs
Professor, Family and Community Medicine
BS, College of New Jersey; DO, University of Medicine and Dentistry of New Jersey - School of Osteopathic Medicine; MS, Wake Forest University

Michael T. Fitch (2018)
Associate Dean for Faculty Affairs, Professor and Vice Chair for Academic Affairs, Emergency Medicine

BS, College of William and Mary; PhD, Case Western Reserve School of Medicine; MD, Case Western Reserve School of Medicine

Beth Gianopulos (2018)
Associate Dean of Faculty Relations and Retention, Senior Counsel, Wake Forest Baptist Medical Center Legal Department, and Assistant Professor of Surgery
JD, Wake Forest University

Terry L. Hales, Jr. (2014)
Senior Vice President, Academic Administration and Operations
Executive Vice Dean
BSBA, Appalachian State; MBA, Wake Forest University

Marquita Hicks (2019)
Assistant Dean of Student Inclusion and Diversity
BA, Hendrix College; MD, University of Kansas

James Hoekstra (2018)
Senior Vice President and Associate Dean, Clinical and Academic Network Development
MD, University of Michigan Medical School

Robert W. Hurley (2020)
Associate Dean for Faculty Development
BA, McGill University; PhD, MD, University of Chicago

Sara R. Jones (2020)
Associate Dean for Basic Science Research
BS, University of Georgia; PhD, University of North Carolina, Chapel Hill

Stephen Kritchevsky (2012)
Associate Dean of Research Development and Director of the Sticht Center on Aging
MSPH, PhD, University of North Carolina, Chapel Hill

Brenda Latham-Sadler (2012)
Associate Dean of Student Inclusion and Diversity
BS, Pace; MD, Wake Forest University

Michael P. Lischke (2001)
Associate Dean of Continuing Medical Education and Richard Janeway, MD Distinguished Director, Northwest Area Health Education Center
BA, MPH, Emory; EdD, Temple

Donald A. McClain (2016)
Associate Dean for Clinical and Translational Science
MD, PhD, The Rockefeller University, Cornell Medical College

Christopher O'Byrne (2016)
Vice President and Associate Dean of Research Administration and Operations
BA, Stonehill College; MS, Northeastern University

Daryl Rosenbaum (2019)
Associate Dean of Admissions and Student Financial Aid
BA, University of Michigan; MD, Wake Forest University

Avinash (Avi) Shetty (2015)
Associate Dean of Global Health
MBBS, University of Bombay; MD, University of Bombay

Mitchell Sokolosky (2014)
Associate Dean of Graduate Medical Education, ACGME Designated Institutional Official, Associate Professor, Emergency Medicine
MD, West Virginia University School of Medicine

Marcia M. Wofford (2013)
Associate Dean of Student Affairs
BA, Millsaps College; MD, University of Mississippi Medical Center

Terri S. Yates (2015)
Vice President and Associate Dean, Healthcare Education Administration
BS, MA, Wake Forest University; PhD, University of North Carolina-Greensboro

The Graduate School

In accord with the prevailing custom among American colleges during the antebellum period, Wake Forest granted honorary master's degrees to selected alumni.

By 1862, when the College closed temporarily because of the Civil War, twenty-nine such degrees had been awarded. The first announcement of a program of study leading to an earned graduate degree at Wake Forest was made in 1866. Between 1871, when the first degrees earned under the plan were awarded to John Bruce Brewer (grandson of Samuel Wait) and Franklin Hobgood, and 1951, 383 Master of Arts and Master of Science degrees were granted. In 1949 the School of Arts and Sciences discontinued admitting applicants for the Master of Arts degree because the rapid increase in the size of the undergraduate student body following World War II had overloaded the faculty. The School of Medicine did not interrupt its graduate program. The first Master of Science degree conferred by the school after it moved to Winston-Salem was awarded in 1943, and the degree was offered regularly thereafter by the departments of Anatomy, Biochemistry, Microbiology, Pharmacology, and Physiology.

During the fifteen years the College and the School of Medicine were located in different towns, the study of graduate education continued on both campuses. The self-study report adopted by the faculty of the School of Arts and Sciences immediately prior to its move to Winston-Salem recommended that graduate study leading to the Master's degree be resumed as soon as practicable. In 1958 the administration of the School of Medicine, in view of an increasing demand for graduate instruction in basic medical and clinical sciences, appointed a Committee on Graduate Studies for the purpose of reorganizing the graduate program.

As a result of these two parallel studies and in recognition of the need for an institution-wide approach to graduate education, the trustees, on January 13, 1961, established the Division of Graduate Studies and authorized it to grant the Master of Arts degree in the School of Arts and Sciences and the Master of Science and Doctor of Philosophy degrees in the School of Medicine. The first PhD degree was awarded in 1964. In 1967 the Master of Arts in Education degree was added to the graduate program in arts and sciences. A program, leading to the Master of Arts in Liberal Studies, was begun in the summer of 1987. The first PhD program on the Reynolda campus was begun in 1970.

Mission of the Graduate School

The mission of the WFU Graduate School of Arts and Sciences is to train and mentor future leaders in research, teaching and innovation for serving humanity. This embodies the Graduate School's vital role as an engine of discovery that fuels the nation's scholarly and creative enterprise. The Graduate School contributes to the academic reputation of the university by educating the next generation of teachers and scholars and by providing mentors and role models for educating undergraduates. A strong graduate program also helps support faculty research and is critical for faculty recruitment and retention.

We seek to instill in our students a sense of professionalism, which includes the ethical behavior inherent in their professional role, as well as respect for their

colleagues, their field, and for society as a whole. We want our students to be critical, independent thinkers and good citizens. They should be motivated to apply their scholastic efforts to enlighten and improve the wellbeing of society. Thus the Graduate School is a key link for collaboration between departments and schools and for achieving WFU's goal of becoming a collegiate university and major academic medical center.

Our values are steadfast and consist of critical thinking, service, diversity, discovery, mentoring, and ethics. These are integral to all our activities in the classroom, the laboratory or other research environments, the broader communities of which we are a part. Our vision is for the Graduate School to be a diverse community of excellence. We achieve our vision and fulfill our mission through strategic activities that build pillars of excellence in:

- Student experience: to create an optimized learning and mentoring experience that prepares students to lead in any career path
- Research: to provide high-quality research partnerships for promoting innovation, discovery and creation of value to the community
- Faculty and staff support: to enable seamless, effective, aligned services for maximizing time and resources for instruction and research
- Internal and external communication: to celebrate the prominence and value of the Graduate School and the University

GRADUATE SCHOOL ADMINISTRATION

The Graduate School is administered by two Deans (one on each campus), and an administrative staff that support students and faculty-based on each campus. On the School of Medicine campus, the Graduate School is supported by a central administrative staff. The leadership for the Graduate School Administration on the School of Medicine campus are shown below.

KEY GRADUATE SCHOOL STAFF

Dwayne W. Godwin (2013)
Dean
BA, University of West Florida; PhD, University of Alabama-Birmingham

Allyn Howlett (2015)
Assistant Dean and Director, Office of Postdoctoral Affairs
BS, Pennsylvania State University; PhD, Rutgers University

Erik D. Brady (2015)
Director
BS, Appalachian State University; MS, PhD, Vanderbilt University

Jennie McGuire (2017)
Manager, Curriculum & Outcomes
BA, MA, EdD, Appalachian State University

Bernard Roper (2017)
Experiential Learning & Internship Director
BS, Winston-Salem State University; MA, Gardner-Webb University; PhD, North Carolina Agricultural and Technical State University

THE GRADUATE COUNCIL

The administration of the Graduate School and its programs is further supported by a Graduate Council composed of ex-officio administrative officials, twelve faculty members elected by the Graduate School faculty, and two graduate students elected by the Graduate Student Association. Six of the twelve are members of the College of Arts and Sciences (representing the Reynolda campus) and six are members of the School of Medicine faculty (representing the Bowman Gray campus).

Dwayne Godwin	Dean, Bowman Gray (BG)	dgodwin@wakehealth.edu
Brad Jones	Dean, Reynolda (RC)	jonesbt@wfu.edu
Allyn Howlett	Assistant Dean (BG)	ahowlette@wakehealth.edu
Sandra Dickson	Senior Associate Dean (RC)	dicksosj@wfu.edu
Debbie Newsome	Associate Dean (RC)	newsomdw@wfu.edu
Jennifer Rogers	Associate Dean (RC)	rogersjh@wfu.edu
Ron Von Burg	Associate Dean (RC)	vonburrl@wfu.edu
Chaowei Zhu	Associate Dean (RC)	zhuc@wfu.edu

Bowman Gray representatives (3-YEAR APPOINTMENTS)			Expires
Tracy Criswell	WF Inst for Regen Medicine	tcriswel@wakehealth.edu	2022
Adam Hall	Biomedical Engineering	arhall@wakehealth.edu	2023
Robert Hampson	Physiology and Pharmacology	rhampson@wakehealth.edu	2022
Elizabeth Jensen	Epidemiology and Prevention	ejensen@wakehealth.edu	2024
Leslie Poole	Biochemistry and Mol Biology	lbpoole@wakehealth.edu	2022
Ravi Singh	Cancer Biology	rasingh@wakehealth.edu	2024

Reynolda representatives (3-YEAR APPOINTMENTS)			Expires
Grey Ballard	Computer Science	ballard@wfu.edu	2022
Jeff Katula	Health and Exercise Science	katulaj@wfu.edu	2024
Sarah Esstman	Biology	mcdonasm@wfu.edu	2023
Ellen Kirkman	Mathematics and Statistics	kirkman@wfu.edu	2022
Fred Salsbury	Physics	salsbufr@wfu.edu	2023
Christian Waugh	Psychology	waughce@wfu.edu	2024

Graduate Student Association (GSA) representatives (1-YEAR APPOINTMENTS)			Expires
Fadi Marayati	Biology	marab15@wfu.edu	2021
Brandon Eberl	Biomedical Engineering	beberl@wakehealth.edu	2022

The Graduate Faculty

The graduate faculty are key contributors to the educational and research experience offered by the Graduate School. To review a full list of current graduate faculty members, with their year of appointment and department affiliations, please access the searchable databased at: https://graduate.wfu.edu/faculty-search/. Additional faculty representatives and liaisons to specific committees, with their departmental affiliation, email address, and appointment periods are shown below. School of Medicine faculty and students with questions about the graduate faculty appointment process, or seeking to secure an appointment as a member of the graduate faculty, should contact Dr. Jennie McGuire (Jennie.McGuire@wakehealth.edu).

Faculty Representatives: University Senate

Graça Almeida-Porada	WF Inst for Regen Medicine	galmeida@wakehealth.edu	2018-22
Ana Itlis	Philosophy	iltisas@wfu.edu	2017-21

Faculty Representatives: Committee on Academic Freedom and Responsibility

Miriam Ashley-Ross	Biology	rossma@wfu.edu	2020-22
Michael Nader	Physiology and Pharmacology	mnader@wakehealth.edu	2020-22

Faculty Liaisons for Faculty Grievances

Alan Brown	Education	brownma@wfu.edu	2018-21
Ben Rowland	Neurobiology and Anatomy	browland@wakehealth.edu	2018-21

Faculty Liaisons for Graduate Student Grievances

Debbie Newsome	Counseling	newsomdw@wfu.edu	2019-22
Timothy Howard	Biochemistry and Mol Biology	howardt@wakehealth.edu	2019-22

The Honor Council

Suspected academic misconduct may be reported to any honor council member.

School of Medicine faculty representatives (3-year appointments)

Name	Graduate Program	Email	Expires
Rong Chen	Integr Physiol & Pharmacology	rchen@wakehealth.edu	2021
Ken Kishida*	Neuroscience	kkishida@wakehealth.edu	2021
Carl Langefeld	Molecular Genetics & Genom	clangefe@wakehealth.edu	2021
Matt Quinn	Comparative Medicine	mquinn@wakehealth.edu	2021
Anna Snavely	Transl & Health Sys Science	asnavely@wakehealth.edu	2021
David Soto Pantoja	Cancer Biology	dsotopan@wakehealth.edu	2021
Jill Urban	Biomedical Engineering	jurban@wakehealth.edu	2021
Raghu Yammani	Mol Med & Transl Science	ryammani@wakehealth.edu	2021

Reynolda faculty representatives (3-year appointments)

Name	Graduate Program	Email	Expires
Kenneth Berenhaut	Math & Statistics	bernhks@wfu.edu	2021
Daniel Canas	Computer Science	canas@wfu.edu	2021

Mary Foskett†	Religious Studies	foskettm@wfu.edu	2021
Elizabeth Gandolfo	Divinity	gandoleo@wfu.edu	2021
Barry Maine	English	maine@wfu.edu	2021
Donal Mulcahy	Education	mulcahde@wfu.edu	2021
Jennifer Rogers	Counseling	rogersjl@wfu.edu	2021
Fred Salsbury	Physics	salsbufr@wfu.edu	2021

School of Medicine student representatives (3-YEAR APPOINTMENTS)

Name	Graduate Program	Email	Expires
Austin Arrigo	Molec & Cellul Biosci	aarrigo@wakehealth.edu	2021
Lanazha Belfield	Mol Med & Transl Science	lbelfiel@wakehealth.edu	2021
Andrew Bray	Microbiol & Immunol	anbray@wakehealth.edu	2021
Amber Brooks	Transl & Health Sys Science	akbrooks@wakehealth.edu	2021
Josh Copus	Biomedical Engineering	jcopus@wakehealth.edu	2021
David De La Cerda	Molecular Genetics & Genom	ddelacer@wakehealth.edu	2021
Steven Forsythe	Cancer Biology	sforsyth@wakehealth.edu	2021
Julia Garcia-Vargas	Biomedical Science (Pre-health)	jgarciav@wakehealth.edu	2021
Patrick Shultz	Biomedical Science (Research)	pshultz@wakehealth.edu	2021
Sarah Sizer	Integr Physiol & Pharmacology	ssizer@wakehealth.edu	2021
Brandi Taylor	Health Disp in Neur-rel Disor	bctaylor@wakehealth.edu	2021

Reynolda student representatives (3-YEAR APPOINTMENTS)

Name	Graduate Program	Email	Expires
Mallory Allred	Liberal Arts Studies	allredmk@wfu.edu	2021
Davita DesRoches	Divinity	dedesrd18@wfu.edu	2021
Bridget Fitzgerald	Documentary Film	fitzbm17@wfu.edu	2021
Norman Fraley	Chemistry	franlne13@wfu.edu	2021
Jessie Hatcher	Sustainability	hatchcjd19@wfu.edu	2021
Jenny Howard	Biology	howajl14@wfu.edu	2021
Christopher Jackson	Communication	jackcj18@wfu.edu	2021
Julianne Key	Psychology	keyjh18@wfu.edu	2021
Andrew Murphy	Education	murpam19@wfu.edu	2021
Luis Pamerin	Interpret & Transl Studies	pamla18@wfu.edu	2021
Spencer Silver	Religious Studies	silvss18@wfu.edu	2021
John Talbot	Bioethics	talbjh18@wfu.edu	2021
Marshall Tate	Counseling	tatem19@wfu.edu	2021
Meara Waxman	English	wasmm19@wfu.edu	2021
Brian White	Math & Statistics	whitbn18@wfu.edu	2021
Patrick Williams	Computer Science	willpj18@wfu.edu	2021
Halle Wright	Health & Exercise Science	wrigh18@wfu.edu	2021
Andrew Zeidell	Physics	zeidam15@wfu.edu	2021

**Serving as Chair for the current academic year.*
†*Serving as Secretary for the current academic year.*

Procedures

All students are responsible for familiarizing themselves with the portions of this bulletin that pertain to their course of study. Procedures are subject to updates at any time within the student's term of enrollment.

ADMISSIONS

How to Apply

Information on the process of applying to a Wake Forest biomedical graduate program, as well as a link to the online application may be found on the School of Medicine's website at https://school.wakehealth.edu/Education-and-Training/Graduate-Programs/How-to-Apply.

Eligibility

Undergraduate seniors and graduates of accredited U.S. colleges and universities or recognized foreign institutions may apply for admission into a graduate program of study. Undergraduates must complete their degree requirements prior to entering the Graduate School. The Graduate School also accepts applications from holders of the MD, DDS, or DVM degrees, or from candidates for these degrees who will have satisfactorily completed the prescribed medical curriculum prior to matriculation in the Graduate School.

Whatever their previous academic training may have been, all applicants should have superior records. This requirement is usually interpreted as at least a B average or standing in the upper quarter of the class or both.

Students with Disabilities

Wake Forest University will consider the application of any qualified student, regardless of disability, on the basis of the selection criteria established by the University which includes personal and academic merit. Upon matriculation, all students will be required to meet the same standards for graduation.

The University endeavors to provide facilities which are in compliance with all laws and regulations regarding access for individuals with disabilities. Additionally, special services are available to reasonably accommodate students with disabilities. For more information on assistance for graduate students, please contact the Learning Assistance Center at 336-758-5929 or lacds@wfu.edu, or consult their student portal/website at https://lac.wfu.edu to establish an account that allow the student to request an accommodation.

Any graduate student may request a disability accommodation provided that the accommodation is reasonable and does not compromise the standards of their graduate program. Accommodations are not approved retroactively, so students are encouraged to request accommodations prior to or at the beginning of the academic term in which an accommodation is desired. The Graduate School also considers granting other

academic accommodations, e.g., religious accommodations, through the Graduate School office. Biomedical graduate students should contact the Curriculum & Outcomes Manager to request a non-disability, academic accommodation.

Admission Categories

Regular Status in a Degree Program. A person with a superior undergraduate record (at least a B average or upper quarter of the class and with the appropriate courses), TOEFL or IELTS scores (for international students), strong recommendations, and otherwise meet the graduate program's admission criteria, may apply for regular admission.

Provisional Status in a Degree Program. Provisional admission may be granted in certain circumstances and is limited to not more than 1 term of full time study or its equivalent in part-time study.

Unclassified Non-Degree Graduate Status. Applicants seeking to enroll in, or audit, biomedical graduate program coursework for credit, but not wishing to formally seek a graduate degree, may apply to take graduate coursework as an unclassified or non-degree seeking student. Applicants are required to complete an application, submit the application fee, meet the School of Medicine's onboarding requirements, and submit an official transcript showing a baccalaureate degree at least one month prior to enrollment. Instructor approval is required for each course prior to enrollment.

Classification of Admitted Students

The Graduate School's classifications are driven by our policy on continuous enrollment, which can be reviewed in the Student Handbook for students on the School of Medicine campus.

Full-Time Status. A student who devotes full-time effort to a graduate program as outlined by his or her faculty committee and is in full-time geographic residence with a minimum of 9 credit hours of coursework in fall and spring terms, including thesis research, is considered a full-time student. During summer terms, 6 credit hours of coursework is considered full-time. Students registered as “Thesis Only” or “Graduate Fee” are considered full-time. Half-time status is defined as 5 hours in fall/spring terms and 3 hours in summer terms.

Part-Time Status. A student registered for less than the required number of hours to be considered full-time is considered a part-time student. Each program will determine whether it is possible to pursue a degree on a part-time basis.

Graduate students enrolled as part-time students are required to register for at least one course or 3 research/project/internship hours in fall and spring terms. Graduate students enrolled for full-time or part-time study are entitled to full privileges regarding libraries and laboratories, and may have access to Reynolda campus extra-curriculum activities. While biomedical graduate students are expected to register in every term, as outlined in our policy on continuous enrollment, part-time students may choose not to enroll in the summer term without taking a leave of absence.

Switching Between Full-Time and Part-Time Status. Graduate students wishing to switch from full-time to part-time status or vice versa may do so by request. Students should consult with their program director about the viability of their desired enrollment classification. Once the student has obtained permission to switch from full-time to part-time, or vice versa, the request should be directed to the Director of the Graduate School.

COST OF ATTENDANCE

Detailed Cost of Attendance is available on the School of Medicine's website: http://www.wakehealth.edu/School/Financial-Aid/Graduate/Cost-of-Attendance.htm.

Tuition Schedule

Summer Term 2021

- Full-time students (minimum 6 hours)	$1,560
- Part-time students (no minimum)	$1,560/credit hour

Fall 2021/Spring 2022 Terms

- Full-time students (minimum 9 hours)	$38,650
- Part-time students (no minimum)	$1,560/credit hour

All Terms

- On-line degree program students	$1,560/credit hour

Fee Schedule

Application fee	$100
Audit fee	$150/credit hour
Thesis-only (administrative)	$150/term
Graduate fee (administrative)	$175/term
Late registration fee	$40/term

The statements concerning expenses are given as information to prospective students. They should not be regarded as forming an irrevocable contract between the student and the University. The costs of instruction and other services outlined here are those in effect on the date this material was printed. Wake Forest University may change the cost of instruction, fee schedule, and other services at any time during the student's term of enrollment.

Tuition Concession

The School of Medicine offers a tuition concession benefit to some Baptist Health staff members. If the Graduate School offers a faculty or staff member a scholarship, that scholarship is designated for tuition and the tuition concession benefit will be applied to net remaining tuition and fees after the tuition scholarship has been applied. For further information, contact the Benefits office.

Tuition for Courses Taken in Reynolda campus-based graduate programs

During fall and spring terms, full-time graduate students may, with the permission of the course director, take graduate courses on the Reynolda campus without additional tuition. During the summer term, full-time graduate students wishing to take a course on the Reynolda campus are charged tuition consistent with Reynolda's tuition fees.

Student Graduate Fees

All students pay the graduate fee shown in the fee schedule during the term in which the student files an intent to graduate form. This is a non-refundable fee and is charged once per degree.

Past Due Balances

Consistent with the policy on Student Payments, which can be reviewed in the Student Handbook for students on the School of Medicine campus, a student carrying a past-due balance will be restricted from:

- Registering for future academic terms
- Receiving an official transcript of academic record
- Having academic credits certified
- Receiving regalia and participating in the Hooding ceremony
- Receiving a diploma at graduation
- Returning from leave of absence
- Being reinstated as a student

In addition, a student with a past-due balance may be subject to having their:

- Current course load cancelled
- Access to parking and facilities eliminated
- Their stipend held, if applicable

A long standing past due balance will result in administrative withdrawal from the Graduate School. If the University deems it necessary to engage the services of a collection agency or attorney to collect or to settle any dispute in connection with an unpaid balance on a student account, the student will be liable for all attorney's fees, reasonable expenses, and costs incurred.

Students expecting tuition or fee payments from a third party should contact the Bursar to ask for an invoice to be sent to the third party source. Students using Veteran's Affairs (VA) education benefits should refer to eligibility and payment requirements at https://school.wakehealth.edu/Education-and-Training/Student-Records/Veteran-Certification.

Tuition Refunds Due to Withdrawal

A student who withdraws from the University during a term or who drops a course before completing it may be entitled to a refund. It is important to note that a withdrawal/course drop may affect financial aid eligibility. Graduate students who wish to explore a tuition refund should refer to the Refund of Tuition and Fees Policy, which includes the Schedule of Adjustments for Withdrawal, as found in the Student Handbook for students on the School of Medicine campus.

A student using scholarships, grants, or loans to help pay educational expenses, whose account was paid-in-full prior to withdrawal, is likely to owe the University after withdrawal. Return of Title IV funds are handled in accordance with federal law. Please refer to the Return of Financial Aid Funds Policy. Students should consult the Office of Financial Aid for more information.

FINANCIAL AID

Financial support for students may be provided from a combination of sources, including Dean's fellowships, graduate fellowships, and tuition scholarships. In addition, many students are supported as graduate research assistants or associates from externally funded sources, typically from federal grants. Fellowships often include some form of tuition scholarship. Students should consult their offer letter for details on awards offered.

Satisfactory Academic Progress

To determine continuing financial aid eligibility, the Office of Student Records evaluates the student's satisfactory academic progress at the end of each term. The receipt of federally- controlled aid requires half- time enrollment, defined as 5 or more hours in fall and spring terms and 3 or more hours in summer terms. In addition to the enrollment requirements, a minimum cumulative grade point average of 2.5 is required. Certain programs have higher academic requirements, which are communicated directly to students by their graduate program. The Dean may revoke institutionally- controlled financial aid for violation of University regulations, including its Honor Code or Non-Academic Code of Conduct policies, or for violation of federal, state, or local laws. For additional information, students may review the Policy on Satisfactory Academic Progress for Financial Aid Eligibility in the Student Handbook for students on the School of Medicine campus.

Should a student fail to meet the requirements described in the policy statement, the Graduate School will notify the student in writing of their status.

Graduation At-Risk Status

Any graduate student who, at the end of a term, has a GPA between 2.5 and 3.0 will receive a letter from the Graduate School that specifies that they will need to take additional graded coursework in order to raise their GPA to the minimum requirement for graduation. At-risk status does not confer any change in federal financial aid eligibility.

Academic Probation

Any student who, at the end of term, has a GPA below 2.5 or has received a Unsatisfactory (U) grade in research, project, or internship courses will receive a letter from the Graduate School that specifies that they are on academic probation and will need to either take additional graded coursework in order to raise their GPA to the minimum requirement for graduation or remedy the unsatisfactory research grade. Students on academic probation are placed on financial aid warning for one term and

remain eligible to receive federal aid during that term. If, at the end of the probationary term, the student has not re-established satisfactory academic standing, the student will become ineligible for federal financial aid and may be dismissed or withdrawn from Graduate School.

Appeal to Financial Aid Ineligibility Status

The Dean may grant a one-term probationary reinstatement of financial aid to any student who can demonstrate extenuating circumstances and appropriate documentation of those circumstances. At the end of this term, the student is re-evaluated for satisfactory academic progress.

Student Loans

Graduate students may contact the Office of Financial Aid for information on federal student loans by phone: 336-716-4264; email: finaid@wakehealth.edu; or in-person at the Bowman Gray Center for Medical Education, 1st floor, Enrollment Services, Monday-Friday, 7:30 AM - 4:30 PM.

The financial aid team contacts all students annually to remind them to complete a Free Application for Federal Student Aid (FAFSA). Students who need to complete a FAFSA in order to apply for financial aid should use the school code E00524. The team also maintains a Canvas resource that includes an orientation to provided services and a set of useful links to financial resources.

A student must be enrolled more than half-time in each term and must be in good academic standing/making satisfactory academic progress toward the degree to be eligible for a student loan. Unclassified (non-degree seeking), certificate program students, and provisionally accepted students are not eligible for federal financial aid.

Graduate School Scholarship Awards

A limited number of merit-based scholarships are available for highly qualified students. Any student interested in the awards listed below should contact their program director for additional information.

- *Gordon A. Melson Outstanding Doctoral and Master's Student Awards* provides a cash award to the students selected as being most outstanding in research, productivity, and quality in the PhD and MS programs at the time of commencement each year. Other factors which are considered are academic record, activity in the discipline, as well as university and departmental citizenship.
- *The Louis Argenta Physician-Scientists Scholar Award Scholarship* seeks to develop leaders in translational science by providing funds to support MD/PhD students during their research years. The new calling for the physician-scientist is to lead these diverse teams. This scholarship will be awarded to MD/PhD students that have outstanding interpersonal skills, superior communication, and the potential to develop into a leader in translational science.
- *The Norman M. Sulkin Scholarship Fund* provides scholarship assistance to a student conducting research in the area of in the neurobiology and anatomy.

- *The Camillo Artom Scholarship* provides annual scholarship grants to one or more students enrolled in programs leading to the MD or PhD degrees with special preference given to students seeking a degree in biochemistry and molecular biology.
- *Herbert C. Cheung PhD Award* provides a cash award to recognize an outstanding graduate student in the Department of Biochemistry and to promote excellence in research in the broad field of biochemistry.
- *The Sandy Lee Cowgill Memorial Scholarship Fund* provides scholarships to at least two students, the first of whom shall be enrolled in the MD program and the second of whom may be enrolled in the MD or PhD program, with preference given to a student in biochemistry and molecular biology.
- *The Mike and Lucy Robbins Fellowship Fund* provides a stipend for a current graduate student conducting cancer-related research.
- *The David K Sundberg Award* provides a cash award to recognize a PhD student with outstanding academic proficiency and professionalism as well as exemplary character as citizens and colleagues in the Department of Physiology & Pharmacology.

ACADEMIC & COURSEWORK PRACTICES

Statement on Student Rights and Responsibilities

The graduate faculty has adopted a formal statement regarding student rights and responsibilities. The statement is a guideline to be used by students with respect to an Honor Code which applies to both teaching and research endeavors. It also includes clearly defined procedures for the handling of student grievances should they arise. These policies may be reviewed in full in the Student Handbook for students on the School of Medicine campus.

Honor Code & Non-Academic Code of Conduct

The graduate faculty has adopted a formal Honor Code and a Non-Academic Code of Conduct policy to provide guidance for student conduct with respect to both academic and non-academic pursuits. These policies may be reviewed in full in the Student Handbook for students on the School of Medicine campus.

Grievance Procedures

Faculty are appointed as liaisons on both campuses to serve as resources to both faculty or students who seek to file a grievance. Graduate students interested in filing a grievance are also encouraged to speak with the chair(s) of the Graduate Student Association or other of its officers to seek advice regarding the grievance procedure. The name and e-mail address for the faculty liaisons and GSA co-chairs may be obtained from the Graduate School office or on the Graduate Student Canvas Resource page.

Non-Academic Grievance Procedures

If a student wishes to file a non-academic grievance, ie, mistreatment in the form of discrimination (on the basis of sex, sexual orientation, gender identity, and gender expression), harassment, physical harm/violence, or general misconduct or unprofessional behavior, these matters should be referred to the Student Advocate in the School of Medicine's Student Affairs office. The Student Advocate will help ensure that other appropriate parties, e.g., Employee Relations or the Title IX office, are appropriately engaged or notified. Students who have experienced gender-based or sexual misconduct may report that misconduct directly to the Title IX office.

Academic Grievance Procedures

1. Initial Response to Perceived Academic Grievance: Situations may arise in which a student believes that he or she has not received fair treatment from a faculty member in an academic matter. In such cases, within two weeks of the student's awareness of the treatment he or she should talk with the faculty member. If the student and faculty member cannot resolve the problem, the student should consult his or her advisor, and their Program Director. If a resolution satisfactory to both parties cannot be reached in a reasonable time, which can vary according to the complexity of the matter, the student may choose to initiate the Graduate Student Academic Grievance Procedure. Initiation of the procedure must be no later than three months after failure to achieve resolution within the program. Failure to initiate the procedure within three months forfeits the student's right to file a grievance with the Graduate School.

2. Liaisons for Student Grievances: The student should first contact either of the two WFU graduate faculty members, one from the School of Medicine Campus and one from the Reynolda Campus, who serve as liaisons for graduate students wishing to file a grievance. The faculty liaisons, who serve a three-year term, are appointed by the Dean of the Graduate School from two candidates from each campus nominated by the Graduate Student Association. They serve as counsel for the student, and are available to advise the student concerning academic problems and grievances and to help the student initiate and continue with the grievance procedure. At the student's request, a faculty liaison may be present during any hearings by the Grievance Committee in order to monitor the proceedings and to insure fair treatment of the student. Graduate students interested in filing a grievance are also encouraged to speak with the chair(s) of the Graduate Student Association or other of its officers to seek advice regarding the grievance procedure. Names and email addresses of the faculty liaisons and GSA co-chairs can be obtained from the Graduate School office.

3. Written Petition: After consulting a Faculty Liaison, the student should submit to the Dean of the Graduate School a written petition requesting initiation of the Graduate Student Academic Grievance Procedure. The petition must include the name of the faculty member against whom the grievance is filed, the specific charge, information about the grievance, and the action or relief requested by the student. If appropriate at this time, documentary material may be submitted in support of the grievance, although such material may be reserved until requested by the Chair of the Grievance Committee. At the time the grievance is submitted, the Dean of the Graduate School shall confer

with the student to ensure that the student has spoken with the faculty member involved, gone through the program's grievance procedure, and contacted a Faculty Liaison.

4. Grievance Committee: Upon receiving a grievance petition, the Dean of the Graduate School shall appoint a five member Grievance Committee composed as follows: a Chair who is a member of the Graduate Council; two faculty members from the graduate faculty at large; and two graduate students selected from a list provided by the Graduate Student Association. Both the student filing the grievance and the faculty member against whom it is filed shall be informed of the names of all members of the Grievance Committee. In appointing members of the Grievance Committee, the Dean of the Graduate School will ensure that no conflict of interest will occur. A new committee shall be appointed for each grievance.

5. Grievance Procedure: The Dean of the Graduate School will forward copies of the grievance petition to the Grievance Committee, the Faculty Liaison with whom the student has consulted, and the faculty member against whom the grievance is filed. The faculty member will then have fourteen days to respond in writing to the grievance. This response will be returned to the Dean of the Graduate School, who will forward copies to the Grievance Committee, the Faculty Liaison, and the student filing the grievance. Within fourteen days of receiving the faculty member's response to the grievance, the Chair shall convene the Grievance Committee to review the charges, to determine if more information and documentation are needed, and to plan and schedule the Grievance Hearing. The Hearing shall be scheduled no sooner than fourteen days but no later than twenty-eight days after the initial committee meeting. The Chair of the Grievance Committee shall ask the parties involved to submit to the Graduate School any further documentation. In addition, each party will submit a list of witnesses who will appear at the Hearing in support of their position, with a one sentence summary of the information each witness will present. All documentation and the list of witnesses must be submitted at least seven school days prior to the scheduled Hearing. After that time, no additional material or witnesses may be introduced or presented, unless of a compelling nature relevant to either the student or faculty member. In such cases the Chair of the Grievance Committee may allow the additional material or witnesses. The Graduate School shall insure that each committee member and both parties involved receive copies of all material and a list of witnesses at least five school days before the scheduled Hearing, and immediately if additional material or witnesses are allowed.

6. Grievance Hearing: The Chair shall preside over the Grievance Hearing, and will vote only to break tie votes of the Grievance Committee. All voting shall be done by secret written ballot. All proceedings during the Hearing shall be recorded on equipment provided by the Graduate School. At all times during the Hearing, the student may have the Faculty Liaison present, and both parties may be represented by legal counsel or another representative.

The purpose of the Hearing is to obtain information which the Grievance Committee can use to make a final evaluation and recommendation to the Dean of the Graduate School.

At all times the Chair of the Grievance Committee shall maintain a civil, reasonable atmosphere. The Hearing shall proceed in the following manner. First the student who filed the grievance, or a representative, will be given the opportunity to discuss the grievance and to review the documentation submitted by both parties, including the response by the faculty member to the grievance. The faculty member, or representative, will then have the opportunity to ask questions of the student, after which any or all members of the Grievance Committee may ask questions. The student may then present witnesses, who can be asked questions by the faculty member and the Grievance Committee. When the student has presented all of his or her material and witnesses, the faculty member, or representative, will be given the opportunity to discuss the grievance and to review the documentation submitted by both parties, including the original grievance petition. The student, or representative, may then ask questions, followed by questions from the Grievance Committee. The faculty member may then present witnesses, who can be asked questions by the student and the Grievance Committee. Reasonable variations of this general procedure may be allowed by the Chair of the Grievance Committee. During the Hearing witnesses will be present only while they are giving information to the Hearing and being asked questions. They will wait outside the hearing room until called by the Grievance Committee, and leave the Hearing after they have spoken. If at any time during the Hearing either side, in the opinion of the Chair, in any way violates civil, reasonable conduct, the Chair may recess the Hearing for ten minutes. If such behavior continues, the Chair may postpone the Hearing for a maximum of one week.

After all material and witnesses have been presented by both sides, the faculty member and then the student, or their representatives, may make a concluding summary statement, touching on all matters they consider relevant to the grievance as filed. Following the student's summary statement, the Hearing will adjourn and the Grievance Committee shall deliberate.

The Grievance Procedure may be stopped at any time upon request of the student to withdraw the grievance. Once withdrawn, that grievance cannot be reactivated. The grievance procedure may be postponed only if either party has an emergency that prevents their preparing for or appearing at a Hearing. The party with the emergency must notify the Chair of the Grievance Committee, with documentation of the nature of the emergency, as soon as possible, and the Chair will determine if a postponement is justified.

7. Recommendation to the Dean of the Graduate School: Within three days after completion of the Grievance Hearing, the Grievance Committee will make a recommendation which will be sent in writing to both parties and to the Dean of the Graduate School.

8. Decision by the Dean of the Graduate School: From the time the recommendation is received by the involved parties and the Dean of the Graduate School, either party will have five days to appeal to the Dean of the Graduate School, in writing, the recommendation of the Grievance Committee. Within two weeks after receiving the

recommendation, the Dean of the Graduate School will make a decision and provide a written explanation of the reasons for the decision to the Chair of the Grievance Committee and to the parties involved. The Dean of the Graduate School will also convey the decision to the Program Director involved. The decision of the Dean of the Graduate School is final.

9. Records: All material related to the Grievance Hearing, including tapes of all sessions, shall be placed on confidential file in the Graduate School office for two years. After that time, all material except the written decision of the Dean of the Graduate School shall be destroyed.

10. Flow Chart: A chart that summarizes the Graduate Student Academic Grievance Procedure may be found in the Canvas All Graduate Student Resource.

REGISTRATION PRACTICES

Term Registration

Late Registration. A continuing student who fails to register for any courses by the first day of classes will be charged a late registration fee.

Course Registration

Repeating a Course. A graduate student may repeat a course in which a B- or lower grade has been received. The course may be counted only one time for credit. The higher grade earned will be factored into the calculation of grade point average. Both grades will appear on the transcript, but it will be noted as to which grade is included in the GPA calculation. In addition, federal financial aid rules dictate that federal aid can only be used twice for the same graded course.

Dropping a Course. During the Add/Drop period, a student may drop a course without penalty or notation on the transcript. After the Add/Drop period, a student may drop a course with the approval of the Dean or Director of the Graduate School with the agreement of the course director. The student is assigned a Drop (DRP). Courses marked Drop are not counted in determining the grade point average. Students should reach out to Student Records to request a course drop. Students are responsible for officially dropping courses to be eligible for a refund of tuition. Nonpayment for classes for which a student is registered or non-attendance in a registered class does not release the student from financial obligation, nor does it result in a withdrawal from the course.

Auditing a Course. Auditing a course consists of participation in a course without receiving a letter grade or credit hours. When space is available after registration of students enrolled for credit, others may request permission of the course director to enter the course as auditors. In no case may anyone register to audit a course before the first meeting of the class. No additional charge is made to full-time students in the Graduate School of Arts and Sciences; for unclassified or non-degree seeking students, an audit fee is assessed. An auditor is subject to attendance regulations and to other requirements of performance established by the course director. Although an auditor

receives no credit, a notation of audit is made on the final grade report and entered on the record of enrolled students who have met the course director's requirements.

Registering for a Course Offered on the Reynolda Campus. Graduate students are permitted to take graduate coursework offered by Reynolda campus-based programs of study for no additional tuition fee in fall and spring terms. Students may review the course schedule at Reynolda by accessing the link on the Canvas All Graduate Student Resource Page. In order to register, the student must contact the course director on the Reynolda campus and request a seat in the course. Once the student has obtained permission, the student should contact student records. Student records will ensure that registration is completed on behalf of the student and that the course and grade will appear on the transcript. Registration in summer term courses may be possible, however, there is an additional tuition fee that will be due from the student. Registration in undergraduate coursework on the Reynolda campus may also result in an additional tuition fee that will be due to the Reynolda campus.

Transfer of Credit. Transfer of graduate credits earned at other universities. A course that was completed at another college or university may be considered for transfer by a Master's program within the Wake Forest University Graduate School, provided that: a) the course was taken at an accredited institution in the United States; b) the course is classified as a graduate course; c) the course was not taken as part of a previous earned degree at another institution; d) the grade in the course is B (or the equivalent thereof as determined by the Graduate School) or better. The maximum number of hours that may be transferred toward a Master's degree within the Graduate School from another college or university may not exceed one-third of the total credits required by the program. Transfer of courses from another college or university for PhD degree candidates are held to the same standards for transfer credits, but are not limited in terms of the count of credit hours. International students wishing to transfer credits are responsible for having their transcript evaluated by World Educational Services (WES), and are to have the evaluation sent directly to Student Records.

Transfer of graduate credits earned while enrolled in a previous graduate degree program at Wake Forest University. A graduate course that was completed while the student was enrolled previously in another graduate or professional program at Wake Forest University may be considered for transfer by a program within the Wake Forest University Graduate School, provided that the course was not counted toward the first degree and a grade of B (or the equivalent thereof as determined by the Graduate School) or better was earned. The maximum number of hours that may be transferred to a Master's degree within the Graduate School from a different program within the University may not exceed two-thirds of the total credit hour requirement of the accepting program.

Students seeking to follow their mentor and enroll at Wake Forest. A student seeking to follow their mentor from another institution and enroll in the Wake Forest Graduate School must apply to the Graduate School using standard application processes. The student may be accepted as a Wake Forest student and credits may be transferred if the

criteria described for the Transfer of Credits Earned at Other Universities are met, and if the student has not yet advanced to candidacy. A student who has advanced to candidacy prior to following their mentor to Wake Forest should remain a student at their current institution.

Grading Practices

Records of progress are kept by the institution on all students enrolled. Grade reports are furnished to students at the end of each term.

Grade of I. The grade of I (Incomplete) may be assigned only when a student fails to complete the work of a course because of illness or some other emergency. If the work recorded as I is not completed within thirty days after the beginning of the student's next enrolled term, the grade automatically becomes F or Unsatisfactory. The instructor must report the final grade to the registrar within forty-five days after the beginning of the student's next enrolled term. In no case is a graduate degree awarded to a student who has an I on record. Incomplete grade forms are available on the Graduate School website.

Grade of NR. The grade of NR (Not Reported) must be resolved within forty-five days after the beginning of the student's next enrolled term or the grade automatically becomes F or Unsatisfactory. In no case is a graduate degree awarded to a student who has an NR on record.

Grade of U (Unsatisfactory) in Thesis/Dissertation Research/Capstone Project/Internship. A student who receives a U in one of these courses may be placed on academic probation even if the student's cumulative GPA is above 2.5. A student who receives a grade of U in one of these courses in two terms may be dismissed from the Graduate School by the Dean upon recommendation of the program.

Minimum Grade Requirements. A student whose cumulative grade point average (GPA) falls below 2.5, or below the program's GPA standard, may be placed on academic probation. The student will have one academic term to bring his/her GPA to 2.5 or greater; otherwise, the student may be dismissed from the Graduate School by the Dean upon the recommendation of the program. The grade point average is obtained by dividing the total number of grade points earned by the total number of hours attempted for a grade, including hours for courses in which the grade is F. Satisfactory/unsatisfactory grades do not factor into the GPA calculation.

Grades Assigned		Grade Points
A	Excellent	4.00
A-		3.67
B+		3.33
B	Good	3.00
B-		2.67

C+		2.33
C	Low Pass	2.00
F	Failed (counted as hours attempted)	
I	Incomplete (becomes passing grade, F, or U)	
S	Satisfactory	
U	Unsatisfactory	
AUD	Audit	
DRP	Official Drop (not counted as hours attempted)	
NC	No credit	
NR	Grade not reported (becomes passing grade, F, or U)	
RPT	Course repeated (see repeating a course)	
WD	Withdrew (not counted as hours attempted)	
WP	Withdrew passing (not counted as hours attempted)	
WF	Withdrew failing (not counted as hours attempted)	

Individual programs may require a higher grade point average than 2.5 for ongoing enrollment. If there is such a requirement, it is stated in the program's policies. A student may be dismissed from the Graduate School by the Dean upon recommendation of the program if the student is failing to make adequate progress. Adequate progress is determined by the standards of the program in which the student is enrolled.

The minimum grade point average required for graduation is 3.0. PhD candidates must have a grade point average of 3.0 in graduate courses at the time of the preliminary examination. A 3.0 grade point average is also required to earn a graduate certificate.

Changes in Status

Leave of Absence. A leave of absence allows a student enrolled in the Wake Forest University Graduate School of Arts and Sciences to interrupt his or her studies for a compelling reason, for example, a medical condition or a personal or family matter requiring absence from campus. A leave of absence is defined as a temporary separation from the Graduate School. To be eligible for a leave of absence, students should be in good academic standing, fulfilling research, service and course obligations.

Students who intend to take a leave of absence must submit a Request for a Leave of Absence form to the appropriate Office of the Dean of the Graduate School of Arts and Sciences. A letter of support should be provided to the Dean, co-signed by the student's graduate program director and advisor. This letter must indicate all unsatisfied degree requirements for the student. If available, other supporting letters should be included in the request for a Leave of Absence.

Until students are notified by the Office of the Dean that the leave has been approved, they remain registered and are expected to fulfill their responsibilities. A Leave of Absence will not be granted retroactively. The maximum time for a leave of absence is one year. The effective date of a Leave of Absence might take into account a reasonable time to arrange for the suspension or completion of ongoing experiments and projects, and proper withdrawal from courses.

Students on leave of absence should submit a request to return to the appropriate Dean at least one month prior to the first date of the term in which a return is planned. This request may require a letter which addresses the suitability of the student's return. Students who have decided not to return from a leave of absence should inform the appropriate Dean of the Graduate School of Arts and Sciences in writing. Students who fail to petition to return after a leave of absence will be withdrawn from The Graduate School of Arts and Sciences and need to apply for readmission in order to return.

Unless allowed by the external funding agency or source supporting the student's stipend, a student may not qualify for stipend support during a Leave of Absence. In all cases, the guidelines provided by the supporting agency will apply. Since these guidelines may vary from one agency to another, students are encouraged to consult agency program officials to determine the agency specific guidelines governing leaves of absence. If the student's stipend is supported by internal funds, the Dean might be able to provide limited stipend support during a Leave of Absence.

If applicable, tuition is refunded on a prorated basis, and the refund schedule is set by the Wake Forest University Board of Trustees.

Approved leaves of absence automatically extend milestone deadlines by the length of the leave. This includes university and departmental requirements such as the qualifying exam deadline and prospectus deadline for PhD students, and the degree deadline for Master's and PhD students. Leaves of absence do not exempt students from meeting the residency requirement or other Graduate School degree requirements.

Students on a leave of absence may not fulfill any degree requirements during the time on leave. If a student plans to be away from the University to work on a thesis, dissertation, or other degree requirements, this does not constitute a leave of absence and requires enrollment.

A student on a leave of absence will have limited access to University facilities normally available to enrolled students. In order to facilitate communication between the student and the Graduate School, access to the campus network will be continued during the leave, but will be deactivated if the student does not return. Library access will be continued during the period of leave, but will be revoked if the student does not return. Badge access will be deactivated during the period of leave.

Students who are granted a Leave of Absence must consult with their health insurance provider about the status of their policy while on leave. Students who have contracted for health insurance through the university should immediately contact the

Student Health Insurance Coordinator. Health insurance is subject to federal and state laws and regulations.

International students who are granted a Leave of Absence must notify either the Office of Global Studies on the Reynolda Campus or the Office of International Studies on the Medical School Campus. Visa status is subject to federal laws and regulations.

Students on an approved leave of absence are not eligible for federal financial aid, including Federal Direct Loans. In some cases, student loans may not be deferred for the entirety of a leave. Students should contact Student Financial Services on the Reynolda Campus or the Office for Student Aid on the Medical School Campus for additional information.

Transferring to a Different Program. A student who wishes to transfer from one program to another are allowed to do so provided the standards of the new program are met. The student should contact the program director of the program to which the student wishes to transfer. After consultation with the program director, the student should interview with one or more prospective advisors. If a prospective advisor is identified, the student's transfer request may be considered further.

Upon receipt of a written request from the student, the Graduate School will forward credentials from the student's file to the program director for evaluation and consideration of financial aid. At the conclusion of this process, the program director sends a transfer recommendation to the Dean of the Graduate School for approval. The student is not required to withdraw from an existing program until the transfer request to the new program has been approved.

It is understood that the program from which the student is transferring would have no further financial responsibility for the student. The student must, however, complete the formal process of withdrawing from the original program by the end of the current term.

Accommodation for Students of Faculty Who Leave the Institution. In the case where a student has advanced to candidacy, and their faculty advisor leaves the institution prior to completion of the degree by his or her student(s), the Dissertation Committee (or Program Director) is responsible for recommending an appropriate plan for the completion of the degree. The plan should address the following: support of stipend and research funding (including lab space), designation of a primary mentor, and designation of a manager to carry out the plan. This plan must be submitted within six weeks of the faculty member's resignation and approved by the Dean.

In the case where a student has advanced to candidacy and chooses to leave the institution with their faculty advisor, the student will be required to continue to register in each term for the remainder of their course of study.

In the case where a student has not yet advanced to candidacy and chooses to leave the institution with their faculty advisor, the student will be required to transfer to the new institution.

Withdrawal from the University. Students who wish to withdraw from the Graduate School must complete the appropriate form, which requires approval from the program and the Dean of the Graduate School. Students who leave without following this procedure will receive a grade of F, or U if appropriate, in each course in progress. If issued by the institution, students are required to return their laptop computers to the Academic Computing office. During the academic year, all students, full- and part-time, receive tuition refunds according to the stated schedule. This policy applies to students dropping courses as well as to those withdrawing. Withdrawals must be official and students must return all institutional materials (badges, keys, etc.) before claiming refunds. Graduate students who are recipients of Title IV federal financial aid should refer to the Return of Financial Aid Funds Policy found in the Student Handbook.

A student who withdraws by the drop date for the term, as established by the academic calendar, will not have a grade recorded for courses in progress. A student who withdraws after the drop date will be assigned a grade of withdraw-passing or withdraw-failing for each course in progress. The withdrawal date for a student enrolled in an on-line program will be determined by the last time the student participated in an online discussion or made contact with a faculty member. Simply logging in to a course is not determinative of participation in the course.

Reinstatement. A student who has withdrawn from the Graduate School and wishes to return within one academic year must request reinstatement in writing to the Dean of the Graduate School at least one month prior to the term in which they wish to re-enter. To be reinstated the student must be in good academic standing and receive approval from the graduate program and the Dean of the Graduate School. The time spent during an approved leave or while withdrawn will not count in the maximum time allotted for the degree. Students who have withdrawn from the Graduate School and who wish to re-enter after one academic year must reapply for admission as stated in the Graduate Bulletin by the application deadline, and must be recommended by the program and accepted by the Dean of the Graduate School.

If a student is approved for readmission to the Graduate School within a five-year period, previous coursework may count towards the degree requirements at the discretion of the Dean of the Graduate School on the recommendation of the program. If the student re-enters Graduate School after a five-year period, previous courses will not count toward the degree requirements.

Dismissal. A student who is failing to make satisfactory academic progress, determined on the basis of the GPA, multiple Unsatisfactory grades, or as determined by the program, may be dismissed from the Graduate School.

STUDENT WELLNESS

Health Service

Students in a graduate program administered by the Graduate office at the School of Medicine are required to have adequate and applicable hospitalization insurance. Any

charges generated that are not covered by the student's insurance policy will be the personal responsibility of the student. Students who are eligible to continue coverage under a parent's or spouse's policy may do so. As an alternative, the School of Medicine offers an affordable student health plan. The cost of this insurance is billed to the student twice a year, with charges routed through the student account. Students are required to waive out or enroll in the plan during open enrollment periods. Notification of open enrollment periods are sent by the Bursar to the student's wakehealth email address. Students who fail to either waive or enroll will be automatically enrolled in the plan and responsible for all premium costs.

Additional Insurance. Optional dental and vision insurance is offered to all students. Premiums for dental and vision are paid annually and have a single open enrollment period each year. Unlike the student health plan, students are not auto-enrolled in dental or vision coverage if they fail to waive during the open enrollment period.

Prior to matriculation, each student is required to comply with the Policy on Student Health Requirements, available in the Student Handbook, or at https://school.wakehealth.edu/-/media/WakeForest/School/Files/About-the-School-of-Medicine/Student-Health-Requirements.pdf. The student is responsible for all costs required to meet matriculation (and continuing/renewal) requirements, including any services received at Employee Health, excepting those items noted in the Student Health Requirements-Wake Forest School of Medicine policy.

Immunizations. Wake Forest University and North Carolina State law require that all new, transfer, re-admit, unclassified, or visiting students, excepting unclassified, distance education, or those with a valid exemption, submit certification of certain immunizations prior to matriculation. Documentation should be submitted through an online data portal that is provided to students during the pre-enrollment period. All documentation must be received by the term's orientation day. Acceptable documentation is (1) the signature of the appropriate official(s) having custody of the immunization records, such as a physician or county health department official, or (2) a certificate from the student's former school containing the approved dates of immunizations, or (3) photocopies of the original records. The Medical Center Employee Health Services will have the responsibility for monitoring compliance with the immunization requirements. The current Policy and the requirements therein can be reviewed at https://school.wakehealth.edu/-/media/WakeForest/School/Files/About-the-School-of-Medicine/Student-Health-Requirements.pdf.

The North Carolina requirements must be documented within thirty days following enrollment. After that time, students not compliant with required immunizations cannot attend classes until their immunizations are documented. Please note that the Hepatitis B series requires several months for completion.

Questions regarding these requirements should be directed to Employee Health Services at 336.716.4801.

In addition, accepted students to programs of study that are conducted on-campus are required to complete a criminal background check and drug screening prior to enrollment. Background checks are submitted through the same portal to which immunization records are submitted. Drug screenings are conducted during orientation day activities.

Counseling Services

Counseling & Well-being Services (CAWS) is located on the 1st floor of the Bowman Gray Center for Medical Education (Building 60N), Room 1213. Paige Bentley, PhD, MAEd., LPC-S, RYT is the Director of Counseling & Well-being Services,Ryan MacLeod, MA, LMFT is a Senior Mental Health Counselor, and Orita Ramseur, MA/MDiv, LCMHC is Outreach Coordinator. Both Dr. Bentley and Mr. MacLeod provide counseling and consultation, and oversee well-being activities to currently enrolled biomedical graduate students. All counseling and consultation services are confidential and are free of charge to students.

Counseling & Well-being Services offers counseling for a variety of concerns including depression, anxiety, personal adjustment, disordered eating, managing stress, school/life balance, sexuality, and relationship issues.

Well-being activities include activities such as yoga, mindfulness meditation, fitness, dancing, and facilitated discussions related to helping students manage demands of graduate school.

Appointments are available to students from 8 am - 5 pm, Monday-Friday. Well-being activities will be posted on the Counseling & Well-being Website Calendar. Although CWS is not a 24/7 crisis center, arrangements can be made for emergent, urgent situations. To make an appointment for counseling, please email counselingservices@wakehealth.edu. If you do not hear back from one of the counselors within two days of requesting an appointment, please contact Dr. Paige Bentley directly at pbentley@wakehealth.edu.

Requirements for Degrees

Degrees Offered

The Graduate School of Arts and Sciences offers graduate programs leading to the Master of Arts (MA), Master of Arts in Education (MAEd), Master of Arts in Human Services (MAHS), Master of Fine Arts (MFA), Master of Healthcare Leadership (MHL), Master of Science (MS), and Doctor of Philosophy (PhD) degrees. On the School of Medicine campus, the Graduate School offers the MS, MHL, and PhD degrees in select programs of study. For information on the degree requirements for all other graduate degrees (MA, MAEd, MAHS, MFA), please consult the Graduate Bulletin maintained and administered through the Reynolda campus.

The following pages contain information on the degree requirements for the MS, MHL, and PhD degrees only.

Thesis/Dissertation Committee Composition & Review Guidelines

For Master's degrees: When required by the program, a thesis is written under the supervision of the student's advisory committee. The thesis committee must have no fewer than 3 members, including:

- The student's advisor
- A second member from within the student's graduate program - co-advisors may occupy this place on the committee
- A third member from outside a) the advisor's academic department or b) the student's area of concentration who serves as the chair and represents the Graduate Council

For the PhD degree: The examining committee for the dissertation must have no fewer than 5 members, including:

- The program director, or a faculty member appointed by the program director
- The student's advisor
- A third member from within the student's graduate program - co-advisors may occupy this place on the committee
- A fourth member from a related area - this member may be drawn from inside or outside of the student's program
- A fifth member from outside a) the advisor's academic department or b) the student's area of focus who serves as the chair and represents the Graduate Council

For all degrees: All members of the student's advisory or examining committee must be members of the graduate faculty. With the approval of his or her advisor, a student may recommend a person who is not on the graduate faculty to serve on the examining committee as a voting member; however, the committee must have a minimum of two members from the graduate faculty. The thesis advisor must justify the participation of this person on the basis of research, publications, and/or professional activities in a letter to the Dean of the Graduate School requesting approval. The responsibility to confirm the committee and its members rest with the Dean of the Graduate School.

Final Examination Assessment

Requirements for thesis submission and format are posted in the student's Canvas program page in the Defense and Ballot Module. The examination verifies the work stated in the thesis and knowledge in related areas. The possible committee decision is: unconditional pass, pass upon rectifying minor deficiencies, pass upon rectifying major deficiencies, and fail. If a student fails, the student may be reexamined only once. The defense must take place by the stated graduation deadlines on the academic calendar, or the student will be required to register for a subsequent term in order to have their degree conferred.

Unconditional Pass

If all committee members agree that the student has passed unconditionally, there is consensus to pass the examination. The committee chair will sign the ballot, submit the ballot to the Graduate School, and the student shall be recommended for award of the degree.

Pass Upon Rectifying Minor Deficiencies

If minor reservations are expressed by committee members, for example, correction of typographical, grammatical, or spelling errors, the chair of the committee will ensure that the reservations are communicated to the student and the Dean of the Graduate School by signing and submitting the ballot to the Graduate School. The student and the advisor are jointly responsible for ensuring that the thesis is modified to address the committee's reservations. Once the thesis has been modified, the student passes the examination, and the student will be recommended for award of the degree.

Pass Upon Rectifying Major Deficiencies

If major reservations are expressed by committee members, for example, new data collection is required for an acceptable work, the chair of the committee will ensure that the reservations are communicated to the student and the Dean of the Graduate School by signing and submitting the ballot to the Graduate School. The student and the advisor are jointly responsible for ensuring that the thesis is modified to address the committee's reservations. Once the thesis has been modified, the student passes the examination, and the student will be recommended for award of the degree.

Fail

If, in the opinion of more than one member of the thesis committee, the student has failed the examination, there is no consensus to pass. The chair of the committee will advise the student that the thesis fails to meet the requirements of the Graduate School. The chair will ensure that the student knows the reason(s) for failure and will submit the ballot to the Graduate School. If the student resubmits or submits a new thesis for consideration by the Graduate School, at least three members for the thesis will be drawn from the original committee. If the modified or new thesis fails to meet the requirements of the Graduate School, the student shall be dismissed.

REQUIREMENTS FOR THE MASTER OF SCIENCE

The Master of Science (MS) degrees administered by the School of Medicine Graduate School office include: Addiction Research and Clinical Health, Biomedical Engineering, Biomedical Science, Clinical Research Management, Comparative Medicine, Health Disparities in Neuroscience-related Disorders, Healthcare Leadership, Molecular Medicine and Translational Science, Neuroscience, and Translational & Health System Science.

Residence Requirement

In general, a minimum of 12 months of full-time work or its equivalent in residence is required for the Master's degree (or the equivalent in Wake Forest online instruction). The total allowable time for completion of the degree must not exceed six years. Course credit may be allowed for as described in the section on coursework transfers at the discretion of the program director and Dean of the Graduate School, but the minimum residence requirement is not thereby reduced.

Course Requirements

An MS candidate must have a minimum of 30 hours of graduate credit, including at least 24 hours of coursework. When a thesis is required, 6 hours of thesis research is the minimum requirement. All of the required 24 hours of coursework must be taken for a grade, although additional courses may be taken Pass/Fail if offered in that mode. Some programs require more than 30 hours for graduation. Additional degree requirements are listed at the beginning of the applicable program section.

The course of study consisting of classes, seminars, and research, capstone project, or internship hours is compiled by the student, the student's advisor, and the program director. It is recommended that, when possible, the course of study include courses in fields other than that of major interest.

Special Skill or Technical Requirement

Some programs may require students to demonstrate either a competence in one or more special skills or a minimum number of hours in a discipline. See the additional degree requirements for the applicable program in the Programs of Study section.

Training in Integrity and Responsible Conduct

The successful completion of a program in research, clinical, or behavioral ethics is required prior to admission to degree candidacy. This requirement is fulfilled either by participating in courses designated by the Graduate School or by satisfactory completion of approved program electives that incorporate extensive discussion of responsible conduct in the research, clinical, or workplace settings.

Admission to Degree Candidacy

An MS student pursuing a thesis-based degree is admitted to degree candidacy by the Dean of the Graduate School after recommendation by the program director. The student must have satisfactorily met any special skills, technical requirements, or

integrity requirements and is expected to complete the MS degree requirements within one term.

Thesis Requirement

Some of the programs granting an MS require a thesis; the student should verify whether a thesis is required with the individual program. If a thesis is required, 6 of the 30 hours required for the MS degree are allocated to thesis research at a minimum. Thesis research courses are graded S (Satisfactory) or U (Unsatisfactory). If a U is assigned, the course must be repeated and an S earned before the degree can be awarded. A student who receives a grade of U in research in two terms may be dismissed from the Graduate School by the Dean upon recommendation of the program. See the previous section on Thesis/Dissertation Committee Composition & Review Guidelines for details on the assessment of the Thesis.

Requirements for the Master of Healthcare Leadership

The Master of Healthcare Leadership (MHL) degree is administered by the Graduate School office at the School of Medicine.

Residence Requirement

In general, a minimum of 5 terms of part-time work is required for the Master's degree. The total allowable time for completion of the degree must not exceed six years. Course credit may be allowed for as described in the section on coursework transfers at the discretion of the program director and Dean of the Graduate School, but the minimum residence requirement is not thereby reduced.

Course Requirements

An MS candidate must have a minimum of 35 hours of graduate credit, including at least 4 hours of capstone project hours. All of the required hours of coursework must be taken for a grade, although additional courses may be taken Satisfactory/Unsatisfactory if offered in that mode. The plan of study consisting of classes, journal clubs, and capstone project is outlined by the student, the student's advisor, and the program director.

Training in Integrity and Responsible Conduct

The successful completion of a program in behavioral ethics is required prior to graduation. This requirement is fulfilled either by participating in courses designated by the Graduate School or by satisfactory completion of approved program electives that incorporate extensive discussion of responsible conduct in workplace settings.

Capstone Project Requirement

For this degree, a capstone project, including completion of 4 of the total 35 hours in project hours is required. The capstone project course is graded S (Satisfactory) or U (Unsatisfactory). If a U is assigned, the course must be repeated and an S earned before the degree can be awarded. A student who receives a grade of U in capstone project in

two terms may be dismissed from the Graduate School by the Dean upon recommendation of the program.

Requirements for the Doctor of Philosophy

The Doctor of Philosophy (PhD) degree administered by the School of Medicine Graduate School office include: Biochemistry and Molecular Biology, Biomedical Engineering, Cancer Biology, Integrative Physiology and Pharmacology, Microbiology and Immunology, Molecular Genetics and Genomics, Molecular Medicine and Translational Science, and Neuroscience.

Residence Requirement

A minimum of three years of full-time study, of which at least two must be in full-time residence at the University (or the equivalent in Wake Forest online instruction). The total allowable time for completion of the degree must not exceed seven years. Course credit may be allowed for as described in the section on coursework transfers at the discretion of the program director and Dean of the Graduate School, but the minimum residence requirement is not thereby reduced.

Course Requirements and Advisory Committee

The number of required courses is not prescribed by the Graduate School for PhD study. Coursework requirements are set by the individual graduate program committees or student advisory committees. Certain programs have required courses; students should consult individual programs for specific course requirements. Coursework plans, or plans of study, are typically arranged by the student's advisory committee with the approval of the program's graduate committee, with the goal of assessing mastery of appropriate fields of concentration. Courses required by programs cannot be taken as Pass/Fail, and graduate committees may designate that certain courses may not be taken Pass/Fail. The advisory committee is appointed by the program director and consists of the student's advisor and a minimum of two other members of the graduate faculty as described above in the Thesis/Dissertation Review Requirements.

Special Skill or Technical Requirement

Some programs may require students to demonstrate either a competence in one or more special skills or a minimum number of hours in a discipline. See the additional degree requirements for the applicable program in the Programs of Study section.

Scientific Integrity and Responsible Conduct of Research

The successful completion of a program in research, clinical, or behavioral ethics is required prior to admission to degree candidacy. This requirement is fulfilled either by participating in courses designated by the Graduate School or by satisfactory completion of approved program electives that incorporate extensive discussion of responsible conduct in the research, clinical, or workplace settings.

Professional Development

The successful completion of a program in professional development is required prior to admission to degree candidacy. This requirement is typically fulfilled by participating in the courses Career Planning in the Biomedical Sciences and Seminars in Professional Development, often taken during the first year of graduate study. The Dean may approve alternative methods for having met this degree requirement.

Preliminary Examination

This examination is conducted by the program. The examining committee selected by the program includes at least three members, one of whom represents a related concentration area. A single written examination or a series of written examinations should cover all areas of concentration and collateral studies. There may also be an oral examination in which any faculty member invited by the examining committee may participate. The examining committee passes or fails the student and notifies the Graduate School of the results. In case of failure, the committee may recommend that the candidate be dismissed from the program. A reexamination may be allowed no earlier than six months from the date of the first examination. A student may be reexamined only once. The preliminary examination is normally given near the end of the student's second year of graduate study and must be passed at least twelve months prior to the date of the awarding of the PhD.

Admission to Degree Candidacy

A student is admitted to degree candidacy by the Dean of the Graduate School after recommendation by the program director. The student must have passed the preliminary examination, satisfactorily met any special skills or technical requirements, integrity, and professional development requirements.

Dissertation Requirement

Under the supervision of an advisor committee, the candidate prepares a dissertation embodying the results of investigative efforts in the field of concentration. Students must submit an electronic copy of the dissertation to the examining committee at least three weeks before the final examination. The committee is polled by the chair of the examining committee at least ten days before the proposed date of the examination to determine the acceptability of the dissertation. Other faculty members may attend the final examination and participate in the questioning. Dissertation research courses are graded S (Satisfactory) or U (Unsatisfactory). If a U is assigned, the course must be repeated and an S earned before the degree can be awarded. A student who receives a grade of U in research in two terms may be dismissed from the Graduate School by the Dean upon recommendation of the program. See the section on Thesis/Dissertation Committee Composition & Review Guidelines for details on the assessment of the Dissertation.

Degree Programs

Credit hours are shown by numerals immediately after the course title, for example, (3) or (3, 3). Some laboratory courses have numerals after the course descriptions showing hours of recitation and laboratory per week, for example, (2-4). The symbols P— and C— followed by course numbers or titles are used to show prerequisites and co-requisites. POI indicates permission of instructor is required. Because graduate study occurs at a level of complexity and specialization exceeding that of undergraduate education, the work required of graduate students in any course in which instruction is combined with undergraduate students will reflect this difference.

Graduate School General Studies (GRAD)

Overview

The Graduate School offers courses for students spanning the range of biomedical graduate programs. Some courses are required by the degree or program, while others serve as general electives. Please consult the degree requirements and the individual program requirements to determine which courses are mandatory.

Courses of Instruction

GRAD TO – Thesis-only (0). This course is intended only for Bowman Gray students who need to continue their relationship with the University until such a time that their degree can be conferred. The requirement is that the Bowman Gray student meets one of two criteria: a) the student defends the thesis at a point in time that precludes them from being able to have their degree conferred within the term, or b) the student leaves the institution with their faculty advisor, but has already advanced to candidacy. *Permission of the Graduate School Director or Dean is required, and a fee will be charged to the student when registering for this course. P—POI.*

GRAD 700 – Independent Study (1-9). This course allows an interested student to pursue a topic covered in another class in greater depth under the guidance of a faculty member. The faculty member will work with the student to clarify the expectations; usually the course requires a combination of extensive reading, tutorial sessions, and a written paper. *May be repeated.*

GRAD 701 – Special Topics (1-9). This course allows an interested student or students to pursue a topic covered in another class in greater depth under the guidance of a faculty member. The faculty member will work with the student or students to clarify the expectations; usually the course requires a combination of extensive reading, tutorial sessions, and a written paper. *May be repeated for different topics.*

GRAD 702 – Internship (1-9). The objective of this experiential course is to prepare graduate students to practice their biomedical science expertise within one of a variety of career settings. The course is appropriate for those seeking either a Master's or PhD in biomedical sciences, preparing the student for roles in pharmaceutical/biotech (research, safety, marketing), law and regulatory agencies, medical writing, science policy, and grants management, among others. *Students should register for this course*

if their internship placement is located within the Wake Forest umbrella. Students with placement outside of the Wake Forest umbrella should register for GRAD 703. Credit hours may be adjusted based on the length of the internship. May be repeated. Satisfactory/Unsatisfactory.

GRAD 703 – Internship (1-9). The objective of this experiential course is to prepare graduate students to practice their biomedical science expertise within one of a variety of career settings. The course is appropriate for those seeking either a Master's or PhD in biomedical sciences, preparing the student for roles in pharmaceutical/biotech (research, safety, marketing), law and regulatory agencies, medical writing, science policy, and grants management, among others. *Students should register for this course if their internship is located outside of the Wake Forest umbrella. Students with placement inside of the Wake Forest umbrella should register for GRAD 702. Credit hours may be adjusted based on the length of the internship. May be repeated. Satisfactory/Unsatisfactory.*

GRAD 704 – Principles of Intellectual Property Development (2). Designed for late-stage graduate students to supplement their scientific background with a greater understanding of intellectual property protection, commercialization, and start-up company formation. Numerous aspects of our knowledge-based economy will be covered including an overview of the diverse types of intellectual property protection available to protect inventions (with a focus on patents), the technology transfer process in an academic setting, a primer of company formation and organization, and an analysis of the different agreements (including confidential disclosure agreements, material transfer agreements, and license agreements) necessary to move a technology from the bench to the bedside. *P—Scientific graduate students only.*

GRAD 705 – Commercializing Innovation (3). This course will explore the processes that are involved from taking an interesting and innovative idea through to successful commercial or organizational application - in going from why something is a promising innovation on to how to develop a potentially successful business. It will look at product and process innovation, as well as the increasingly important area of business model innovation. There will be strong emphasis on practical application, group work and learning from experience. Guest lecturers will be used to illuminate some of the key issues in the commercialization process. *Typically offered in spring terms.*

GRAD 706 – Regulation and Reimbursement of Novel Drugs, Biologics & Medical Devices (3). This course is an overview of the key areas of strategic clinical development, Regulatory Affairs and the FDA-imposed regulations pertinent to the product lifecycle in the pharmaceutical, biologics, and medical device industries. The course also explores the basics of market access and reimbursement as a "second approval" prior to the product entering the market. The implications for available scientific and clinical evidence in light of market access issues will be discussed and linked back to the design of successful clinical development programs. Students will gain insight into the key elements of the regulatory process and market access in various health sector industries, governmental agencies and consultancies.

GRAD 707 – Professional Responsibilities and Conduct I (1). Students learn to identify general and discipline-specific professional norms and obligations for the

responsible practice of science. Emphasizes development of professional decision-making skills. *This course or equivalent is required for Reynolda campus Master's students who will be supported on federal grants. Pass/Fail.*

GRAD 708 – Communicating Science (1). This course is meant to train students in the best practices of taking highly technically scientific content and translating into formats that can be more easily comprehended by non-scientists and laypersons. The course will rely heavily on student presentations, often of their own research, followed by constructive critique from other class members. *Typically offered in the summer term.*

GRAD 709/710 – Scientific Outreach (1). This course provides hands-on engagement with teaching and educational opportunities directed at the lay public or other, non-university groups. Planning outreach events and communicating scientific concepts to the lay public are essential skills for any scientist-in-training, especially those who may be involved in academic lecturing or public policy. The scope of such activities will derive from the scientific disciplines of the students involved, but will include activities involving the informal teaching of basic and translational science concepts in the biomedical sciences and other STEM-related disciplines. Examples of such engagement include K-12 school visits, involvement in public symposia related to science for lay audiences, or any similar activity performed under faculty guidance. *May be repeated for credit not to exceed 6 hours each. Satisfactory/Unsatisfactory.*

GRAD 711 – Introduction to College Teaching (1). Prepares graduate teaching assistants for teaching roles. Coursework includes a 1-2 day orientation introducing students to the role and responsibility of being a teaching assistant, departmental orientation to teaching in the discipline, a series of educational workshops conducted by the Teaching and Learning Center, and classroom observation. *Satisfactory/Unsatisfactory*.

GRAD 712 – Clinical Integrity and Professionalism (2). This course offers foundational ethics and integrity training to Bowman Gray graduate students focused in pre-clinical studies. This course will utilize a combination of didactic presentations and small group, problem-based learning experiences to teach students methodology for addressing future ethical concerns in clinical and research practice. The course will provide an overview of the historical context and theoretical frameworks of biomedical ethics. Emphasis will be placed on the use of case studies to discuss topics including but not limited to: the doctor-patient relationship, professionalism, the principles of biomedical ethics, informed consent, privacy and confidentiality, medical research, social factors in healthcare, and ethical issues at the beginning and end of life. *This course satisfies graduation requirements for ethics training for biomedical graduate students. Satisfactory/Unsatisfactory*.

GRAD 713 – Foundations of Scientific Integrity and Professionalism (1). A short-course designed to offer foundational ethics and integrity training to incoming Bowman Gray graduate students. Key concepts will include introduction to key professional norms in science, including, but not limited to, responsible conduct of research, new professional expectations, as well as student life. An introduction to topics, that will be further explored using case-studies in GRAD 714, will include:

plagiarism, animal & human subject research, record keeping, data management, grant writing, the student and advisor relationship, laboratory dynamics, and managing conflicts of interest. *Typically offered immediately following fall orientation. Satisfactory/Unsatisfactory.*

GRAD 714 – Scientific Integrity and Professionalism (2). A small-group, problem-based learning formatted course designed to teach discipline-specific and broad, professional norms and obligations for the ethical practice of science, primarily for first-year graduate students on the Bowman Gray campus. The content will present ethical dilemmas and promote professional behavior on, but not limited to, the responsible conduct of research and the current regulatory climate with emphasis on the underlying principles that shape these concepts. Topics will include plagiarism, animal & human subject research, record keeping, data management, grant writing, the student and advisor relationship, laboratory dynamics, and managing conflicts of interest. *Typically offered weekly at 2-hour discussion sections during the spring term. This course satisfies graduation requirements for ethics training for Bowman Gray students. Satisfactory/Unsatisfactory.*

GRAD 715 – Career Planning in the Biomedical Sciences (1). A weekly seminar course, primarily for first-year graduate students on the Bowman Gray campus, in which invited alumni panelists share details on career options in the biomedical sciences, typically grouped by industry, highlighting a wide range of career paths. Speakers will share details from their own experiences in preparing for their chosen career paths, and may include: undergraduate college teaching, pharmaceutical research, law careers, medical writing, science policy, and grants management, among other careers. In addition to the panel discussions, students will have the opportunity to complete self-assessment exercises to help narrow their career focus, will begin to discuss best practices in resume, curriculum vitae, cover letter writing, and interviewing skills. *Recommended for all students on the Bowman Gray campus. Typically offered in fall terms.*

GRAD 716 – Seminars in Professional Development (1). A weekly seminar course, primarily for first-year graduate students on the Bowman Gray campus, in which invited speakers give presentations organized around offering students best practices in professional behaviors on topics, including: animal & human subjects research, record keeping, authorship, grant writing, preparing talks and posters, and managing conflicts of interest. *Required for PhD students on the Bowman Gray campus; recommended for MS students on the Bowman Gray campus. Typically offered in spring terms.*

GRAD 720 – Topics in College-Level Teaching (1-3). Students participate in the preparation and delivery of one or more lectures, homework assignments, and examinations, and facilitate small group learning sessions. Students attend at least two professional development workshops on a variety of aspects of the educational process. *P—Successful completion of the first year of coursework in a biomedical graduate training program and POI.* Satisfactory/Unsatisfactory.

GRAD 722 – Teaching Skills and Strategies Seminar (2). Designed to provide students with formal training and development in teaching strategies and teaching

scholarship. A variety of theories and pedagogies are reviewed and discussed. Students receive some practical experience in developing and delivering instructional materials and assessment tools. *Meets weekly for two hours throughout the spring term.*

GRAD 724 – Biosafety in Research Laboratories (3). This one-term course provides an overview of the types of biohazards that may be encountered while conducting scientific research, with emphasis on laboratories, and effective methods to minimize the risks associated with those hazards. *P—At least one microbiology course and laboratory experience.*

GRAD 725 – Speaking with Confidence (3). Introduction to logic and rhetoric as well as grammar, comprehension, idioms, pronunciation, and vocabulary. Focuses on increasing self-confidence to improve speaking abilities as well as future employment opportunities.

GRAD 726 – Written English for the Professional Graduate (3). Explores the different forms of written English and their application. Focuses on increasing understanding the application of grammar, structure, rhetoric, and idioms to improve future employment opportunities.

Other Graduate Coursework Available Through Reynolda-campus Based Programs of Study

Overview

Most Reynolda-campus based graduate programs offer additional coursework that is available for no additional tuition fee in fall and spring terms. Courses offered in the summer term may require a School of Medicine-based graduate student to pay additional tuition. The Bioethics graduate program requires School of Medicine-based graduate students to pay extra tuition in all terms. The following selected list of course offerings are those that School of Medicine-based graduate students have taken in previous terms. Students interested in these or other graduate courses hosted by Reynolda-campus based programs should obtain permission to enroll from the course director of the course. Once permission is received, the student should contact the School of Medicine's Registrar to complete enrollment in the course. For course descriptions and additional course listings, please consult the Reynolda-campus Graduate Bulletin.

Selected Courses of Instruction

BIE 703 – Bioethics Theory (3).

BIE 733 – Bioethics at Work: The Clinical Context (1-3).

BIE 737 – Bioethics and Genetics (3).

BIE 757 – Biotechnology Law and Policy (2-3).

BIOL 620 – Comparative Anatomy (4).

BIOL 622 – Biomechanics (4).

BIOL 625 – Chronobiology (3).

BIOL 626 – Microbiology (4).

BIOL 646 – Neurobiology (4).

BIOL 654 – Endocrinology (3).

BIOL 657 – Bioinspiration and Biomimetics (3).

BIOL 662 – Immunology (3).

BIOL 670 – Biochemistry: Macromolecules and Metabolism (3). *Crosslisted as BIOL/CHM 670.*

BIOL 680 – Biostatistics (3).

BIOL 685 – Bioinformatics (3). *Crosslisted as BIOL/CSC/PHY 685.*

BIOL 715 – Foundations of Physiology (1-4).

BIOL 775 – Microscopy for the Biological Sciences (4).

CHM 670 – Biochemistry: Macromolecules and Metabolism (3). *Crosslisted as BIOL/CHM 670.*

COMM 655 – Health Communication (3).

CSC 621 – Database Management Systems (3).

CSC 631 – Software Engineering (3).

CSC 652 – Numerical Linear Algebra (3).

CSC 655 – Introduction to Numerical Methods (3). *Crosslisted as CSC/MST 655.*

CSC 671 – Artificial Intelligence (3).

CSC 621 – Database Management Systems (3).

CSC 685 – Bioinformatics (3). *Crosslisted as BIOL/CSC/PHY 685.*

CSC 687 – Computational Systems Biology (3).

CSC 702 – Theory of Computation (3).

CSC 721 – Theory of Algorithms (3).

CSC 753 – Nonlinear Optimization (3). *Crosslisted as CSC/MST 753.*

CSC 775 – Neural Networks (3).

HES 721 – Data Analysis and Interpretation (3).

HES 763 – Advanced Biomechanics (3).

HES 765 – Graded Exercise Testing and Exercise Prescription (3).

MST 605 – Applied Multivariable Mathematics (3).

MST 606 – Advanced Mathematics for the Physical Sciences (3).

MST 611 – Introductory Real Analysis I (3).

MST 622 – Modern Algebra II (3).

MST 624 – Linear Algebra II (3).

MST 626 – Numerical Linear Algebra (3).

MST 631 – Geometry (3).

MST 647 – Graph Theory (3).

MST 651 – Introduction to Mathematical Modeling (3).

MST 652 – Partial Differential Equations (3).

MST 655 – Introduction to Numerical Methods (3). *Crosslisted as CSC/MST 655.*

MST 711 – Real Analysis (3).

MST 731 – Topology (3).

MST 753 – Nonlinear Optimization (3). *Crosslisted as CSC/MST 753.*

PHY 620 – Physics of Biological Macromolecules (3).

PHY 685 – Bioinformatics (3). *Crosslisted as BIOL/CSC/PHY 685.*

PSY 629 – Perception (3).

PSY 715 – Research Design and Analysis in Psychology (3).

PSY 728 – Human Cognition (3).

SCB 701 – Structural and Computational Biophysics Journal Club (1).

SCB 710 – Research Topics in Structural and Computational Biophysics (1).

STA 610 – Probability (3).

STA 662 – Multivariate Statistics (3).

STA 663 – Introduction to Statistical Learning (3).

ADDICTION RESEARCH AND CLINICAL HEALTH (ARCH)

Program Director	Elizabeth Shilling
Professors	Laura Veach
Assistant Professors	Jaylyn Clark, Katie Duckworth, Yasmin Gay, Elizabeth Shilling
Adjunct Graduate Faculty	Ellyn Essic

Overview

To meet the critical needs for addiction care and treatment, the Addiction Research and Clinical Health (ARCH) Master of Science program at Wake Forest University provides graduate training at the master's level to prepare specialists in addiction services.

The ARCH program provides three track options, one focused on a clinical outcome, and another focused on addictions research with an emphasis on neuroscience, and a third health services track focused on the overall health implications of addiction.

ARCH integrates student learning and research experiences throughout our medical community. The program, considered the first of its kind, is perfectly suited for the innovative environment at Wake Forest and is helping to create a workforce that will make a direct impact on the addiction crises faced by our patients, our community, and our nation.

The program goals are to: (1) Provide evidence-based integrated care effectively and ethically; (2) Value diversity, life-long learning, self-awareness, and personal growth; (3) Champion empathy, multicultural competencies, and the highest quality of skills; and (4) Base care on treating others with dignity and respect.

ARCH welcomes students from multiple disciplines, and can enhance the likelihood for further advanced studies in psychology, counseling, social work, medicine, or nursing, as well as provide opportunities for those who already hold an advanced degree and want to pursue further addiction specialized education.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: All students are required to take 18 course credit hours in core courses.

Clinical Track: Students must complete a minimum of 39 course credit hours, including core courses, and 9 credit hours of clinical internship experiences amounting to a minimum of 600 hours of clinical experience.

Research Track: Students must complete a minimum of 39 course credit hours, including core courses, and 9 credit hours of a research internship.

Health Services Track: Students must complete a minimum of 30 course credit hours, including core courses, 6 project hours, and a capstone project on a topic agreed upon by the advisor and student.

Courses of Instruction

ARCH 701 – Foundations of Addiction (2). This course is designed as a broad introduction to foundational concepts of addictive substances and disorders. Major topics of the course include the primary categories of substances of abuse; epidemiology, etiology, and effects of substance use; and current scientific findings related to addictive behaviors.

ARCH 702 – Human Development, Addictive Disorders, & Human Services (3). The course addresses development and cognitive processes governing learning from conception to death with an emphasis on the implications for addictive disorders and the treatment of addictive disorders. Normative, non-normative and historical effects within childhood, adolescence, adulthood and later life are presented. Formal developmental and learning theory is emphasized in conjunction with practical interpretation and application. The course provides an orientation and background for sound educational and clinical practices. *Typically offered in fall term.*

ARCH 703 – Helping Skills in Addiction & Human Services (3). Helping Skills in Addiction & Human Services investigates techniques of helping skills and multi-disciplinary intervention options for addictive disorders. The course teaches fundamental helping skills such as relationship building, basic assessment, goal setting, selecting interventions and evaluation of client outcomes in the context of addictive disorders in human services settings. *Typically offered in fall term.*

ARCH 704 – Theories of Addictive Disorders (3). Theories of Addictive Disorders is designed to introduce students to the theoretical, philosophical, and historical premises upon which addictive disorders are explained and treatment and prevention of addictive disorders are based. Biological, psychological, and sociological aspects of substance abuse and dependence will be the frameworks upon which the course will be taught. *Typically offered in fall term.*

ARCH 705 – Addictive Disorders Treatment: Individuals, Families, and Groups (3). This course is an introduction to basic therapeutic counseling skills for use with chemically dependent clients and/or their families. It is designed for counseling students who have worked as professional substance abuse counselors and for those who have little or no such experience. The course helps prepare students for certification as North Carolina Licensed Clinical Addictions Specialists (LCAS). *Typically offered in spring term.*

ARCH 706 – Assessment & Diagnosis: Addictive Disorders (3). This course is an introduction to assessing and diagnosing risky misuse and addiction disorders with the use/abuse & dependency continuum. It is designed for graduate students preparing to work as a professional Clinical Addiction Specialist. The course helps prepare

students for certification as North Carolina Licensed Clinical Addictions Specialists (LCAS) through the approved program at Wake Forest Graduate School – Biomedical campus. *Typically offered in spring term.*

ARCH 707 – Addictive Disorders Symposium (3). The Addictive Disorders Symposium will explore contemporary issues in the field of addictive disorders and their influences on the roles of clinical addictive specialists and researchers. This course is designed to benefit clinical addictive disorders researchers, scientists and specialists. Students will actively participate in discussions related to the theme and sessions will feature researchers who will share their current thinking and agenda relevant to the concerns of addictive disorders professionals. *Typically offered in summer term. P—POI.*

ARCH 708 – Advanced Study in Addictive Disorders (3). The Advanced Study in Addictive Disorders is a course designed to provide an in-depth look at special topics related to addictive disorders such as process disorders, codependency, emerging practices and more. The disease of substance abuse and dependence has many unique characteristics when it occurs in persons and groups outside the typical family unit. In this course, an examination of those characteristics is explored among special populations including adolescents, the elderly, racial and ethnic minorities, gas/lesbians, the physically and developmentally disabled and the chronically ill. *P—ARCH 703.*

ARCH 709 – Ethics in Health, Addictive Disorders & Human Services (3). The Ethics in Health, Addictive Disorders & Human Services course is designed to examine the ethical and legal standards required by the industry, state entities, or federal entities that affect the practice of addiction prevention and addiction treatment of adults and minors. This course discusses five principles of ethical decision-making in addictive disorders clinical practice and provides a step-by-step model for resolving ethical dilemmas. The course also explores specific ethical and legal issues as they relate to addictive disorders treatment.

ARCH 710 – Addictive Disorders Clinical Experience I & Lab (3). The Addictive Disorders Clinical Experience I & Lab is the introductory professional experience in a student's program. It is an opportunity to increase an understanding of addictive disorders treatment and the clinical, personal and professional skills necessary to be successful in this profession. Through experiences at a clinical addiction site and with classmates, students will grow in the use of intervention and helping skills, case conceptualization skills and self-awareness. *P—ARCH 703. Satisfactory/Unsatisfactory.*

ARCH 711 – Addictive Disorders Clinical Experience II & Lab (3). The Addictive Disorders Clinical Experience II & Lab is the second comprehensive professional experience in a student's program. It is an opportunity to continue to synthesize and apply knowledge with supervised training at a site congruent with the student's career goals, while also helping clients representative of the ethnic, lifestyle,

and demographic diversity in the community. Through the sharing of experiences in the lab experiences, students refine previously learned skills in an increasingly autonomous role with clients. *P—ARCH 706, ARCH 710. Satisfactory/Unsatisfactory.*

ARCH 712 – Addictive Disorders Clinical Experience III & Lab (3). The Addictive Disorders Clinical Experience III & Lab is the final comprehensive professional experience in a student's program. It is an opportunity to continue to synthesize and apply knowledge with supervised training at a site congruent with the student's career goals, while also helping clients representative of the ethnic, lifestyle, and demographic diversity in the community. Through the sharing of experiences in the lab experiences, students refine previously learned skills in an increasingly autonomous role with clients. *P—ARCH 711. Satisfactory/Unsatisfactory.*

ARCH 713 – Addictive Disorders Research Internship I (3). The Addictive Disorders Research Internship sequence of courses represent the final comprehensive professional experience in a research student's program. It is an opportunity to synthesize and apply knowledge with supervised training in up to three research laboratory experiences with the student's career goals. *Satisfactory/Unsatisfactory.*

ARCH 714 – Addictive Disorders Research Internship II (3). The Addictive Disorders Research Internship sequence of courses represent the final comprehensive professional experience in a research student's program. It is an opportunity to synthesize and apply knowledge with supervised training in up to three research laboratory experiences with the student's career goals. *P—ARCH 713; Satisfactory/Unsatisfactory.*

ARCH 715 – Capstone Project (1-6). This course provides students with the opportunity to work one-on-one with a faculty member on a particular topic or creative project. Students will be engaged in directed study through readings, projects, papers, and other activities.

ARCH 719/720 – Addiction Research & Clinical Health Journal Club (1). This journal club focuses on articles related to current trends in addiction research and addictive disorders treatment. Students are encouraged to review current research articles on addictive disorders with particular attention given to the implications of sociocultural, demographic, and lifestyle diversity. Each week a different student presents an article providing a thorough review of the article and relevant background information.

ARCH 721 – Social & Cultural Diversity in Additive Disorders (2). The clinical addiction profession strives to account for and thoroughly consider issues of cultural and ethnic diversity. The purpose of this course is to help students gain awareness of their cultural values and biases, of other's worldviews, and of culturally appropriate research and intervention strategies related to addictive disorders.

Biochemistry and Molecular Biology (BAMB)

Program Director	Tom Hollis
Professors	Rebecca Alexander, Reto Asmis, Donald Bowden, Cristina Furdui, Greg Hawkins, Tom Hollis, Tim Howard, Greg Kucera, Todd Lowther, Doug Lyles, Gloria Muday, John Parks, Fred Perrino, Leslie Poole
Associate Professors	Nichole Allred, Jed Macosko, Allen Tsang
Assistant Professors	Derek Parsonage, Susan Sergeant, Terrence Smalley

Overview

The graduate training program in Biochemistry and Molecular Biology of the Department of Biochemistry is designed to prepare students for careers of investigation and teaching in biochemistry, molecular biology, and in related sciences that involve biochemical, structural and molecular approaches and techniques. Although the programs of study are individually planned, all students are expected to possess competence in certain basic areas of biochemistry and related sciences. Programs leading to the PhD degree in biochemistry and molecular biology are offered.

Students enter the program through the Molecular and Cellular Biosciences Track and participate in the MCB common curriculum in the first year. Curriculum in subsequent years includes participation in Scientific Communication, Topics in Biochemical Literature and electives of the student's choice. The student also participates in the department's program of research seminars.

Dissertation research under the supervision of a faculty member may be pursued in various areas of biochemistry, including enzymology, NMR and X-ray structure determination of macromolecules, virus assembly, relation of lipid and protein metabolism and of protein-lipid association to membrane structure and function, biological oxidations and bioenergetics, molecular genetics and nucleic acid function, biophysics, biochemical pharmacology of anticancer agents, leukocyte metabolism and function, signal transduction mechanisms in normal and cancerous cells, and molecular mechanisms of blood coagulation. The department has specialized equipment and facilities to support training and investigation in these areas.

The biochemistry program participates in the Interdisciplinary Graduate Track in Structural and Computational Biophysics. For more information, refer to the pages in this bulletin regarding the program. The graduate program was begun in 1941, and the PhD degree has been offered since 1962.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: Students are required to take BAMB 700/701 Scientific Communication in year 2 and BAMB 709/710 Special Topics in Biochemical Literature in years 2 and 3.

Courses of Instruction

MCB Track Electives

MCB 711 – Biological Systems and Structures (2). In depth study of macromolecular assembly and interactions, as well as the application of structural biology and proteomics technology. Contemporary concepts of the principles of protein and nucleic acid structure are discussed. Other topics include methods for structure determination such as X-ray diffraction, NMR spectrometry, and molecular modeling. Typically offered in the fall term. *Intended for all graduate students in biochemistry and molecular biology (BAMB); open to students in other tracks or programs.*

MCB 712 – Biological Spectroscopy (2). Principles and practicalities of the study of biomolecules using spectroscopic techniques such as absorbance, fluorescence and circular dichroism analyses. Other biophysical approaches such as mass spectrometry and sedimentation analysis will be included. Topics in the study of enzymes utilizing these techniques will be discussed. Typically offered in the fall term. *Intended for all graduate students in biochemistry and molecular biology (BAMB); open to students in other tracks or programs.*

MCB 715 – Fundamentals of Redox Biology and Medicine (2). Redox chemistry as it applies to biological systems is a specialized field where a fundamental understanding of the underlying biochemistry and appropriate methodologies for evaluating redox regulation and its effects on cellular function are essential. This course will provide the theoretical background and emphasize highly quantitative and robust approaches to evaluate redox changes when these are investigated 1) at the level of single molecules (e.g. working with redox-regulated recombinant proteins; 2) in vitro at the cellular level; 3) in vivo using animal models; and 4) in clinical studies.

BAMB Advanced Courses

BAMB 700/701 – Scientific Communication (1). Instruction and practice in oral and written scientific communication. *Meets weekly.*

BAMB 706 – Intracellular Signaling (3). Advanced study of the biochemical mechanisms involved in intracellular signaling of normal and malignant cells, including 1) growth factor and G protein-coupled receptors 2) second messengers, 3) protein kinase cascades, 4) gene regulation, and 5) oncogenes. Lectures and discussions provide in-depth coverage of each topic with emphasis on recent advances and current literature.

BAMB 709/710 – Special Topics in Biochemical Literature (2). Critical reading and interpretation of the recent literature in biochemistry. Emphasis is decided by

students and staff. *Meets weekly. Required of second and third year graduate students in the Biochemistry and Molecular Biology program.*

BAMB 711 – Advanced Topics in Protein Structure Determination (2). Emphasizes methods for modern structure determination using X-ray crystallographic methods. Students are exposed to practical techniques in growth of protein crystals, collection and processing of X-ray diffraction data, phase determination, model building and refinement. Students are also expected to develop an in-depth understanding of the latest instrumentation and programs used in protein structure determination.

BAMB 713 – Large Experimental Datasets and Analysis: Advanced (3). Conducted as a combination of lectures, reading assignments, and student-led discussions. Lectures detail experimental methods that generate large-scale datasets. Topics will include genotyping, expression profiling, metabolomics, high-content cellular imaging techniques and practical examples of bioinformatic software and statistical analyses.

BAMB 714 – Instrumental Techniques (3). Theoretical and technical aspects of instrumentation currently employed in the biological sciences. Experience is provided on a variety of instruments including high performance liquid chromatographs; gas chromatographs; gas chromatograph/mass spectrometer; nuclear magnetic resonance spectrometer; electron paramagnetic resonance spectrometer; ultraviolet, visible, and infrared spectrophotometers; spectrofluorometers; and cell sorter/cytofluorograph. *P—general chemistry through physical chemistry and two terms of physics or POI. Offered in odd-numbered years.*

BAMB 715/716 – Special Topics in Biochemistry (1-9). Advanced conference course that considers various areas of current interest or rapid development. Topics are developed depending on the interests of students and staff.

BAMB 717/718 – Principles and Practice of Teaching Biochemistry (2). Structured participation of students as mentors in existing biochemistry classes. Under the supervision of biochemistry faculty, students create laboratory demonstrations, field questions, write and grade exam questions, conduct review sessions and participate in one-on-one instruction. *P—POI*

BAMB 719/720 – Dissertation Research (1-9). The department offers opportunities for investigation in a wide variety of biochemical subjects under the guidance of staff members. *Satisfactory/Unsatisfactory*

BAMB 734 – Human Molecular Genetics (2). Combined lecture/seminar course providing an overview of current theoretical and technical approaches for locating, identifying, and cloning human genes.

BIOMEDICAL ENGINEERING (BMES)

Program Director	Emmanuel Opara
Professors	Graça Almeida-Porada, Evelyn Anthony, Anthony Atala, , Daniel Bourland, Arjun Chatterjee, , William Gmeiner, Metin Gurcan, Adam Katz, Daniel Kim-Shapiro, Paul Laurienti, Michael Morykwas, Michael Munley, Emmanuel Opara, Boris Pasche, Olga Pierrakos, Christopher Porada, Thomas Smith, Shay Soker, Joel Stitzel, Charles Tegeler, William Wagner, Chris Whitlow, James Yoo
Associate Professors	, Tracy Criswell, Kerry Danelson, Craig Hamilton, Scott Gayzik, Adam Hall, Ken Kishida, Sang Jin Lee, Nicole Levi-Polyachenko, Xin Ming, Sean Murphy, Alexander Powers, Edgar Alfonso Romero-Sandoval, Sean Simpson, Umit Topaloglu, Pierre Vidi, Ashley Weaver, Jeff Willey, Saami Yazdani, Dawen Zhao
Assistant Professors	Kristin Beavers, Philip Brown, , Erin Henslee, Bethany Kerr, , Khalid Niazi, Kristen Nicholson, Ellie Rahbar, Hooman Sadri, Jillian Urban, Jim Ververs, Jared Weis
Adjunct Graduate Faculty	Don Gage

Overview

The Department of Biomedical Engineering offers PhD and MS degrees in biomedical engineering in conjunction with the joint degree program in the Virginia Tech–Wake Forest University School of Biomedical Engineering and Sciences (SBES). The program emphasizes medical applications, particularly in image and signal processing and analysis, regenerative medicine/tissue engineering, biomechanics, medical physics, nanotechnology, and translational cancer research. Qualified applicants should have undergraduate degrees in technical fields, including engineering, computer science, mathematics, and physics. Additional training in life sciences is desirable but not essential.

The program consists of traditional classroom instruction, independent research with a mentoring team, and clinical experience. Courses come from engineering and life science core courses and selected electives in engineering, life sciences, and related physical sciences, offerings include courses in the physics, mathematics, and computer science departments. The program is very flexible, and selection of elective courses can be individualized to complement the student's background and interests.

A clinical rotation is offered to PhD students during their first year of study. Students are exposed to technical equipment with medical applications, and to patient care and procedures used in medical centers, thus providing relevance and context for their classroom studies and research.

Office and laboratory space are located throughout the Medical Center and include the Image Analysis Lab, the Movement Biomechanics Lab, the Tissue Mechanics Lab, the Center for Injury Biomechanics, the Wake Forest Institute for Regenerative Medicine, Radiation Oncology, Plastic and Reconstructive Surgery, and other campus locations. Facilities also include a chemistry lab and a machine shop with associated instrumentation and tools, including the Wake Health Additive Manufacturing core lab. Academic space is provided in the Wake Forest Biotech Place Building. Computer and network facilities are state of the art, and several projects utilize the cluster computer facility, the DEAC Cluster. Associated labs in clinical and basic science departments also provide equipment for student research.

More information is available on the website, www.sbes.vt.edu. Prospective students are encouraged to contact individual faculty members or schedule a visit to the department.

Degree Requirements: As applicable, please see "Requirements for the Doctor of Philosophy Degree" of the "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: For the MS degree, students must take a minimum of 21-24 course 42 credit hours and 6-9 hours in research for a minimum of 30 credit hours. For the PhD degree, students must take 35-50 course credit hours and 40-55 dissertation research hours for a total of 90 credit hours.

Courses of Instruction

BMES 602 – Biomedical Engineering and Human Disease (3). Comprehensive overview of a variety of human diseases, including neurological disorders, cardio-vascular disease, infectious disease, and cancer, designed primarily for graduate students majoring in engineering and other related areas who have a long-term academic and professional goal in the field of biomedical engineering and life sciences. Introduction to state-of-the-art biomedical engineering approaches used for the study of early detection/diagnosis, treatment, and prevention of human disease.

BMES 605 – Quantitative Cell Physiology (3). This course in mathematical modeling and simulation will include the following: quantitative descriptions of cell physiology and control pathways; numerical simulations of cellular physiologic processes such as, reaction kinetics, inhibition and cooperatively, passive transport, facilitated and carrier-mediated reaction kinetics; cell membrane resting potential in nerve and muscle tissue. Additionally, the course will cover modeling of neuronal processes such as voltage-gated channels, neurotransmitter release and uptake kinetics, and postsynaptic membrane potentials. *For SBES graduate students only*.

BMES 606 – Quantitative Organ Systems Physiology (3). Mathematical modeling, simulation, quantitative description of organ physiology and control. Numerical simulation of cardiovascular physiologic processes including regulation of cardiac output, the baroreceptor - stroke volume model, venous return, and closed-loop control. Respiratory ventilation mechanics, gas exchange, pulmonary circulation, alveolar-capillary diffusion, and respiratory ventilation control. Nephron countercurrent mechanism and hemodialysis. Modeling of endocrine system functions. For SBES graduate students only. *P—MATH 5495/ESM 5725/BMES 5044 or equivalent; BMES*

605 and/or experience with computer programming (Matlab); coursework in Ordinary Differential Equations.

BMES 612 – Advanced Musculoskeletal Biomechanics (3). Skeletal anatomy and mechanics. Muscle anatomy and mechanics. Theory and application of electromyography. Motion and force measuring equipment and techniques. Inverse dynamics modeling of the human body. Current topics in musculoskeletal biomechanics research.

BMES 616 – Advanced Impact Biomechanics (3). Review of impact biomechanics and critical investigation of the impact response of the human body. Participants study the dynamic response of the head, neck, chest, abdomen, upper and lower extremities. Real-world examples from automobile safety, military applications, and sport biomechanics. *P—POI.*

BMES 617 – Biomechanics of Crash Injury Prevention (3). Presents an introduction to the design and analysis of crash injury prevention methods in vehicle crashes. Encompasses three major focus areas: crash energy absorption in (1) the vehicle structure, (2) the occupant, and (3) the occupant restraints.

BMES 618 – Injury Physiology (3). Presents an introduction to the physiology of injury. Focuses on the pathophysiology, mechanisms, and outcomes of injury in mammalian tissues. Explores injury physiology at the organ, tissue, and cellular level. Topics include physiology of injury to tissues of the peripheral and central nervous systems, the musculoskeletal system, the pulmonary system, the abdomen, the pregnant female, and the eye.

BMES 621 – Human Physical Capabilities (3). Examination of human physical attributes in human-technology systems, with emphasis on models of anthropometry and biomechanics, on intero- and exteroreceptors, and on the work environment; force fields (transitory and sustained), sound, light, and climate. *P—POI.*

BMES 624 – Biofluids (3). Fluid dynamics of physiological systems with a focus on cardiovascular and respiratory systems. Addresses the heart, arterial blood vessels, airways, cardiac and pulmonary circulations, anatomy and function of the heart and respiratory systems. Topics covered, include: mechanics of soft tissues, basic fluid mechanics, continuum mechanics and constitutive modeling, rheology of blood, Newtonian and non-Newtonian fluids, viscous flows in vessels, Navier-Stokes, mathematical analysis of pulsatile flows, pulse-wave propagation through vessels, particulate flows and particle transport on airways. *P-POI.*

BMES 630 – Biological Transport Phenomena (3). The fundamental principles of mass transport phenomena are introduced and applied to the characterization of transport behavior in biological systems (e.g. cell, tissues, organs, people). Topics include active, passive, and convective molecular transport mechanism. These fundamentals will be used to develop analytical and predictive models and describe phenomena such as oxygen transport, kidney function, systemic drug delivery, and design of extracorporeal devices. *P—Undergraduate courses in fluid mechanics and transport phenomena.*

BMES 631 – Introduction to Regenerative Medicine I (3). The course explores the current state of the field of regenerative medicine with specific emphasis on the technological challenges that limit the efficacy and clinical translation of engineered tissues and therapies. Course content will be presented from both the life science (e.g., cell biology, organ physiology, biochemical methods) and engineering perspective (e.g. transport phenomena, materials engineering) to compare and evaluate alternative approaches and strategies that are being developed and tested. Emphasis is placed on the promising roles of stem cells, biologically-inspired materials, and gene therapies. *P—Graduate standing or POI. Undergraduate biology and calculus are suggested.*

BMES 641 – Advanced Biomaterials (3). Lectures and problems dealing with materials used to mimic/replace body functions. Topics include basic material types and possible functions, tissue response mechanisms, and considerations for long-term usage. Issues of multicomponent materials design in prosthetic devices for hard and soft tissues are discussed.

BMES 643 – Polymeric Biomaterials (3). The major objective of this course is to introduce principles and concepts critical to the successful design of polymer-based biomaterials, drug-delivery devices, and bio-implants. The course will be broken down into the following four areas, polymer design and processing, inflammatory responses to polymers, interaction of blood with polymeric materials, and the effect of mechanical, chemical, and surface properties of polymers on cells.

BMES 651 – Digital Signal Processing (3). The fundamentals of digital signal processing of data experimentally obtained from mechanical systems is covered. Attention is given to data acquisition, A/D conversion, aliasing, anti-aliasing filtering, sampling rates, valid frequency ranges, windowing functions, leakage, and various transform methods. Special attention is given to random, transient, and harmonic function data processing. Various methods of estimation of frequency response function (FRF) are explored. The estimation methods are assessed as to their impact on FRF estimation errors.

BMES 652 – Stochastic Signals and Systems (3). An introductory graduate course on the engineering applications of probability theory, random variables, and random processes. Major topics will include: probability theory, random variables, random vectors, stochastic processes, analysis and processing of random signals, and Markov chains. *P—Probability and Statistics for Electrical Engineers or equivalent background.*

BMES 655 – Biomedical Signal and Image Processing (3). The mathematical theory underlying the processing of one and two dimensional signals, including Fourier transforms, sampling, quantization, correlation, and filtering. For images, the topics of segmentation, restoration, enhancement, color, and registration will be explored. Matlab projects will be utilized extensively, with an emphasis on biomedical signals and images.

BMES 671 – Biomedical Microdevices (3). Builds the foundation necessary for engineering research in micro- and nano- biotechnology. Covers micro- and nano-fabrication techniques; the fundamentals of microfluidics; micro- and nano-particle manipulation; and engineering aspects of cells and their membranes. Provides students

with the knowledge required to create biomedical micro- and nano-devices with a focus on the unique physics, biology and design aspects at these scales. Students are expected to know undergraduate engineering, physics, and calculus.

BMES 676 – Biomedical Nanoengineering (3). Biomedical Nanoengineering is an interdisciplinary course intended for graduate students (and undergraduates by permission of instructor) that will introduce major concepts in the design, production, and utility of micro- and nanotechnologies in biomedicine. The learning objectives of the course are to: (i) understand techniques critical to the fabrication of molecular sensors and nanodevices; (ii) explain fundamental physical and engineering principles at play in such devices; and (iii) describe practicable applications of the technologies to biomedicine. Students will learn about contemporary and emerging technologies, understand their working concepts, and read and critique high-impact papers in the field to appreciate the current state-of-the-art.

BMES 694 – Seminar (1). The focus of this course is on presentation of scientific work. Attendance at all SBES-sponsored, invited lectures is required. Students must attend 2/3 of all invited SBES seminars. First year graduate students are required to attend additional lectures aimed toward presentation skills, grant writing, and other special topics. A short formal presentation of research is required of all first year graduate students.

BMES 697 – Independent Study (3). Opportunity to pursue a topic covered in a regular course in greater depth. Usually involves extensive reading and tutorial sessions with a faculty supervisor. Written papers may be required.

BMES 698 – Special Study (3). Designed for a group of students. It may be used to study a timely topic—one in which there is current, but not necessarily lasting interest. It also may be used to launch an experimental course before the course is incorporated into the regular curriculum.

BMES 706 – Clinical Rotation (2). Offers both a broad view of the use of engineering principles in medicine and general clinical care, together with an in-depth study of a particular aspect of medicine under the direct supervision of a physician. The student sees the operation and maintenance of various clinical modalities, systems, and devices under the guidance of a working engineer or technician. Students participate in clinical rounds and in image reading sessions to gain insight into the actual operation and needs of departments using medical imaging modalities. *For SBES PhD students only*.

BMES 708 – Topics in Biomedical Engineering (1-6). Topics in biomedical engineering that are not considered in regular courses.

BMES 710 – Multi-scale Cancer Engineering (3). A multidisciplinary, multi-scale approach to analyzing cancer etiology, progression, detection, and therapy. Traditional and emerging methods of analyzing bio-molecular aspects of cancer. Tumor micro-environment modeling and analysis. Physical oncology-inspired cancer therapy.

BMES 716 – Computational Modeling in Impact Biomechanics (3). Dynamic modeling of the human body subjected to impact loading. A combination of finite

element analysis and multi-body simulation techniques. Utilizes software packages with dynamic solvers. Applications include computer-aided design for automobile safety, sports, biomechanics, and military restraint systems.

BMES 717 – Advanced Human Modeling: Injury and Tissue Biomechanics (3). Serves as a continuation of BMES 616 and BMES 716. It covers the basics of the finite element method as it applies to high-rate phenomenon. Focus is on practical problems and the use of commercial codes for solving vehicle crash-worthiness and biomechanics problems. Real-world examples from biomedical engineering, automobile safety, military applications, and sport biomechanics are used to augment lecture material. *P—BMES 616 and 716*.

BMES 718 – Advanced Computational Methods and Modeling for Biomedical Applications (3). Computational development and analysis of biomedical simulations using advanced numerical techniques for the solution of ordinary and partial differential equations. Emphasis will be on graduate research related topics within biomedical modeling: biotransport, biomechanics, tumor growth dynamics, model-based medical imaging techniques, etc. Methods for analyzing the limitations of these techniques and for understanding their proper use.

BMES 730 – Cardiovascular Mechanics I (3). Mechanics of the heart, arterial blood vessels and microcirculation; history of the circulation; anatomy and physiology of the heart; mechanics of cardiac contraction; cardiac fluid mechanics; work, energy, efficiency of cardiac function. *P—An understanding of ordinary and partial differential equations will be necessary in order to master the course material*.

BMES 752 – Cancer Diagnostics and Therapeutics (3). This class will take a broad integrative view of cancer, with particular emphasis on engineering approaches to diagnosis and treatment. Topics will include cancer genetics and phenotypes, the tumor microenvironment, cancer stem cells, immunology and tumor-microbiome interactions, and novel therapies being developed in the field as a whole, as well as at Virginia Tech and Wake Forest. The class will include a significant amount of critical analysis of the contemporary research literature, working through a number of case studies, as well as several group projects focused on posing specific research questions, and approaches to analyze these.

BMES 753 – Advanced Topics in Regenerative Medicine (3). The remarkable advances in biomaterials, stem cell biology, and genetic manipulation over the last several years have now made it possible to begin devising means of treating diseases that were previously incurable, and developing corrective therapies for crippling injuries. These advances have led to the emergence of the field of research/clinical investigation that is known as Regenerative Medicine, and this field promises to revolutionize the way we treat/manage both disease and injury. In this course, students will learn about the major organ/tissue systems of the body, the key enabling technologies that make regenerative medicine possible, and how these technologies can be applied to each organ/tissue to mediate regeneration/repair to treat disease/repair injury. Students will then embark on projects that will require them to apply the knowledge gained from the lectures to develop realistic and clinically translational solutions to generate specific organs for transplantation. Students will present their

projects to the class at the end of the term. *This course is cross-listed as MCB 753. P—BMES 631.*

BMES 771 – Radiological Physics (3). The nature and fundamental concepts of ionizing radiation including: ionizing radiation, radiation quantities, attenuation and stopping power, charged particle and radiation equilibria, radioactive decay, photon interactions, charged and uncharged particle interactions, x-ray production and quality, dosimetry concepts, ionization cavity theory, and calibration of ionizing radiation beams. *P—POI.*

BMES 773 – Radiation Therapy Physics (3). The physics of radiation treatment including: radiation producing equipment, character of photon and electron radiation beams, radiation dose functions, computerized radiation treatment planning, brachytherapy, special radiation treatment procedures, quality assurance, and radiation shielding for high energy facilities. *P—POI.*

BMES 774 – Physics of Medical Imaging (3). The physical principles, mathematical algorithms and devices used in diagnostic medical imaging, covering the following imaging modalities: x-ray physics, x-ray digital imaging, digital image receptors, computerized tomography and reconstruction algorithms, ultrasound imaging, magnetic resonance imaging, and nuclear medicine imaging.

BMES 776 – Medical Health Physics of Radiation (3). Physical and biological aspects for the use of ionizing radiation in medical environments, biological consequences of human radiation exposure, principles of ionizing radiation protection, operational dosimetry, radiation exposure recommendations and regulations, physical principles of radiation shielding design, personnel monitoring, medical health physics instrumentation, and waste disposal.

BMES 797, 798 – Research (1-9). *Satisfactory/Unsatisfactory.*

BIOMEDICAL SCIENCE (BMSC)

Program Director	Allen Tsang
Professors	Martha Alexander-Miller, Graça Almeida-Porada, Anthony Atala, Colin Bishop, Goldie Byrd, Mark Cline, Laura Cox, Paul Czoty, Lisa David, Waldemar Debinski, James Eisenach, Cristina Furdui, Dwayne Godwin, William Gmeiner, Rob Hampson, Tim Howard, Allyn Howlett, Todd Lowther, Doug Lyles, Amy McMichael, Carol Milligan, Boris Pasche, Fred Perrino, Leslie Poole, Christopher Porada, Tom Register, John Sanders, Carol Shively, Shay Soker, Leah Solberg-Woods, Peiqing Sun
Associate Professors	Nichole Allred, Ramon Casanova, Rong Chen, Tracy Criswell, Swapan Das, Nancy Denizard-Thompson, Clark Files, Jason Grayson, TanYa Gwathmey-Williams, Karen Haas, Kristen Hairston, Marquita Hicks, Kylie Kavanagh, Ken Kishida, Steve Kridel, Brenda Latham-Sadler, Tao Ma, Candice McNeil, Edgar Alfonso Romero-Sandoval, Jimmy Ruiz, Neveen Said, Aarti Sarwal, David Soto Pantoja, Allen Tsang, Pierre Vidi, Ashley Weaver, Jeff Willey, Raghu Yammani
Assistant Professors	Andrew Bishop, Heather Brown-Harding, Adam Hall, Chia-Chi Chuang Key, Emily Lisi, Matt Lisi, Shannon Macauley-Rambach, Sean Murphy, Ellen Quillen, Matt Quinn, Kimberly Reeves, Susan Sergeant, Nathan Shaller, Elizabeth Shilling, Kiran Solingapuram Sai, Jillian Urban, Marlena Westcott, Xuewei Zhu
Adjunct Graduate Faculty	Joseph Andrews, Erik Brady, Megan Irby, Carla Lema-Tomé, David Lyons, Jennie McGuire, Bita Nickkholgh, Justin Rawley, Bernard Roper, Peter Sheldrake, Chris York

Overview

The graduate program in Biomedical Science offers a program of study leading to the MS degree. This program is a full-time, graduate degree that is designed to help students with a bachelor's degree, preferably having majored in the sciences, improve their academic foundation in the biomedical sciences and improve their credentials for admission into health professional programs, medical school, doctoral study in the biomedical sciences, or to enter the workforce. All students take a minimum of 30-36 credit hours (see Degree Options below) in the basic sciences. Courses are in disciplines that include: biochemistry, molecular cell biology, neuroscience, biomedical engineering, genetics, human physiology, microbiology, immunology, pharmacology, scientific professionalism and the responsible conduct of research. Elective credits, offered in a variety of disciplines, include other courses offered outside of the BMSC

program. These electives improve critical thinking skills, study skills, and enhance the student's preparation for professional schools or entrance to the workforce.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

In addition, the Biomedical Science MS degree has multiple options for the completion of the degree, shown below. Specific coursework taken by students is typically driven by the area of concentration or specialization desired by the student. Academic advising is offered by an assigned faculty director based on the student's chosen Degree Option and their chosen area of Concentration of Specialization.

Degree Options

Option 1 - MS Degree with a Thesis: requires 30 credit hours including a minimum of 6 thesis research hours in the student's chosen area of specialty and a successfully completed thesis.

Option 2 - MS Degree with an Internship: requires 30 credit hours including 6 internship hours with a mentor and a written report that summarizes the experience. The report will be evaluated by the mentor, the Program Director in the student's area of specialty, and one other faculty member.

Option 3 - MS Degree with a Capstone Project: requires 30 credit hours including 6 project hours and a capstone project on a topic agreed upon by the advisor and student. The review will be evaluated by the advisor, Program Director in the student's area of specialty, and one other faculty member.

Option 4 - MS Degree without Thesis, Internship, or Project: 36 course credit hours are required. At the discretion of the Dean, for students who switch from a research-based degree option, satisfactory work in thesis research may count at course credit toward the coursework-only degree option.

Areas of Concentration

Antimicrobial Stewardship & Infectious Disease
Cancer Biology (Thesis is required)
Integrative Physiology & Pharmacology
Neuroscience (Thesis is required; *discontinued and only available to students who were enrolled prior to 4/23/19 or earlier*)
Regenerative Medicine

Areas of Specialization

Biochemistry & Molecular Biology
Biomedical Engineering
Microbiology & Immunology
Molecular & Cellular Biosciences
Molecular Genetics & Genomics
Molecular Medicine & Translational Science
Pre-health

Courses of Instruction

BMSC 620 – Roots of Health Inequity (2). The Roots of Health Inequity course is designed to examine the social processes that produce health inequities in the distribution of disease and illness. In this course, students will strategize more effective ways to act on the root causes of health inequity and discuss approaches to remove health inequities. A combination of online modules and in-class discussions will be used. This course is recommended for all Biomedical Science Pre-Health students. *Typically offered in summer terms.*

BMSC 700 – Independent Study (1-9). This course allows an interested student to pursue a topic covered in another class in greater depth under the guidance of a faculty member. The faculty member will work with the students to clarify the expectations; usually the course requires a combination of extensive reading, tutorial sessions, and a written paper. *May be repeated.*

BMSC 701 – Medical Career Path I (1). This course is designed for individualized career exploration, serve as an adjunct to career mentoring and provide students with a reasonable path/map for career goals. They will learn about professionalism, explore real life opportunities for building their professional portfolio and pathway to medical licensure and practice of medicine. *Satisfactory/Unsatisfactory*.

BMSC 702 – Medical Career Path II (1). This course is designed as a continuation of individualized career exploration, serve as an adjunct to career mentoring and provide students with a reasonable path/map for career goals. They will learn about professionalism, explore real life opportunities for building their professional portfolio and pathway to medical licensure and practice of medicine. *Satisfactory/Unsatisfactory*.

BMSC 705 – Problem Based Learning I (1). Small group sessions designed for post-baccalaureate student interested in healthcare professions. These weekly sessions are designed to introduce students to basic history taking and clinical reasoning skills and the integration of basic and clinical science patient care. Topics on ethics, professionalism and the doctor-patient relationship are discussed. A combination of case studies, reading assignments, course notes, group discussion and group presentations will be used.

BMSC 706 – Problem Based Learning II (1). Small group sessions designed for post-baccalaureate student interested in healthcare profession and who have completed BMSC 705. These weekly sessions are designed to integrate history taking skills and basic science into more advanced clinical reasoning. Students will be asked to use patient history, as well as laboratory data and imaging to solve weekly cases. In addition to topics on ethics, professionalism and the doctor-patient relationship, issues regarding health equality and high value health care will be discussed. A combination of case studies, reading assignments, course notes, group discussion and group presentations will be used. *P—BMSC 705*

BMSC 707/708 – Topics in Biomedical Science (1-6). This course will consider current topics in Biomedical Science that are not considered in regular courses. Course

requirements and grading may be based on participation written assignments or hands-on projects. Content will vary.

BMSC 709 – Special Topics (1-9). Designed for a group of students interested in a timely topic, or in a topic not covered in other coursework. This course may also be used to test a new course prior to its incorporation into the standing curriculum. *May be repeated.*

BMSC 710 – Human Gross Anatomy (4). A regional and systemic approach to the study of human gross anatomy, incorporating cross-sections, x-ray films, CT and MRI scans with clinical implications. *Course fees may apply. Typically offered in spring terms.*

BMSC 711 – Medical Genetics (3). Introduction to the principles and clinical evaluation of human genetic diseases. Covers modes of inheritance, etiology, characteristics, epidemiology, pathogenesis, and clinical features of a wide variety of medical genetic disorders. Procedures for diagnostic confirmation (cytogenetic, molecular, biochemical), considerations for management, and aspects of genetic counseling are presented. Advanced math skills, specifically an understanding of probability and basic statistics, are encouraged. *Typically offered in fall terms.*

BMSC 712 – Foundations of Biochemistry (3). Conducted as a combination of lectures, case studies, reading assignments, course notes, and group conferences. The sequence of topics is: a) protein structure, b) enzyme mechanisms, c) bioenergetics, d) signal transduction, e) intermediary metabolism and f) interorgan metabolism. The principles of each topic are discussed in relation to clinical disease entities, e.g. protein structure: hemoglobin/sickle cell anemia/sickle cell hemoglobin/sickle cell disease due to abnormal hemoglobin structure. *Typically offered in summer and fall terms.*

BMSC 713 – Applications of Epidemiology (4). This course is designed to give students an introductory understanding of the concepts of epidemiology as it applies to public health. The course will also help students understand and evaluate the research reported by others, and apply epidemiologic concepts to public health practice. The course will cover topics such as measures of disease occurrence and association, epidemiologic study design, threats to validity, data interpretation, and reporting research results. Application of epidemiological principles to contemporary public health challenges will be introduced throughout the course. *Typically offered in spring terms.*

BMSC 721 – Foundations of Clinical Pharmacology (3). Foundation of Clinical Pharmacology is a 3 credit hour course designed as a basic translational scientific course to provide pre-health students a strong foundation in basic concepts of pharmacology necessary for clinical practice. This course specifically designed for pre-health master students who would like to pursue medicine as medical doctors or physician assistants. The students who enroll in this course should have basic knowledge of biochemistry to be able to understand the lectures and class discussions. This 16-week course discusses the Drug-receptor concept, pharmacokinetics, drug metabolism and transport, pharmacodynamics, pharmacogenomics, assessment of drug effects, drug interaction, drug therapy in special populations, and drug discovery and development.

BMSC 723 – Foundations of Clinical Neuroanatomy (3). Foundations of Clinical Neuroanatomy is a 3-credit hour course designed to introduce students in the pre-health program to the structure, organization, and function of the human nervous system, with application both to clinical reasoning and basic science inquiry. Students should have a strong foundation in biology; anatomy and physiology; organic, and biochemistry. This 16-week course will explore neuroanatomy from the cellular to systems level, focusing on anatomical and functional divisions, neuroanatomical circuits and how communication between them is mediated, as well as how perturbations to these system at any level can lead to clinical deficits.

BMSC 795 – Project (1-9). A written review of a scholarly topic or project in biomedical sciences, developed in consultation with the student's graduate advisor. *Satisfactory/Unsatisfactory*.

BMSC 796 – Thesis Research (1-9). Lab research in all areas of biomedical science. This course is taken in support of research done to fulfill degree requirements for the Master's degree in Biomedical Science. *May be repeated. Satisfactory/Unsatisfactory*.

CANCER BIOLOGY (CABI)

Program Director	Steve Kridel
Professors	Rebecca Alexander, Ulrich Bierbach, Waldemar Debinski, Cristina Furdui, Patricia Gallagher, William Gmeiner, Martin Guthold, Colleen Hanlon, Bruce King, Greg Kucera, Hui-Kuan Lin, Hui-Wen Lo, Frank Marini, Mikhail Nikiforov, Boris Pasche, Fred Salsbury, Shay Soker, Peiqing Sun, Ann Tallant, Pierre Triozzi, Kounosuke Watabe, Mark Welker, Wei Zhang
Associate Professors	Katherine Cook, Gagan Deep, Karen Haas, Paul Jones, Steve Kridel, George Kulik, Linda Metheny-Barlow, Lance Miller, Xin Ming, David Ornelles, Tim Pardee, Neveen Said, Yusuke Shiozawa, Ravi Singh, David Soto Pantoja, Umit Topaloglu, Pierre Vidi, Dawen Zhao
Assistant Professors	Elizabeth Alli, , Guangxu Jin, Bethany Kerr, Liang Liu, , Fei Xing

Overview

The Cancer Biology graduate program was established in 1997. The graduate training program of the Department of Cancer Biology is designed to prepare students for future research careers focused on the issues relevant to human cancer. Applicants must have completed college-level fundamental courses in biology, and general and organic chemistry. Courses in physics and mathematics through calculus are encouraged, but not required.

Students enter the Cancer Biology training program through the Molecular and Cellular Biosciences (MCB) track. During the first year, in addition to the MCB common curriculum, students considering the Cancer Biology training program should consider taking one or more of the following electives: MCB 721 Basic Concepts in Cancer Biology, MCB 722 Basic Concepts in Cancer Research, and MCB 723 Topics in Cancer Biology. If not taken as electives in Year 1, students matriculating in the Cancer Biology training program will be required to complete these courses in subsequent years. Additional coursework in subsequent years will include Advanced Topics in Cancer Biology, Statistical Experimental Design, Cancer Cell Biology, Tutorials in Cancer Biology, and elective courses of the students' choice. Students also participate in the Cancer Biology seminar series.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Courses of Instruction

MCB Track Electives

MCB 721 – Basic Concepts in Cancer Biology (2). This course will cover fundamental concepts in cancer biology including etiology, genetic abnormalities, gene expression reprogramming, signal transduction aberration, and stem cell regulation in various tumor types, such as, cancers of the breast, prostate, lung, CNS, lung, ovary, and bladder. *The course is open to all students.*

MCB 722 – Basic Concepts in Cancer Research (2). Over the last half century scientists have generated a complex body of knowledge illuminating the origins of cancer and revealed it to be a dynamic interplay between the genome and the cellular environment. MCB 722 is a hypothesis-driven and problem solving-based course that explores this interplay and the requirements for malignant transformation. This course is offered in the spring term. *The course is open to all students in thesis driven tracks and required for all graduate students in cancer biology (CABI). Students not performing thesis research are able to register but should recognize the course requires an understanding of experimental design and data analysis for course assignments.*

MCB 723 – Topics in Cancer Biology (2). Teaches students how to evaluate and communicate scientifically in the area of cell biology and cancer. Examples are taken from all areas of cancer in this advanced course. Uses current peer-reviewed journal articles to teach fundamental concepts and act as a medium for allowing the students to communicate ideas with an emphasis on presentation skills. *Typically offered in the spring term. Intended for all graduate students in cancer biology (CABI); open to students in other tracks or programs.*

CABI Advanced Courses

CABI 701/702 – Cancer Biology Seminar Series (1). The course will consist of weekly student and postdoctoral presentations to the Cancer Biology faculty and their peers based on their ongoing research projects. Required of all students who matriculate in Cancer Biology starting in their second year and continuing throughout their training period. Students and postdoctoral fellows will be expected to present at least once per year. Emphasis will be based on developing presentation skills and learning to critique colleagues in a professional manner. *Satisfactory/Unsatisfactory.*

CABI 705 – Cancer Cell Biology (3). This is an intensive treatment to learn how to critically review the literature and requires the writing of a proposal that is critically reviewed. The course covers apoptosis, cell-cycle, angiogenesis, cancer genomics, metastasis, cancer immunology, and tumor suppressor genes. The translational aspects of research are emphasized.

CABI 707/708 – Topics in Cancer Lecture Series (1). A weekly lecture series taken during the second year. Each week throughout the fall and spring terms, a different topic in the clinical presentation, course, and treatment of human malignancies is presented. Designed to be a comprehensive overview of clinical oncology for clinical medical and radiation oncology fellows and cancer biology graduate students. *Satisfactory/Unsatisfactory.*

CABI 711/712 – Advanced Topics in Cancer Biology (1). Focuses on new and important aspects of research in cancer biology with an emphasis on the current

literature. Themes are chosen by the course director and the students. A topic is selected for presentation by each student; with the help of the course director, the student prepares a short lecture to introduce the topic, assigns two key papers for participants to read, and provides a supplemental reading list. The following week, the student leads a discussion of key experimental findings. Broad participation from faculty, postdoctoral fellows, and graduate students is encouraged. *Satisfactory/Unsatisfactory*.

CABI 713/714 – Cancer Biology Tutorials (2). Focuses on specific topics related to cancer predisposition, development, progression, and treatment. Topics include, but are not limited to, DNA damage and repair, damage signaling, cell death response, cell cycle checkpoint control, animal models and cancer treatment. The purpose of the tutorial is to provide an opportunity to discuss one of the above-mentioned topics in more detail than is possible in an overview-based lecture. The topic for upcoming terms will be determined by the faculty. The class is a combination of lectures providing background information and student presentations introducing specific topics and related research articles in the field, followed by group discussions. Attendance and at least one full length presentation are mandatory to obtain credit.

CABI 716 – Special Topics: Teaching in the Small Group Setting (2). Teaches students how to use a problem-based interactive approach to facilitate student self-learning. Introduces students to general methods of teaching with a focus on teaching in the small group setting of a literature-based course. Topics covered include teaching skills for reading scientific papers, oral presentation techniques, and scientific writing. Each student facilitates two weeks (4 class sessions) of the course including in-class participation as well as assisting with the written evaluation portion of the class.

CABI 718 – Introduction to Radiation Biology (3). Focuses on the biological changes which follow the interaction of ionizing and non-ionizing radiation with living matter. Emphasis is on the role of ionizing radiation in the treatment of cancer, mechanisms of radiation-induced carcinogenesis, and changes in normal and tumor cells at the molecular, cellular and tissue levels.

CABI 723/724 – Research in Cancer Biology (1-9). Opportunities for investigation in a variety of the facets of cancer biology under the guidance of staff members. *Satisfactory/Unsatisfactory*.

CABI 730 – Approaches to Cancer Prevention and Treatment (2). This elective course will offer an overview of various methods to intercept cancer. The overall goals are to provide a mechanistic understanding of current anti-cancer strategies and to introduce tools for the discovery and development of novel approaches. It is intended for graduate students interested in: 1) relating basic science mechanisms to preventing or treatment cancer, 2) exploring translational cancer research, and/or 3) understanding the clinical applications of anti-cancer drugs. *P—MCB 701 and MCB 702 (or equivalent) or POI.*

CABI 740 – Omics Data: Generation, Analysis & Exploration (3). This course will provide a firm foundation in central concepts related to large-scale "omics" data generation, structure, analysis and mining. An emphasis will be placed on teaching students practical know-how via familiarization with robust tools and data resources. Topics to be covered in blocks: 1) basic introduction to R programming and utilization of

common R scripts for data generation and visualization; 2) germline/somatic mutation detection and analysis, common tools and public data repositories; 3) transcriptomics, including RNAseq and single cell RNAseq, clustering and gene ontology enrichment analysis, TCGA/GDC, cBioPortal and FireBrowse tools and data repositories; 4) epigenetics, including DNA methylation detection and analysis, and Chip-Seq/ENCODE resource; 5) proteomics/metabolomics; and 6) functional genomics approaches, CRISPR/Cas9, and gene discovery. *P- POI*.

CLINICAL RESEARCH MANAGEMENT (CRM)

Program Director	Ralph D'Agostino Jr.
Professors	Ralph D'Agostino Jr., Nancy King
Associate Professors	Elizabeth Jensen, Umit Topaloglu
Assistant Professors	Lucy McGowan, Nate O'Connell, Anna Snavely, Jamie Speiser
Adjunct Graduate Faculty	Joseph Andrews, Allison Booth, Michael Booth, Suzanne Cook, Lori Flores, Dan Fogel, Lyn Hardy, Carol Hayes, Carla Lema-Tomé, Jim Kremidas, Beth Loots, Patrick McGowan, Rebecca Neiberg, Mary Shatzoff, Mysha Sissine

Overview

Clinical research management is a vast and expanding field that involves the processes by which products (drugs, devices, biologics) and treatment protocols are developed to improve patient care. Clinical research management continues to evolve into a more global and complex set of integrated research and business processes. This online Master of Science in Clinical Research Management (CRM) program will provide participants with state-of-the-art information on clinical, regulatory and business requirements in the development of new therapeutics and conduct of clinical trials. Designed for working clinical research professionals, or those in a related field, this degree program expands participants' knowledge of drug and medical device development, clinical trial conduct, monitoring, and the business, ethical and legal perspectives of the clinical research industry.

The Master of Science in Clinical Research Management (CRM) online program will be an accelerated, intense course of study focused on leading transformative change in the clinical research industry as well as the National Institutes of Health (NIH) supported clinical research environment. The program's faculty and participants will have deep experience in the clinical research industry and will be fully engaged in addressing the gaps and constraints of the current clinical research system as we look at our systems and others around the globe. The material will be tailored to this industry for current and future leaders. This program will provide a range of learning experiences that add up to a powerful transformative experience.

Clinical research management includes studies in the following areas:

1. Scientific Concepts and Research Design
2. Ethical and Participant Safety Consideration
3. Medicines Development and Regulation
4. Clinical Trials Operations (GCPs)
5. Study and Site Management

6. Data Management and Informatics
7. Leadership and Professionalism
8. Communication and Teamwork

A minimum requirement of 20 months of part-time online work will be needed for the master's degree. Students will learn to explore the commercial and ethical dimensions of medical innovation and be prepared to lead in clinical research while earning 35 credit hours.

The program will culminate with the Capstone Experience in which students will complete an independent or group project that spans the duration of the CRM program. We ask each participant to identify a critical challenge related to healthcare while applying to the CRM program and confirm the selection early in their coursework. The challenge could relate to his/her organization or to a personal interest. Throughout the CRM, each student will work collaboratively with a variety of people including their CRM peers, professional colleagues, course faculty, advisors, and chairs, integrating various perspectives across healthcare sectors to develop possible solutions to his/her challenge.

Participants draw upon knowledge and skills from their coursework with an emphasis on collaborating across healthcare sectors, considering strategic and ethical implications, communicating effectively and developing feasible, viable, and transformative solutions.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: Students are required to take a minimum of 35 graduate course credit hours, with 4 hours in an elective area. Students are required to take the following set of courses:

CRM 701, CRM 702, CRM 703, CRM 704, CRM 711, CRM 712, CRM 715, CRM 721, CRM 722, CRM 731, and CRM 732

Courses of Instruction

CRM 701 – Research Design and Methods in Clinical Research (3). The Research Design and Methods in Clinical Research course addresses scientific, clinical, and regulatory concepts required in medical agent and/or device development. Students will explore ethical design and methods used in clinical research, measurement issues in conducting research across diverse populations, and appropriate statistical measurement and analysis for given study designs. Issues concerning practical considerations and rare disease studies will also be included. Intended for all graduate students in Clinical Research Management (CRM). *C—CRM 702.*

CRM 702 – Data Analysis and Interpretation in Clinical Research (3). The Data Analysis and Interpretation in Clinical Research course introduces the principles of biostatistical methods used in biomedical and public health research. Analysis of clinical

trials data and interpretation of statistical results in biomedical studies will be emphasized. Intended for all graduate students in Clinical Research Management (CRM). *C—CRM 701.*

CRM 703 – Leadership and Professionalism I (1). The Leadership and Professionalism I course covers essential skills and knowledge areas related to clinical research management. Participants assess their own leadership skills and knowledge and develop a specific plan for leadership skills development. This course also develops skills for team management and leading an organization toward goals accomplishment. Participants acquire knowledge and develop skills through case studies, experimentation with their own behaviors, and feedback from faculty and peers. Intended for all graduate students in Clinical Research Management (CRM).

CRM 704 – Leadership and Professionalism II (1). The Leadership and Professionalism II course covers essential skills and knowledge areas related to clinical research management. Participants assess their own leadership skills and knowledge and develop a specific plan for leadership skills development. This course also develops skills for team management and leading an organization toward goals accomplishment. Participants acquire knowledge and develop skills through case studies, experimentation with their own behaviors, and feedback from faculty and peers. Intended for all graduate students in Clinical Research Management (CRM). *P—CRM 703.*

CRM 711 – Ethical and Participant Safety Considerations (3). The Ethical and Participant Safety Considerations course examines clinical trials management topics within an ethical context. Ethical issues confronted by most organizations and the approach to ethical decision making are discussed. Topics include conducting research with vulnerable populations, conflict of interest, and scientific misconduct. Students will develop study protocols, progress reports, journal publications, and scientific presentations. The course may also provide opportunities for students to develop the ethical aspects of any study protocols, journal publications, or scientific presentations they prepare in other courses in the program. Intended for all graduate students in Clinical Research Management (CRM).

CRM 712 – Medicines Development, Regulation, Industry (3). The Medicines Development, Regulation, Industry course explores legal and regulatory decision making as well as the structure and role of key U.S. and international regulatory bodies. Participants explore how healthcare is regulated. Risk management, public health, and product/drug regulations are discussed. Other topics include changes to health care and advancement in technology. Intended for all graduate students in Clinical Research Management (CRM).

CRM 715 – Capstone Experience (1-3). The Capstone Experience course is an independent or group project that spans the duration of the Clinical Research Management graduate program. Participants identify a critical challenge related to healthcare and work collaboratively with peers, colleagues, course faculty, advisors, and

chairs to integrate various perspectives across healthcare sectors and develop possible solutions to the identified challenge. Participants draw upon knowledge and skills from their coursework with an emphasis on collaborating across healthcare sectors, considering strategies, and ethical implications, communicating effectively, and developing feasible, viable, and transformative solutions. Intended for all graduate students in Clinical Research Management (CRM).

CRM 721 – Clinical Operations and Project Management (3). The Clinical Operations and Project Management course integrates project management principles and clinical operations by exploring regulatory, policy, ethical, and practical considerations associated with the engagement, recruitment, retention, and interaction with human research subjects. Operational planning of clinical trials are discussed, including budgeting, study timeline, site evaluation and selection, study initiation, content and timing of monitoring visits, quality assurance, study closure procedures, decision-making models, cross cultural competency, and interdisciplinary team dynamics. Intended for all graduate students in Clinical Research Management (CRM). *P—CRM 701 or POI*.

CRM 722 – Clinical Studies Development (2). The Clinical Studies Development course examines the nonclinical, clinical, commercial, regulatory, and risk assessment strategies required to develop a clinical development plan for an approvable, marketable new therapeutic or device. Intended for all graduate students in Clinical Research Management (CRM).

CRM 731 – Quality Systems and Risk Management (3). The Quality Systems and Risk Management course explores how to manage risk and safety assessments to ensure quality in clinical research. Students will examine how management concepts and training methods are used in managing risk and ensuring quality. Other topics include post marketing for new products and data quality assurance methods. Intended for all graduate students in Clinical Research Management (CRM).

CRM 732 – Data Management and Informatics (3). The Data Management and Informatics course provides an introduction to database design, data management, quality assurance and technology assessment in clinical research administration. Topics include establishing budgets for clinical trials, methods for tracking participants and findings, complexities of ethical data management, and evaluation of data sources and data quality. Intended for all graduate students in Clinical Research Management (CRM).

Electives for Strategic Leadership/Communications Concentration

CRM 751 – Conflict Resolution and Negotiations (2). This course studies key management concepts and roles of management and how they apply in successful, dynamic organizations. Students will examine the competencies of effective managers in developing customer focus, planning, selecting and developing individuals and teams, communicating, managing resources, using technology and being adaptable. Additional

topics include the theory and process of effective negotiation and various team building and conflict resolution strategies in a variety of contexts.

CRM 752 – Design Thinking (2). In this course, participants will learn how to solve complex business challenges and promote industry leadership with a systematic approach to creativity and innovation. Design will be used as a practical, everyday process to spur innovation, organic organizational growth, and effective strategy implementation. Topics include the best procedures for generating and testing concepts, how to engage customer feedback and solicit new ideas, and testing assumptions to discover which problems/solutions matter the most to customers.

CRM 753 – Business Communication Skills for Healthcare Professionals (2). This course focuses on developing effective business communication skills for professionals in managerial/senior roles in healthcare and life sciences. Writing scenarios include: preparing briefings and updates using presentation software and/or briefing packets; organizing data; constructing proposals and reports; solicitations; coordinating projects via email; and drafting and editing group documents. On-the-job examples from each participant's workplace are used throughout the course.

Electives for Operations Concentration

CRM 761 – Project Management (2). This course integrates project management principles, decision-making models, cross cultural competency, and interdisciplinary team dynamics to facilitate effective and efficient conduct of clinical trials. The curricula is designed to take participants through the entire life cycle of a project, while assessing organizational, cultural, and personnel factors that influence successful clinical trial performance.

CRM 762 – Financial Management for Clinical Research Professionals (2). This course focuses on the area of financial management as applied to healthcare and life sciences organizations. The emphasis in this course is to apply the principles and concepts of financial management to health and life science providers that represent innovative new structures and organizations, such as Accountable Care Organizations (ACOs) offering integrated patient care. Participants will gain competency in the application of financial and analysis tools and techniques internationally through a case study approach. Upon completion of this course, participants will be able to utilize a comprehensive range of tools and techniques that can assist them in future financial decision making in complex, multinational healthcare and life science organizations.

CRM 763 – Technical Writing for the Regulatory Professional (2). This course focuses on the technical writing skills required for the regulatory professional. Students will construct coherent written regulatory documents using "Plain Language" techniques, synthesize valid, scientific information to support regulatory decisions, and appraise supporting regulatory documents and exhibits for appropriate use in argument development. Additional topics include how to constructively critique, evaluate, and revise written documents and oral presentations.

COMPARATIVE MEDICINE (COMD)

Program Director	Susan Appt
Professors	Mark Cline, Nancy Kock, Tom Register, Carol Shively
Associate Professors	Susan Appt, David Caudell, Matthew Jorgensen, Kylie Kavanagh
Assistant Professors	Heather DeLoid, , Melaney Gee, Matt Quinn

Overview

The Section on Comparative Medicine in the Department of Pathology offers a program leading to the Master of Science (MS) degree in Comparative Medicine for individuals that have previously achieved the MD or DVM degree. The MS degree has been offered since 1964. Students enrolled in the Comparative Medicine program typically conduct research on the Clarkson campus.

Research is an important facet of departmental activities, and research training is emphasized in its educational programs. Investigative efforts focus on animals as models of human disease and the use of animals in biomedical research. Major interests include cardiovascular disease, cancer biology and risk assessment, diabetes and obesity, behavioral biology such as depression and anxiety, women's health/reproductive medicine, nutrition, comparative pathology, and radiation countermeasures.

There is an active interest in the biology and diseases of nonhuman primates as translational surrogates for the study of human diseases. Approximately 600 nonhuman primates of several species are maintained to provide ample opportunity for students interested in nonhuman primate biology. Other large animal models and rodents are also studied in collaboration with other biomedical research programs at Wake Forest University. A full description of research interests may be found by linking to the Department of Pathology/Section on Comparative Medicine https://school.wakehealth.edu/Departments/Pathology/Comparative-Medicine.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Courses of Instruction

COMD 703 – Diseases of Laboratory Animals (3). Naturally occurring diseases of laboratory animals are considered in depth. Lectures are organized by animal species and are designed to emphasize the prevalence and physiological and pathological expression of both infectious and metabolic/degenerative diseases. Additional emphasis is on the diagnosis and management of these diseases in the laboratory animal facility. Special topics, including disease surveillance, zoonoses, and strain differences in disease

susceptibility, are also presented. Offered every other year. *P—DVM or MD degree or POI*.

COMD 706 – Animal Models in Biomedical Research (3). Designed to provide the student with the current knowledge about animal models used in biomedical research. The major disease problems of man are discussed by organ system. For each disease problem, the advantages and disadvantages of animal models in current use are discussed. Both experimentally induced and naturally occurring diseases of animals are considered. Offered every other year. *P—POI*.

COMD 709, 710 – Advanced Topics in Comparative Medicine (1-5). An advanced lecture and student participation course dealing with areas of new knowledge in comparative medicine. *P—General biochemistry, general pathology, or equivalents*.

COMD 711, 712 – Comparative Pathology Conference (1). Necropsy cases are presented and discussed by postdoctoral fellows and staff. Management of current medical problems and the comparative aspects of the materials presented are emphasized.

COMD 713, 714 – Research (1-9). Research in a variety of topics in comparative medicine, including research in preparation for the master's thesis and the doctoral dissertation. *Satisfactory/Unsatisfactory*.

COMD 715 – Ultrastructural Pathology (1). This Course provides didactic and case-oriented training in basic principles of biomedical transmission electron microscopy and ultrastructural anatomy of major organ systems in animals and humans, and advanced case studies of ultrastructural pathology of animal and human diseases. Infectious, metabolic, neoplastic, toxic and other disease processes are covered. *P—POI*.

COMD 716 – Toxicologic Pathology (1). This course provides didactic and case-oriented training in basic principles of toxicologic pathology of major organ systems in animals and humans, supplemented by case studies of regulatory and forensic toxicology in animals. *P—POI*.

COMD 717/718 – Comparative Medicine Journal Club and Scientific Review (1). A key aspect of biomedical and translational medicine is the use of animal models. The appropriateness of the species, model, methods and attention to welfare is a knowledge base that has to be learned. This course will cover the application of large and small animal models in preclinical research and discuss them in a journal club and research seminar format. The student will be expected to present an article that utilizes animals in research and critically review the science. The student will be expected to review the weekly journal club article, attend research seminars, and actively participate in discussions in person. Typically offered in the fall and spring terms. *Satisfactory/Unsatisfactory*.

GENETIC COUNSELING (GENC)

Program Director	Emily Lisi
Assistant Program Director	Lauren Baldwin
Medical Director	Amelia Kirby
Professors	Tim Howard, Tamison Jewett, Laura Veach
Associate Professors	Nichole Allred, Amelia Kirby
Assistant Professors	Katie Duckworth, Emily Lisi
Adjunct Graduate Faculty	Aly Athens, Alexandra Bailey, Peggy Berry, Daragh Conrad, Kristen Deak, Shelley Dills, Karen Corneliussen, Adel Gilbert, Mariah Gleason, Megan Irby, Dana Mittag, Gretchen Rosso, Christy Stanley, Thuy My Vu, Kelly Warsinske

Overview

The Genetic Counseling graduate program at Wake Forest University is designed to train students for a healthcare career in genetic counseling. The program involves didactic curriculum, clinical rotations, and a capstone research requirement. Students will attain a deep understanding of the etiology and pathogenicity of hereditary disease, clinical genetic and genomic testing strategies, and current bioethical issues associated with advances in genomic medicine. Additionally, students will develop advanced counseling skills needed to facilitate patient decision-making and assist patients in coping with genetic disease. Progression of clinical skill development will be achieved through rotations through various clinical settings throughout the region which are supervised by certified genetic counselors. The capstone requirement for this degree has two options: a clinical research track and a community outreach track. The former involves conducting a clinical research study and disseminating the results in a publishable manuscript, while the latter involves planning and implementing a genetics education project to meet an identified need in the community. At graduation, students will have developed the Practice-Based Competencies required by the Accreditation Council of Genetic Counseling (ACGC) and will be prepared to take the American Board of Genetic Counseling (ABGC) certification exam. This program will emphasize critical review and reflection of the current practice of genetic counseling and how genetic counselors can best meet the growing need for patient education and support surrounding genomic medicine now and in the future.

Degree Requirements: Please see “Requirements for the Master of Science Degree” in the “Degree Requirements” section of the Graduate Bulletin.

Courses of Instruction

GENC 701 – Introduction to Genetic Counseling (2). Introduction to the foundations of genetic counseling with an emphasis on practical skill development. Topics to include: history of the practice, code of ethics, pedigree drawing and analysis, risk assessment, contracting with clients, agenda development, genetic counseling focus areas, and technologies used in genetic counseling practice. Includes clinical observations. *P – POI. This course is only open to Genetic Counseling MS students.*

GENC 705 – Professional Issues in Genetic Counseling (2). A seminar course developed to address professional issues that arise as a practicing genetic counselor, including: professionalism, job searching, CV development, negotiation techniques, billing and reimbursement, stress management, and self-care techniques. *P - GENC 701.*

GENC 711 – Human Genetics for the Genetic Counselor (3). This course will provide instruction on the principles of human genetics pertinent for the genetic counseling profession, including Mendelian and non-Mendelian inheritance, the central dogma, population and quantitative genetics, complex diseases, human variation and disease susceptibility, risk analysis, and mechanisms of cytogenetic abnormalities. *P – POI.*

GENC 712 – Medical Genetics (3). Introduction to clinical genetic counseling and management strategies for a variety of common genetic conditions including: chromosome abnormalities, imprinting disorders, trinucleotide repeat disorders, mitochondrial disorders, overgrowth conditions, neurogenetic conditions, hereditary cardiovascular conditions, etc. psychiatric genetics, etc. Elements of the medical history intake and dysmorphology will also be discussed. *P - GENC 711.*

GENC 713 – Prenatal Genetics (2). This 2-credit course (half-term) provides an introduction to the practice of prenatal genetic counseling, including typical pregnancy experiences, indications for referral, preconceptual and prenatal screening modalities, prenatal diagnostic testing, ultrasound anomalies, teratogenic exposures, assisted reproductive technologies, and fetal therapy. *C - GENC 721.*

GENC 714 – Psychosocial Impact of Genetic Disease (3). This course supports the development of more advanced counseling skills, with emphasis on genetic counseling strategies and techniques and appreciation of psychosocial impacts of genetic disease across the lifespan, dynamics of grief and bereavement, and crisis intervention. *P - GENC 701 and ARCH 703, or POI.*

GENC 718 – Clinical Genetic Testing in the 21st Century (2). This course is designed to give students an in-depth understanding of the process and applicability of clinically available genetic testing, including cytogenetic testing (karyotype, chromosomal microarray, SNP array), molecular genetics (Sanger sequencing, Next generation sequencing, Panel testing, whole exome/genome sequencing), and biochemical testing strategies. Emphasis will be placed on available bioinformatics strategies for variant interpretation. The role of the genetic counselor in the clinical laboratory will also be explored. *P – POI.*

GENC 721 – Embryology and Abnormal Fetal Development (2). This half-term course covers human development from fertilization to birth through the lens of a genetic counselor. The influence of genes, gene variants, epigenetics, and teratogens will be explored. Topics will include how these influences impact normal and abnormal development in embryogenesis, neural tube folding, limb formation, cardiac maturation, craniofacial and musculoskeletal development. Emphasis will also be placed on fetal anomalies that are identified in prenatal screening.. This class will be held online with both live virtual classes and online learning. *C - GENC 713.*

GENC 722 – Basic Concepts in Cancer Genetic Counseling (2). This course will cover fundamental concepts in cancer biology including etiology; genetic abnormalities; gene expression reprogramming; cancers of the breast, ovary, and colon, etc. The course will provide emphasis on the practice of oncology and hereditary cancer syndromes and their management. *P - GENC 701 or POI.*

GENC 732 – Precision Medicine and the Future of Genomics (2). Seminar course discussing current hot topics in genetics and genomics and future directions of the field of genetic counseling using recently published journal articles and societal position statements. Topics will include epigenetics, pharmacogenomics, metabolomics, studies of the microbiome, and gene editing. Includes both didactic instruction from faculty as well as student literature review and presentation on relevant topics. *P - GENC 701 and GENC 711, or POI.*

GENC 734 – Healthcare Delivery Systems/Public Health (2). Designed to help students develop an appreciation for current health and social policy, local and national public health resources, population-based screening methods and their impact, and healthcare delivery and insurance models both in the United States and internationally. Includes lectures from experts in the field and potential implications on changes to healthcare policies. *P – POI.*

GENC 771/772 – Genetic Counseling Seminar (1). Weekly seminar involving review of published article pertinent to the genetic counseling field, lectures from faculty, and/or patient panels. Students required to critically analyze a paper each week with a brief written analysis submitted to the learning management system. Each student is required to pick an article, have it approved by the course director, and present the article at one journal club per term. *P – POI.*

GENC 781/782 – Clinical Rotation (3-4). Clinical training and fieldwork experiences with opportunities to have first-hand experience with individuals and families affected by a broad range of genetic conditions. Clinical rotation experiences will include, but are not limited to: prenatal, cancer, general genetics, metabolic genetics, cardiovascular genetics, neurogenetics, telegenetics, and others. Clinical Rotation A will encompass 4 weeks of full-time, on-site training (or equivalent). Clinical Rotations B and C will involve 2-3 days a week of training for 8 weeks each. Clinical Rotations D and E will involve 4 days a week of training for 4 weeks. *This course is only open to Genetic Counseling MS students.*

GENC 784 – Simulated Patient Experiences in Genetic Counseling (1). This course is required in second (Spring 1) and last (Spring 2) terms for Genetic Counseling students. Students will have the opportunity to provide partial or full genetic counseling sessions to simulated patients for a wide variety of indications through the Center for Experiential and Applied Learning at Wake Forest. The patient encounters will be videoed and recorded, with feedback provided to students by the program faculty to promote learning and skill growth in a safe environment. *This course is only open to Genetic Counseling MS students.*

GENC 791 – Introduction to Research (2). Overview of clinical research practices, including both qualitative and quantitative experimental design. Topics include critical review of the literature, research idea development, sound experimental design, IRB submission, data collection, data interpretation, and manuscript preparation. *P – POI.*

GENC 792/793 – Research (1-9). Students will have two options to fulfill the research requirement for the genetic counseling program. Option 1 will involve the creation and execution of a novel clinical research study with a resulting publishable manuscript. Option 2 will entail conducting a significant project to provide to the community around genetics or genetic counseling education. Each term, beginning in Spring I, students will have specific goals and deadlines to meet to achieve a satisfactory grade for their capstone requirement. *P - GENC 791. This course is only open to Genetic Counseling MS students.*

HEALTH DISPARITIES IN NEUROSCIENCE-RELATED DISORDERS (HDND)

Program Co-directors	Alain Bertoni, Carol Milligan
Professors	Ronny Bell, Alain Bertoni, Cheryl Bushnell, Michael Cartwright, Dwayne Godwin, Carol Milligan, Laura Veach, Chris Whitlow
Associate Professors	Sabina Gesell, Kathleen Hayden, Christina Hugenschmidt, Timothy Hughes, Ken Kishida, Roy Strowd, Rebecca Wells
Assistant Professors	Joost Maier
Adjunct Graduate Faculty	Leslie Allison

Overview

Disparities in presentation, care, severity, and disability for neurological disorders such as stroke, Alzheimer's disease, epilepsy and Parkinson's have been identified in U.S. minority populations. Addressing health disparities becomes critical when considering the cost and burden on society of unequal care and treatment of what will be more than 50% of our society by 2060. The goal of the Health Disparities in Neuroscience-related Disorders master's program is to recruit students from diverse backgrounds into Health Disparities research program. The program builds on unique resources at Wake Forest University that make it an ideal institution for students to succeed.

The product of this program will be a solid foundation in Neuroscience, Epidemiology and Biostatistics training and hands-on, practical research projects. Another goal is to interest students in a career choice in health disparity and to develop a love of neuroscience and understanding neurological disorders to motivate students to consider moving onto PhD and MD programs and careers addressing these important issues.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: The program includes required coursework, a thesis research project, mentoring, and career development. A plan of study is available from the program co-directors.

HEALTHCARE LEADERSHIP (HCL)

Program Director	Bret Nicks
Professors	Bret Nicks, John Sanders, Tom Wierzba
Adjunct Graduate Faculty	Eddie Alcorn, Bill Atkinson, Amy Bell, Darren Coleman, Forrest Faison, Dan Fogel, Jennifer Houlihan, Kirk Jensen, Joel Lee

Overview

Healthcare is undergoing persistent, disruptive and increasingly rapid change. Visionary leadership is essential in the ongoing transformation required for healthcare organizations to continually improve the delivery of quality care in the midst of a dynamic and ever-changing environment. The Wake Forest Master of Science in Healthcare Leadership (HCL) will prepare leaders for the task of quality transformations and sustainability amidst inherent challenges and change. The program goes beyond the traditional MBA and MHA programs, integrating longitudinal leadership competency development focused on the specialized sector of healthcare.

In today's complex work environment, healthcare organizations need leadership that is dynamic, diverse and reflective of the communities in which they operate, the organizations and patients they serve, and increasingly global impact on health. Leadership development is needed to help achieve this balance. This program provides outstanding professional development along with affinity group access to explore solutions to current issues and future uncertainties within healthcare industries in a diverse cohort of healthcare experts.

If you seek to make a positive impact in the future of healthcare, the health of society, and establishing an incredible forward-reaching legacy, this is the program for you.

Healthcare Leadership includes studies in the following areas:

Leadership Essentials Skills Workshops
Strategic Thinking and Decision-Making for Healthcare Leaders
Healthcare Policy and Law: Past, Present and Future
Healthcare Leadership Journal Club
Financial Management in Healthcare Organizations
Quality Outcomes and Improvement
Marketing in Transformative Healthcare
Leveraging Big Data for Data-Driven Decision Making
Optimizing Healthcare Operations
Healthcare Leadership: Wins, Losses, and Lessons
Crossroads: Population and Global Health

A minimum requirement of 20 months of part-time online work will be needed for the master's degree which will also include 2 short (4 day) on-site residential sessions.

The program will culminate with the Capstone Experience in which students will complete a group project that spans the duration of the program. Students draw upon knowledge and skills from their coursework with an emphasis on collaborating across healthcare sectors, considering strategic and ethical implications, communicating effectively, and developing feasible, viable, and transformative solutions.

Degree Requirements: Please see "Requirements for the Master of Healthcare Leadership Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: Students are required to take a minimum of 35 graduate course credit hours. Students are required to take the following set of courses:

Courses of Instruction

HCL 701 – Healthcare Policy & Law: Past, Present, and Future (3). This course evaluates past and current political, legal, technological, and economic healthcare policy developments and critically examines the implementation of alternative methods of health services delivery and financing within multiple global healthcare systems. Students question assumptions, think creatively, and consider integrated patient care solutions to prepare for change and new paradigms within the global healthcare sector. In addition, this course will integrate legal and regulatory decision-making as well as the structure and role of key U.S. and international regulatory bodies.

HCL 702 – Leveraging Big Data for Data-Driven Decision Making (3). This course provides an overview of the methods and applications of therapy economics, biostatistics, and epidemiology in healthcare decision-making. Specific topics include: pharmaco-economics, decision analysis, comparative effectiveness research, and technology assessment; program evaluation; the critical review and interpretation of published epidemiological studies, institutional oversight of epidemiological research programs; and the key four steps of statistical analysis (identification of scientific programs or problems of interest, collection of the required data, analysis and summary of data, and generation of a conclusion). In this course, students will work collaboratively to develop and implement an analytical plan that relates to their Capstone Experience. *P—HCL 701; HCL 721.*

HCL 705 – Crossroads: Population and Global Health (3). This course prepares students to examine and respond to both challenges and opportunities to improve health within and across populations. The course explores the ethical issues confronted by most organizations and how to approach ethical decision making. In this course, students will: (1) Identify determinants of population health that impact health outcomes in a community and apply the essentials of public health practice to design low cost interventions; (2) Lead the formation and management of contemporary health care systems that consist of, and rely upon, diverse stakeholders in the organization and

delivery of community-based models of care; (3) Communicate effectively to constituencies both within and outside of the health system; (4) Articulate and apply frameworks for collecting, analyzing, and using data to inform decisions, facilitate care coordination, and improve health outcomes of targeted populations within and outside the health system; and (5) Develop effective collaboratives and support state and local public health. *P—HCL 701; HCL 721.*

HCL 711 – Healthcare Leadership Journal Club: Refining Yourself as an Organizational Leader (0.5). This Healthcare Leadership Journal Club: Refining Yourself as an Organizational Leader course will be conducted longitudinally throughout the program. The primary course focus is on the role of the students as current and future transformational leaders, and understanding and development of the skills required for these roles. It will incorporate attribute analysis and development to move beyond being positional leaders, focusing on many of the foundational attributes of successful leaders and the future projections of healthcare. This course will incorporate select readings on impactful leadership topics, integrated activities applying these topics and open discussion of each content application to the healthcare sector. Students will enroll in the course 4 terms, for a total of 2 credit hours. *P—HCL 701; HCL 721.*

HCL 712 – Healthcare Leadership: Wins, Losses and Lessons (3). This course focuses on the foundations of effective healthcare leadership seen through numerous examples of successes and failures and the unique insights gleaned through these endeavors. This course challenges learners to not only acknowledge their own leadership approach, but provide opportunities to analyze the attributes that led to the respective outcomes demonstrated. Topics include analysis of various healthcare business cases of various success, preparing analysis of respective cases, and constructing assessments and interventions. *P—HCL 701; HCL 721.*

HCL 713 – Health Leadership Skills Workshop I (1). This course is focused on the role of students as leaders in their current or future healthcare organizations. During the online course launch week, leadership essential skills workshops will be provided to enhance the leadership capacity of each student. This will serve as the foundation for developing and refining leadership characteristics and techniques. The workshops will parallel journal-club readings on topics such as conflict management, resiliency, effective communication, organizational culture, diversity, and inclusion. The workshops will also include self-assessment testing. Students will explore the meaning of value creation in healthcare organizations - how it relates to high performance, how it varies and is measured in different healthcare segments, and how it is embodied in the structure and performance on their own organizations. *P—HCL 701; HCL 721.*

HCL 714 – Health Leadership Skills Workshop II (1). This course is focused on the role of students as leaders in their current or future healthcare organizations. During the on-site residency experience, the leadership essential skills workshops will be provided to enhance the leadership capacity of each student. This will serve as the

foundation for developing and refining leadership characteristics and techniques. The workshops will parallel journal-club readings on topics such as conflict management, resiliency, effective communication, organizational culture, diversity, and inclusion. The workshops will also include self-assessment testing. Students will explore the meaning of value creation in healthcare organizations - how it relates to high performance, how it varies and is measured in different healthcare segments, and how it is embodied in the structure and performance on their own organizations. *P—HCL 701; HCL 713; HCL 721.*

HCL 715 – Capstone Experience (0.5-2.5). The Capstone Experience course is an independent or group project that spans the duration of the Healthcare Leadership graduate program. In this course, students identify a critical challenge related to healthcare and work collaboratively with a variety of people including their HCLs peers, professional colleagues, course faculty, advisors, and chairs, integrating various perspectives across healthcare sectors to develop possible solutions to his or her challenge. Students draw upon knowledge and skills from their coursework with an emphasis on collaborating across healthcare sectors, considering strategic and ethical implications, communicating effectively, and developing feasible, viable, and transformative solutions. *P—HCL 701; HCL 721.*

HCL 721 – Strategic Thinking and Decision-Making for Healthcare Leaders (3). This course examines principles and applications of strategic management and the change management applied to healthcare organizations. A structured approach to the strategic management process is explored, including methods for assessing key features of organization environments and competitive situations, approaches for developing where to engage in healthcare services and how to offer them, and processes for ensuring successful strategy implementation. The course will also foster the ability to integrate strategic concepts into actionable, forward-focused steps and apply principles to a variety of business models. Additional topics include basic economics; demand management; concepts of efficiency, production, and distribution of healthcare services; impact of regulation and reimbursement; and economic incentives in healthcare.

HCL 722 – Quality Outcomes and Improvement (3). This course explores the quality improvement drivers, principles, systems, and tools that help create a healthcare learning organization and includes topics on performance measurement and safety and the development of high-reliability organizations optimizing variation reduction, and efficiency. Additional topics include how quality improvement creates value; how to demonstrate the value of quality improvement to their colleagues; and how to ultimately develop a culture of learning within their organization. Students compare the learning needs of healthcare organizations to those in other industries, design and implement a quality improvement project within their own organization, and develop a "learning organization roadmap" for their organization. *P—HCL 701; HCL 721.*

HCL 731 – Financial Management of Healthcare Organizations (3). This course focuses on the area of financial management as applied to healthcare organizations. The course's emphasis is to apply the principles and concepts of health

financial management to health providers that represent innovative new structures and organizations, such as Accountable Care Organizations (ACOs) offering integrated patient care. Students will gain competency in the application of financial analysis tools and techniques internationally through a case study approach. The financial tools and techniques covered include: (1) working capital management and cash budgeting; (2) break-even analysis and contribution margin analysis using "what-if" scenarios; (3) pricing analysis techniques under different competitive conditions; (4) financial condition analysis using financial statements from international healthcare companies; (5) capital budgeting and cost of capital analysis techniques; (6) return on investment analysis techniques as applied to global healthcare investment ventures; and (7) financial forecasting of future cash flows. *P—HCL 701; HCL 721.*

HCL 732 – Marketing in Transformative Healthcare (3). In this course, students develop several essential marketing and customer-related skills, specifically in branding, product and services design, channel selection, pricing, and positioning. This course will include how to use data to make decision. Other topics include how to dissect marketing plans and exploration of approaches to healthcare customers and consumers. *P—HCL 701; HCL 721.*

HCL 733 – Healthcare Operations (3). This course examines the common failures around healthcare operations and introduces a framework to analyze current and future states and integrate emerging technologies with a global mindset. Topics include analysis of various operational challenges common in healthcare organizations today and developing a skillset to analyze, devise, implement, monitor and refine approaches to address those challenges. *P—HCL 701; HCL 721.*

INTEGRATIVE PHYSIOLOGY AND PHARMACOLOGY (IPP)

Program Director	Paul Czoty
Professors	Graça Almeida-Porada, Reto Asmis, Anthony Atala, Michael Berry, Colin Bishop, Don Bowden, David Carroll, Mark Chappell, Mark Cline, Suzanne Craft, Paul Czoty, Osvaldo Delbono, Debra Diz, Eric Donny, Matthew Edwards, Jim Eisenach, Carlos Ferrario, Jorge Figueroa, Patricia Gallagher, Randolph Geary, Bill Gmeiner, Dwayne Godwin, Leanne Groban, Rob Hampson, Colleen Hanlon, David Herrington, Tim Howard, Allyn Howlett, Sara Jones, Holden Ko, Nancy Kock, Greg Kucera, Paul Laurienti, Hui-Wen Lo, Frank Marini, Brian McCool, Stephen Messier, Shannon Mihalko, Michael Nader, Barb Nicklas, Pat Nixon, Christopher Porada, Linda Porrino, Wayne Pratt, Tom Register, Carol Shively, Thomas Smith, Shay Soker, Leah Solberg-Woods, Ann Tallant, Richard Weinberg, Jeff Weiner, Koudy Williams, James Yoo
Associate Professors	Susan Appt, Evgeny Budygin, David Caudell, Rong Chen, Katherine Cook, Tracy Criswell, James Daunais, Ryan Drenan, TanYa Gwathmey-Williams, Karen Haas, Jim Jordan, Matthew Jorgensen, Jeff Katula, Kylie Kavanagh, Ken Kishida, Nicole Levi-Polyachenko, Tao Ma, Jeff Martin, Gary Miller, Justin Moore, Kimberly Raab-Graham, Edgar Alfonso Romero-Sandoval, Hossam Shaltout, David Soto Pantoja, Andrew South, Allen Tsang, Jeff Willey, Liliya Yamaleyeva, Raghu Yammani
Assistant Professors	Heather Douglas, Mark Ferris, Robert Gould, Jamie Justice, Sam Lockhart, Shannon Macauley-Rambach, Miranda Orr, Snezana Petrovic, Matt Quinn, Ellie Rahbar, Jack Rejeski, Hooman Sadri

Overview

The Integrative Physiology and Pharmacology (IPP) graduate program at Wake Forest University is designed to train students for a research career in the physiological and pharmacological sciences. The IPP program has excelled in obtaining federal and foundational funding for many years, with dozens of well-funded investigators working in a highly collaborative research environment. Research interests of the IPP program include a strong emphasis on substance abuse, cardiovascular disease, regenerative medicine, cancer therapeutics, life-span physiology and neuropsychiatric disorders.

There are currently 28 PhD students in various stages of training, and there are more than 90 full-time primary faculty members.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Courses of Instruction

IPP 601 – Foundations of Pharmacology (3). This introductory course for MS students presents basic elements of pharmacology, with an emphasis on clinical and translational relevance of drug administration, distribution, metabolism, elimination and pharmacokinetics, and the pharmacodynamics of receptors and their cellular signaling.

IPP 701 – Principles of Pharmacology (1-3). The first required course for physiology and pharmacology PhD students introduces students to basic principles of physiology and pharmacology and the cellular, ADME principles (administration, distribution, metabolism, elimination), pharmacokinetics, and pharmacodynamics (receptors and signal transduction).

IPP 702 – Systems Physiology and Pharmacology (1-6). The second required course for physiology and pharmacology PhD students is composed of six blocks on the physiology and pharmacology of neural (Block 1), endocrine (Block 2), renal/vascular (Block 3), gastrointestinal physiology and pharmacology/metabolism (Block 4), and cardiac/pulmonary (Block 5) as well as regenerative physiology (Block 6). *Each block can also be taken for 1 credit. If all six blocks are taken, students must register for the 6-credit IPP 702 course rather than six individual blocks.*

IPP 703/704 – Student Seminar (1). Students present seminars as well as attend seminars by other IPP students and post-doctoral researchers once per academic year. Students provide a written critique of a journal article once per year. Course may be repeated.

IPP 711/712 – Advanced Topics (1-6). An advanced lecture and conference course that considers various topics of current research interest and concepts under rapid development. Areas of interest within the department are covered on a rotating basis. Additional topics can be offered by announcement.

IPP 713/714 – Advanced Readings (1-4). Individualized instruction involving detailed review of literature pertaining to a specific area of interest in physiology or pharmacology.

IPP 715 – Physiological Techniques (1). Provides students with an introduction to the techniques used to assess physiological parameters by a combination of lectures and demonstrations.

IPP 716 – Translational and Educational Research Topics (1). Topics covered in this course include translational research, conducting clinical trials, inter-

professional research, qualitative research, educational research, and an overview of statistical procedures. Professional skills developed during this course focus on team-effort, written and oral communications, and maximizing the mentor-mentee relationship. *This course is available for both MS and PhD students, and is a co-requisite for THSS 761 and THSS 762.*

IPP 717 – Current Topics in Drug Abuse (3). Provides students with a contemporary perspective in the problem of drug abuse by introducing cutting-edge technologies, emerging issues and persistent controversies. Defines the basic issues central to the field of drug abuse, including concepts of tolerance, physical dependence and reinforcement mechanisms, and relates them to the current problems of drug abuse in society. Describes how current research in drug abuse contributes to the design of rational treatment and prevention programs. *Also listed as NEUR 717.*

IPP 718 – Making Medicines (1). Offers students an opportunity to experience the process of taking a preclinical product through the innovation life cycle from ideation to clinical trials and FDA approval. The course utilizes prepared online materials which students complete at their own pace, and a group project that is presented at the end of the term. Intended for PhD and MS students who are interested in learning about careers in the pharmaceutical and related industries. *Typically offered in the summer term.*

IPP 722 – Behavioral Pharmacology (3). Focuses on behavioral factors that influence the effects of drugs. Material presented provides a detailed review of the rate-dependent, reinforcing, and stimulus effects of drugs. Additional topics include behavioral factors related to tolerance and sensitization and a review of animal models of drug action. *This course is cross-listed as NEUR 722.*

IPP 724 – Biology of Alcohol Abuse—Alcoholism (3). Designed to instruct graduate and postdoctoral students on the pharmacological, physiological, and behavioral effects of alcohol. Lectures cover topics ranging from the epidemiology and etiology of alcohol abuse and alcoholism to the basic biochemistry, metabolism, and pharmacokinetics of alcohol in the mammalian system. Lectures focusing on the effects of alcohol on the nervous system include neuroreceptor interactions, ethanol's effects on intracellular signaling processes, neuroanatomical substrates for the actions of alcohol, systems electrophysiology, and mechanism of the behavioral effects of alcohol such as the reinforcing effects, anxiolytic effects, amnestic effects, and motor impairing effects. These lectures provide the basis for an exploration of the conditions leading to tolerance and dependence, and how the brain adapts to prolonged exposure to alcohol. This course is cross-listed as NEUR 724.

IPP 726 – Toxicology (2). Lecture course designed to provide the student with the basic concepts and mechanisms underlying toxic responses to xenobiotics. Emphasis is on the toxicology relevant to the diagnosis and prevention of poisoning in humans from occupational, environmental, or iatrogenic origin. Broad area studies are general

principles of toxicology, common toxic agents, and target organs. Experimental models and methodologies of risk assessment are explored.

IPP 730 – Lifespan Physiology and Pharmacology (1-2). Lectures on the physiology of development and aging and the study of drugs during development and aging. Presentations address current topics relevant to age-dependent changes in various organ systems and theories of aging. The topics of age-related alterations in drug absorption, kinetics, and metabolism are also examined.

IPP 736 – Endocrinology (2). Recent advances in endocrinology, with emphasis on receptor-linked functions, hormonally-active drugs, and influences of pharmacologic agents on endocrine function. In a tutorial setting, students study principles of structure and function, examine current technology and published literature, and design and critique experimental approaches.

IPP 738 – Advanced Cardiovascular Physiology and Pharmacology (2). Lectures, readings and discussions center on normal and abnormal cardiovascular physiology and recent developments in drugs affecting the heart and circulation.

IPP 740 – Neuropharmacology (2-3). General survey of neuropharmacology, emphasizing neurotransmitters, receptors and their interactions. Discussion of published literature with some lectures. Discusses general principles of drug action, including receptor binding, second messengers, and neurotransmitter metabolism. Surveys neurotransmitter function, including acetylcholine, biogenic amines, excitatory and other amino acids, and neuropeptides. Also covers techniques used to measure receptor function. *This course is cross listed as NEUR 740.*

IPP 741 – Quantitative Methods in Bioscience (3). An introduction to essential concepts and methods for the quantitative analysis of biological data, with a focus on descriptive and inferential statistics. General topics include basic concepts in statistics such as probability theory and chance models, samples and populations, analyses of the relationships between variables, analysis of normal data, analysis of non-normal data and non-parametric analyses, an introduction to Bayesian frameworks, clustering analysis, and multivariate analyses. Didactic lectures cover core frameworks, analytic approach, and the mechanics and intuitive logic behind the methods. Laboratory sessions provide experience using a software platform (R) for data analysis and visualization using practical problems. *This course is cross-listed as NEUR 741.*

IPP 743/744 – Clinical Experience in Substance Abuse (1). This experience aims to introduce the student to the professional management of addiction medicine. Addiction is a multifactorial problem that involves complex biological, psychological, and social factors. The student will work with the Department of Psychiatry and Behavioral Medicine at the Jonestown Road clinic. The student will be given and expected to read the "Alcoholics Anonymous" book which describes the history and philosophy of the AA program as well as patient stories. Additional experience may also be obtained via attending AA meetings – which may be available online.

IPP 755 – Nanotherapeutics (3). Interdisciplinary survey course intended to introduce students to the potential benefits and challenges of nanomedicine. The primary focus will be on the development and characterization of nanoparticles and nano-structured materials for applications in imaging, drug delivery, diagnostics, and tissue regeneration. Additional topics will explore the utility of nanomaterials in personalized medicine for mitigating cancer and infectious disease. *Satisfactory/Unsatisfactory*.

IPP 781/782 – Alcohol Research Journal Club (1). This journal club covers articles related to alcohol abuse and alcoholism including cellular/molecular, pharmacological, behavioral, and anatomical studies. Students are encouraged to review current research findings from all aspects of alcohol research including basic science, translational and clinical studies. Students present articles providing a thorough review of relevant background information drawing upon seminal and related papers.

IPP 783/784 – Cardiovascular Sciences Journal Club (1). This journal club discusses peer-reviewed articles related to molecular mechanisms of cardiovascular diseases and disorders including hypertension, congestive heart failure, coronary artery disease, stroke, atherosclerosis, cardio-oncology, angiogenesis, and obesity. Participating students will review current research reporting on all aspects of cardio-health from basic science to translational and clinical studies. Every week a student will present a published article and provide a comprehensive review of relevant background, methods, results, clinical implications, and conclusions. Student should also include a discussion of the article's rigor and reproducibility as defined by the NIH guidelines.

IPP 785/786 – Regenerative Medicine Journal Club (1). This journal club covers articles related to all aspects of regenerative medicine including stem cells, gene therapy and gene editing, tissue engineering, small molecules, nanotechnology, and cell and organ transplantation Students are encouraged to review current research findings from all aspects of regenerative medicine including basic science, translational and clinical studies. Each week a student presents an article, providing a thorough review of relevant background information drawing upon seminal and related papers.

IPP 797/798 – Research (1-9). Mentored research on physiological or pharmacological problems in preparation for the thesis. *Course may be repeated. Satisfactory/Unsatisfactory*.

MICROBIOLOGY AND IMMUNOLOGY (MICR)

Program Director	Jason Grayson
Professors	Martha Alexander-Miller, Waldemar Debinski, Charles McCall
Associate Professors	Jason Grayson, Karen Haas, David Ornelles
Assistant Professors	Regina Cordy, Andy He, Yong Lu, Ammar Zafar, Xuewei Zhu

Overview

The Microbiology and Immunology program offers a graduate course of study leading to the PhD degree. The program prepares students for careers in research and teaching in the fields of bacteriology, immunology, molecular biology, and virology.

Students enter the program through the Molecular and Cellular Biosciences Track and participate in the MCB common curriculum in the first year. At the end of the first year, students select their research area and dissertation advisor. Students entering the program may choose to do their thesis work among the areas of bacterial and viral pathogenesis, cellular and molecular immunology, and the cell and molecular biology of the microbe-host interaction.

See the Department of Microbiology and Immunology homepage (www.wakehealth/microbio) for further information and detailed descriptions of faculty research interests.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: In addition to completion of the course curriculum, all students are required to take MCB 731 Fundamentals of Virology; MCB 732 Fundamentals of Bacteriology; and MCB 734 Fundamentals of Immunology. In the second and third years, all students are required to take MICR 749/750 Advanced Topics in Microbiology and Immunology.

Courses of Instruction

MCB Track Electives

MCB 731 – Fundamentals of Virology (2). Basic aspects of the structure, replication, and pathogenesis of animal viruses are taught through a mixture of lectures and discussions based on current literature. *Typically offered in the spring term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MCB 732 – Fundamentals of Bacteriology (2). Basic aspects of bacterial structure, physiology, genetics, and pathogenesis are taught through a mixture of lectures and discussions based on the current literature. *Typically offered in the spring term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MCB 734 – Fundamentals of Immunology (2). This course focuses on the cellular, biochemical, and molecular aspects of innate, cellular and humoral immunity. *Typically offered in the fall term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MICR Advanced Courses

MICR 704 – Microbiology of Infectious Diseases (3). An in-depth study of the role of microbial agents in host-parasite interactions. The course includes a survey of the basic properties of bacteria, viruses, fungi, and parasites. The pathways leading from exposure to successful infection to disease are examined. Specific examples of major pathogens and the diseases they cause are discussed in detail in the context of clinical situations employing the problem-based learning format. *P—POI.*

MICR 707 – Scientific Methodology (1). Instruction in the scientific method as applied to basic research in bacteriology, virology, and immunology and microbial pathogenesis. Examples from the scientific literature are used to provide practical training in effective oral communication and expository scientific writing. *P—POI.*

MICR 711 – Tutorial in Medical Microbiology (1-3). Guided reading and discussion of the pathogenesis of infectious diseases.

MICR 716 – Practical Statistics in Microbiology and Immunology (1). Provides a practical introduction to the application of statistical methods commonly required for studies in bacteriology, virology, and immunology. Consists of a mixture of lectures and in-class exercises based on problems drawn from current research in the department. Topics include sampling principles, descriptive statistics, parametric and non-parametric tests, one-way analysis of variance, contingency tables, linear regression, and power calculations. Emphasis is on recognizing and applying the appropriate methods. *P—POI.*

MICR 719/720 – Research in Microbiology (1-9). *Satisfactory/Unsatisfactory.*

MICR 721/722 – Teacher Training (0). Advanced graduate students give a lecture in their areas of specialization in one of the graduate courses offered by the department. *P—Advanced standing.*

MICR 749/750 – Advanced Topics in Microbiology and Immunology (2). Seminar course dedicated to the analysis of current research literature on the fundamental biochemical and molecular processes involved in the growth, differentiation, and functions of bacteria, viruses, and eukaryotic cells. The course not only provides the student with experience in literature analysis, but also offers a broad

exposure to timely and important themes and principles that link the disciplines of microbiology, virology, and immunology. *P—bacteriology, immunology, and virology or POI.*

MOLECULAR AND CELLULAR BIOSCIENCES (MCB)

Track Director Steve Kridel

Overview

Molecular and Cellular Biosciences (MCB) is an interdisciplinary graduate track that provides students with opportunities to choose from mentors whose research spans basic and translational fields of cutting-edge molecular and cellular biology. Graduate programs within the MCB track enable students to earn a PhD in Biochemistry and Molecular Biology (BAMB), Cancer Biology (CABI), Microbiology and Immunology (MICR), Molecular Genetics and Genomics (MOGN), or Molecular Medicine and Translational Science (MMTS), as well as a Certificate in Structural and Computational Biophysics (SCB).

Degree Requirements: Degrees are not awarded by Molecular and Cellular Biosciences. All students admitted to the track must select a program after completing the first year of the MCB core curriculum.

Program Requirements: In their first year, MCB students will complete a short course in analytical skills followed by a year-long core course that first examines macromolecular structure, synthesis and function, as well as gene expression and genetics; the second term focuses on cell structure, cell communication, organ systems integration and physiology and pathology. MCB students will also select three program-specific electives. They will explore a range of research opportunities by participating in three research rotations, each in a different MCB laboratory. These rotations introduce them to new techniques and guide their selection of a graduate program and dissertation research advisor; as 2nd year students they will complete program-specific requirements along their path toward a doctoral degree.

Courses of Instruction

MCB 700 – Analytical Skills (1). Molecular and Cellular Biosciences students will begin their graduate education with this 1-credit course focused on data acquisition and analysis methods. Balancing theory and practice, it will refresh their mathematical skills; describe techniques for isolating and characterizing cells and their macromolecular components; explore methods for manipulating genes and performing high-throughput assays; and introduce bioinformatics approaches. A series of take-home exercises reinforce problem-based learning. *MCB 700 will be offered as 10 x 1.5 h sessions in the two weeks preceding the fall term. Intended for all graduate students enrolled in MCB, or BMSC students with an MCB specialization. Open to students in all programs.*

MCB 701 – Molecular and Cellular Biosciences (1-6). Molecular and Cellular Biosciences students will take a two-term core course that will cover fundamental principles of the discipline. The overall goal of the course is to develop the student's

understanding of molecular and cellular biosciences in the context of biomedical research as it relates to human disease. In the first term students will focus on the basic building blocks of the cell, their synthesis, cellular metabolism and intracellular transport. The term is broken into five blocks or themes that in order roughly cover; 1) proteins and enzymes; 2) carbohydrates and lipids; 3) DNA and microbial genetics; 4), mammalian genetics and genomics; and 5) intracellular sorting, cytoskeleton, extracellular matrix. The course is in the format of didactic lectures and meets for 6 hrs per week (four 90 minute lectures/week). Students are evaluated on the performance of 5 written exams given at the end of each block. *Intended for all graduate students enrolled in MCB, or BMSC students with an MCB specialization. Open to students in all programs. Other tracks or programs may elect to have students take one or more blocks as 1 credit hour courses.*

MCB 702 – Molecular and Cellular Biosciences (1-6). In the second term students will focus on additional cell biological topics followed by several units devoted to integrative physiology. The term is broken into six blocks or themes that cover 1) cell signaling and cell-cell communication; 2) cell cycle, cell death, cancer, and development; 3) vascular and renal physiology; 4) gastrointestinal physiology and metabolism; 5) cardiac and pulmonary physiology; and 6) microbiology and immunology. The course is in the format of didactic lectures and meets for 6 hours per week (four 90 minute lectures/week). Students are evaluated on the performance of 6 written exams given at the end of each block. *Intended for all graduate students enrolled in MCB, or BMSC students with an MCB specialization. Open to students in all programs. Other tracks or programs may elect to have students take one or more blocks as 1 credit hour courses. Although not required, it is expected that students are familiar with material covered in MCB 701.*

MCB 703/704/705 – Introduction to Molecular and Cellular Biosciences Research (1-6). Molecular and Cellular Bioscience students will gain experience with the planning and execution of research, and the interpretation and presentation of experimental results. To put these principles into practice, they will carry out mentored research projects in the laboratories of three different Molecular and Cellular Biosciences faculty members with an optional fourth rotation during the summer term. *Intended for all graduate students enrolled in MCB. Satisfactory/Unsatisfactory.*

MCB Electives: Biochemistry and Molecular Biology (BAMB) Focus

MCB 711 – Biological Systems and Structures (2). In depth study of macromolecular assembly and interactions, as well as the application of structural biology and proteomics technology. Contemporary concepts of the principles of protein and nucleic acid structure will be presented. Other topics include methods for structure determination such as X-ray diffraction, NMR spectrometry, and molecular modeling. *Typically offered in the fall term. Intended for all graduate students in biochemistry and molecular biology (BAMB); open to students in other tracks or programs.*

MCB 712 – Biological Spectroscopy (2). Principles and practicalities of the study of biomolecules using spectroscopic techniques such as absorbance, fluorescence and circular dichroism analyses will be covered. Other biophysical approaches such as mass spectrometry and sedimentation analysis will be included. Topics in the study of enzymes utilizing these techniques will be discussed. *Typically offered in the spring term. Intended for all graduate students in biochemistry and molecular biology (BAMB); open to students in other tracks or programs.*

MCB 715 – Fundamentals of Redox Biology and Medicine (2). Redox chemistry as it applies to biological systems is a specialized field where a fundamental understanding of the underlying biochemistry and appropriate methodologies for evaluating redox regulation and its effects on cell signaling and human health are essential. This course will emphasize the need to use highly quantitative and robust approaches to evaluate redox changes when these are investigated 1) at the level of single molecules (e.g., working with redox-regulated recombinant proteins); 2) in vitro at the cellular level; 3) in vivo using animal models; and 4) in clinical studies.

MCB Electives: Cancer Biology (CABI) Focus

MCB 721 – Basic Concepts in Cancer Biology (2). This course will cover fundamental concepts in cancer biology including etiology, genetic abnormalities, gene expression reprogramming, signal transduction aberration, and stem cell regulation in various tumor types, such as, cancers of the breast, prostate, lung, CNS, lung, ovary, and bladder. *The course is open to all students.*

MCB 722 – Basic Concepts in Cancer Research (2). Over the last half century scientists have generated a complex body of knowledge illuminating the origins of cancer and revealed it to be a dynamic interplay between the genome and the cellular environment. MCB 722 is a hypothesis-driven and problem solving-based course that explores this interplay and the requirements for malignant transformation. This course is offered in the spring term. *The course is open to all students in thesis driven tracks and required for all graduate students in cancer biology (CABI). Students not performing thesis research are able to register but should recognize the course requires an understanding of experimental design and data analysis for course assignments.*

MCB 723 – Topics in Cancer Biology (2). Teaches students how to evaluate and communicate scientifically in the area of cell biology and cancer. Examples are taken from all areas of cancer in this advanced course. Uses current peer-reviewed journal articles to teach fundamental concepts and act as a medium for allowing the students to communicate ideas with an emphasis on presentation skills. *Typically offered in the spring term. Intended for all graduate students in cancer biology (CABI); open to students in other tracks or programs.*

MCB Electives: Microbiology and Immunology (MICR) Focus

MCB 731 – Fundamentals of Virology (2). Basic aspects of the structure, replication, and pathogenesis of animal viruses are taught through a mixture of lectures

and discussions based on current literature. *Typically offered in the spring term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MCB 732 – Fundamentals of Bacteriology (2). Basic aspects of bacterial structure, physiology, genetics, and pathogenesis are taught through a mixture of lectures and discussions based on the current literature. *Typically offered in the spring term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MCB 734 – Fundamentals of Immunology (2). This course focuses on the cellular, biochemical, and molecular aspects of innate, cellular and humoral immunity. *Typically offered in the fall term. Intended for all graduate students in microbiology and immunology (MICR); open to students in other tracks or programs.*

MCB Electives: Molecular Genetics and Genomics (MOGN) Focus

MCB 742 – Molecular Genetics and Genomics of Human Disease (2). This course will introduce students to applications of molecular genetic and genomic methods for the identification and functional characterization of genes contributing to human disease. In addition, complementary lectures will address the application of cell and animal model systems and methods which provide functional insights into the mechanism of action of genes that contribute to disease. *Typically offered in the spring term. Intended for all graduate students in molecular genetics and genomics (MOGN); open to students in other tracks or programs.*

MCB Electives: Molecular Medicine and Translational Science (MMTS) Focus

MCB 752 – Foundations of Translational Science (2). Builds on the student's basic biochemistry and cell biology knowledge with an intensive examination of the molecular basis of human disease and its' treatment. The course mixes lectures with a case-based approach to take students through the diagnosis, physiology, pathophysiology, and the molecular mechanisms of several diseases. Learning issues are developed by the group, centered upon treatment options, their mechanisms of action, the appropriate design of clinical trials to test new therapies, and the research base for further advances in prevention and treatment. MD and PhD facilitators assist with student-led discussions. Relevant, current literature is examined. *Typically offered in the spring term. Intended for all graduate students in molecular medicine and translational science (MMTS); open to students in other tracks or programs.*

MCB 753 – Advanced Topics in Regenerative Medicine (3). The remarkable advances in biomaterials, stem cell biology, and genetic manipulation over the last several years have now made it possible to begin devising means of treating diseases that were previously incurable, and developing corrective therapies for crippling injuries. These advances have led to the emergence of the field of research/clinical investigation that is known as Regenerative Medicine, and this field promises to revolutionize the way we treat/manage both disease and injury. In this course, students

will learn about the major organ/tissue systems of the body, the key enabling technologies that make regenerative medicine possible, and how these technologies can be applied to each organ/tissue to mediate regeneration/repair to treat disease/repair injury. Students will then embark on projects that will require them to apply the knowledge gained from the lectures to develop realistic and clinically translational solutions to generate specific organs for transplantation. Students will present their projects to the class at the end of the term. *Typically offered in the spring term. Intended for all graduate students in molecular medicine and translational science (MMTS); open to students in other tracks or programs. This course is cross-listed as BMES 753.*

MOLECULAR GENETICS AND GENOMICS (MOGN)

Program Director	Tim Howard
Professors	Rebecca Alexander, Martha Alexander-Miller, Colin Bishop, Don Bowden, , Laura Cox, Waldemar Debinski, Bill Gmeiner, Greg Hawkins, Tim Howard, Fang-Chi Hsu, Daniel Kim-Shapiro, Carl Langefeld, Todd Lowther, Doug Lyles, Charles McCall, Carol Milligan, Gloria Muday, Barb Nicklas, Michael Olivier, John Parks, Fred Perrino, Mark Pettenati, Leslie Poole, Thomas Register, Beverly Snively, Shay Soker, Ann Tallant, Stephen Walker, Richard Weinberg
Associate Professors	Nichole Allred, , Tom Hollis, Steve Kridel, Lance Miller, David Ornelles, Tim Pardee, Ke Zhang Reid
Assistant Professors	Hannah Ainsworth, Derek Parsonage, James Pease, Ellen Quillen
Adjunct Graduate Faculty	Martin Childers

Overview

The graduate training program in Molecular Genetics and Genomics is an interdisciplinary curriculum that leads to the PhD degree in Molecular Genetics and Genomics. The major goal of the program is to train students for independent research and teaching in the fields of laboratory molecular and cellular biology or computational analysis in genetics and genomics. The program faculty has departmental affiliations in both basic science and clinical departments of the Medical School, and departments on the Reynolda Campus.

The graduate program in Molecular Genetics and Genomics provides specialized training in the field of Molecular Genetics and Genomics while integrating student training as much as possible with traditional departmental disciplines. Students may elect to pursue this program of study after successful completion of the first year common curriculum of the Molecular and Cellular Biosciences (MCB) Track.

The program accepts students with a variety of undergraduate degrees including majors in the biological sciences, chemistry, mathematics, computer science and statistics. Students with a laboratory focus have typically completed courses in general biology, general chemistry, organic chemistry, physics, statistics, and mathematics through calculus. Students with analytical interests have typically completed advanced courses in mathematics, statistics, and/or computer science.

Dissertation research is performed under the supervision of a program faculty member and is tailored to meet the interests and training objectives of the individual student.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: During the second year, students begin research in their dissertation laboratory and take specialty courses relevant to the area of research conducted in that laboratory. The majority of the required courses for the program are fulfilled in the first-year MCB curriculum. A total of four (4) elective courses are required, three of which are usually completed in the first-year MCB curriculum. Second-year courses include the advanced seminar-style courses, 741 and 742. Attendance at seminars is strongly encouraged to broaden the educational experience of graduate students. Each student is expected to present his/her research once each year in an appropriate seminar series, such as those within the advisor's home department. Each student must fulfill the following requirements for admission to candidacy in the PhD program: 1) pass the MCB required core courses with final grades of B or better (the cumulative GPA must be at least 3.0); 2) pass four approved elective courses; and 3) pass an oral defense of a written research proposal.

Courses of Instruction

MCB Track Electives

MCB 742 – Molecular Genetics and Genomics of Human Disease (2). Introduces students to applications of molecular genetic and genomic methods for the identification and functional characterization of genes contributing to human disease. In addition, complementary lectures address the application of cell and animal model systems and methods which provide functional insights into the mechanism of action of genes that contribute to disease. *Typically offered in the spring term. Intended for all graduate students in molecular genetics and genomics (MOGN); open to students in other tracks or programs.*

MOGN Advanced Courses

MOGN 701/702 – Research in Molecular Genetics (1-9). Research investigations in molecular genetics are conducted in the laboratories of program members studying a wide range of disciplines. *Satisfactory/Unsatisfactory.*

MOGN 726 – Genetic Epidemiology (2). Presents fundamental concepts and methods in genetic epidemiology. Introduces various genetic epidemiology study designs in related and unrelated individuals and covers basic analysis, inferences, plus their strengths and limitations. Lecture and lab. *P—MCB 701, THSS 720; THSS 730, or POI*

MOGN 734 – Human Molecular Genetics (2). A combined lecture/seminar course providing an overview of current theoretical and technical approaches for locating, identifying, and cloning human genes using molecular genetic methods. Emphasis is on the search for genes that contribute to simple single-gene disorders and common complex diseases. Topics include genetic mapping and association studies, chromosome

structure at the molecular level, identification of coding sequences and disease susceptibility genes, and functional analysis of gene products. *Typically offered in the spring term. P—MCB 701 or POI.*

MOGN 741/742 – Tutorials in Molecular Biology (2). Seminar course that focuses on new and important aspects of research in molecular and cellular biology with an emphasis on the current literature. Each term, the course explores specific themes chosen by a committee of faculty and students. Students select topics for presentation and lead discussions with faculty and graduate students.

MOLECULAR MEDICINE AND TRANSLATIONAL SCIENCE (MMTS)

Program Director	John Parks
Program Co-director	Don McClain
Professors	Martha Alexander-Miller, Graça Almeida-Porada, Reto Asmis, Anthony Atala, Werner Bischoff, Daniel Bourland, Don Bowden, Che Ping Cheng, Mark Cline, Laura Cox, Osvaldo Delbono, Carlos Ferrario, Barry Freedman, Cristina Furdui, Randolph Geary, Bill Gmeiner, Dwayne Godwin, Jason Hoth, Tim Howard, Allyn Howlett, Daniel Kim-Shapiro, Nancy Kock, Charles McCall, Donald McClain, Michael Olivier, Emmanuel Opara, John Parks, Boris Pasche, Leslie Poole, Christopher Porada, Thomas Register, Michael Shapiro, Carol Shively, Thomas Smith, Shay Soker, Leah Solberg-Woods, Ann Tallant, Richard Weinberg, Koudy Williams, James Yoo
Associate Professors	Susan Appt, David Caudell, Rong Chen, Tracy Criswell, Kerry Danelson, Swapan Das, Andy Dezarn, Clark Files, Jason Grayson, TanYa Gwathmey-Williams, Karen Hass, John Jackson, Kylie Kavanagh, George Kulik, Sang Jin Lee, Nicole Levi-Polyachenko, Victor Ortega, Neveen Said, Allen Tsang, Pierre Vidi, Jeff Willey, Liliya Yamaleyeva, Raghu Yammani
Assistant Professors	Andrew Bishop, Joshua Currie, Genesio Karere, Bethany Kerr, Chia-Chi Chuang Key, Sean Murphy, Kristen Nicholson, Snezana Petrovic, Johannes Plate, Ellen Quillen, Matt Quinn, Ellie Rahbar, Tony Reeves, Mike Seeds, David Soto-Pantoja, Andrew South, Fei Xing, , Xuewei Zhu

Overview

The graduate program in Molecular Medicine and Translational Science (MMTS), an interdisciplinary program offering the Doctor of Philosophy (PhD) and Master of Science (MS) degrees, is specifically designed to meet the challenge of training basic scientists to function successfully in clinical environments. The last decade has brought about fundamental and radical advances in a number of disciplines including biochemistry, cellular and molecular biology, and immunology. These changes have led to unparalleled opportunities to advance medical research and patient care. Both basic and clinical scientists can now test novel and provocative hypotheses using tools such as recombinant DNA technologies, functional imaging techniques, mass spectrometry, and monoclonal antibody therapy and quickly acquire results that would have seemed fanciful science fiction only a few years ago. These new approaches have not only made

it possible to understand cellular and molecular mechanisms of human disease, but they also offer the promise of new and revolutionary therapeutic options for clinicians.

Translating new advances in science to improved bedside care for patients requires erasing many of the historical divisions between basic and clinical scientists. For modern-day clinicians to understand and take advantage of new developments, a great deal of time must be spent at both the bedside and the bench. Conversely, the potential to understand mechanisms of illness and its treatment brings relevance and urgency to the work of basic scientists, moving them closer to their clinical colleagues. This movement into the clinical arena facilitates the challenge of viewing a complex clinical disorder through the eyes of the basic scientist. For these reasons, there has been a major emphasis by national, private, and industrial granting organizations to fund basic research that has the potential to immediately impact human disease. This creates a unique niche for basic (PhD) scientists who are trained on the cutting edge of molecular advances to perform “translational” research in human biology and disease.

The MMTS program provides training in the use of cellular, molecular, and integrative approaches to investigate biologic events with an emphasis on human disease. The multidisciplinary faculty consists of scientists who have major ongoing human research programs. The program offers PhD students a comprehensive knowledge of human biology and disease that allows them to develop basic research programs with fundamental clinical implications. It is also designed to train biomedical researchers to fill an important niche in academia or industry.

For MD, DVM or DO-trained physician-scientists on faculty or in training at Wake Forest University Baptist Medical Center, a Master’s or PhD degree in MMTS is also available for qualified candidates. The overall objective of the clinician-scientist program is to train individuals who already hold an MD degree in the cellular and molecular techniques needed to integrate basic science with clinical applications involving human disease. An additional benefit of the program is that it enhances interaction between MDs in clinical departments and PhDs who are engaged in fundamental bench research focused on human disease.

The MMTS program participates in the Molecular and Cellular Biosciences (MCB) PhD track. Prospective students interested in MMTS apply to the MCB track and can indicate their interest in the MMTS program on the application. Applicants to the MCB Program should have a solid background in biological and/or physical sciences, prior research experience and a passion for scientific inquiry. Students enter the program through the MCB Track and participate in the MCB common curriculum in the first year. Curriculum in subsequent years includes participation in Translational Science Seminar Series, Clinical Experience, Foundations of Translational Science, Scientific Development and Business of Science course, and electives of the student’s choice.

Prospective students are encouraged to contact individual faculty members whose research is of particular interest.

Degree Requirements: As applicable, please see "Requirements for the Doctor of Philosophy Degree" of the "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: Students who enter the MMTS program are required to take the following set of courses: MCB 752, MMTS 711, 712, 715, 716, 724, 791, 792, and a statistics course. Students who have an MD or are in the combined MD/PhD program are exempt from MCB 752 and MMTS 715/716. Possible statistics courses include one of the following: HES 721 – Data Analysis and Interpretation; THSS 730 – Introduction to Statistics; IPP/NEUR 741 – Quantitative Methods in Bioscience. See statistics course descriptions within the appropriate program sections.

Before a student can schedule the defense of their dissertation, it is required that at least one first author publication of original data from their work at Wake Forest be accepted in a peer-reviewed journal.

Courses of Instruction

MCB Track Electives

MCB 752 – Foundations of Translational Science (2). Builds on the student's basic biochemistry and cell biology knowledge with an intensive examination of the molecular basis of human disease and treatment. The course mixes lectures with a case-based approach to take students through the diagnosis, physiology, pathophysiology, and the molecular mechanisms of several diseases. Learning issues are developed by the group, centered upon treatment options, their mechanisms of action, the appropriate design of clinical trials to test new therapies, and the research base for further advances in prevention and treatment. MD and PhD facilitators assist with student-led discussions. Relevant, current literature is examined. *Typically offered in the spring term. Intended for all graduate students in MMTS; open to students in other tracks or programs.*

MCB 753 – Advanced Topics in Regenerative Medicine (2). The remarkable advances in biomaterials, stem cell biology, and genetic manipulation over the last several years have now made it possible to begin devising means of treating diseases that were previously incurable, and developing corrective therapies for crippling injuries. These advances have led to the emergence of the field of research/clinical investigation that is known as Regenerative Medicine (RM), and this field promises to revolutionize the way we treat/manage both disease and injury. In this course, students will learn about the major the major organ/tissue systems of the body, the key enabling technologies that make regenerative medicine possible, and how these technologies can be applied to each organ/tissue to mediate regeneration/repair to treat disease/repair injury. Students will then embark on projects that will require them to apply the knowledge gained from the lectures to develop realistic and clinically translational solutions to generate specific organs for transplantation. Students will present their projects to the class at the end of the term. *Typically offered in the spring term.*

Intended for all graduate students in MMTS; open to students in other tracks or programs.

MMTS Advanced Courses

MMTS 711/712 – Translational Science Seminar Series (1). Faculty and students jointly describe their research in a human disease, first in clinical terms and then to follow the development of the understanding of that disease to the molecular level with an emphasis on translational applications. Presentations introduce students to potential preceptors and experimental strategies used to study human disease. Students present their own research to gain experience and professional skills for seminars and national meeting presentations.

MMTS 713 – Advanced Readings in MMTS (1-2). This course allows individualized advisor-student discussion of literature pertaining to a specific area of interest in Molecular Medicine. *Satisfactory/Unsatisfactory.*

MMTS 715/716 – Clinical Experience (1). Students who choose to enter the MMTS program must take this course in the fall (MMTS 715) and spring (MMTS 716) term. This course serves as an introduction to clinical medicine for the PhD students. Each student observes and participates in 10 hours of clinical immersion with his/her clinical mentor. Experiences are custom-designed by the clinical mentor for each student. At the end of the term, students enrolled in the course meet and each student presents a case study, based on his/her personal clinical experience. *P—POI.*

MMTS 719/720 – Special Topics in Stem Cell Biology (2). This course utilizes directed readings and student presentations of primary literature to introduce students to the field of stem cell biology. Content focuses primarily on human stem cell properties, including pluripotency and its maintenance, the role of chromatin remodeling in fate determination and lineage restriction, self-renewal and differentiation, and the genetic conversion of somatic cells into pluripotent stem cells. The field is expanding rapidly and course content will be modified as needed to incorporate new findings and applications in stem cell biology and translational medicine. A background in the form of undergraduate or graduate courses in developmental biology is strongly recommended. *This course is cross-listed as MOGN 719/720. P—POI.*

MMTS 721 – Regenerative Medicine Immersion - Fundamentals, Principles and Clinical Applications (1-2). The course will provide a state-of-the-art review of various aspects of RM addressing the fundamental principles and progress in tissue engineering and regenerative medicine in recent years, including background material, key scientific components of RM, ethical, economic and other issues important to the field. RM has the potential to deliver cures to many diseases while also improving quality of life. RM integrates the principles of cell and molecular biology, materials science, biomedical engineering, and clinical science with the goal to develop materials and therapies to repair or replace cells, tissue, and organs damaged by disease, trauma,

or congenital conditions. In recent years, approaches are being used routinely in daily clinical practice, with others in clinical studies, and multitudes in preclinical testing phase. The course addresses the interdisciplinary nature of RM, major components necessary to produce engineered tissues and organs, opportunities and today's most critical challenges. A series of eight topic areas features prominent faculty members of the Wake Forest Institute for Regenerative Medicine (WFIRM) along with distinguished invited experts in the field. The eight content areas are grouped thematically and address a breadth of topics spanning: stem cells, cell sources, biomaterials, cellular therapies, enabling technologies and animal models, as well as legal, commercial, regulatory and ethical issues. In addition to the formal presentations, students also have the opportunity to interact with speakers in smaller groups during lunch and other informal, social networking events and settings. *Typically offered in the summer term. This course does have enrollment limits, and registrations are accommodated on a first-come, first-served basis. Satisfactory/Unsatisfactory.*

MMTS 724 – Scientific Development and the Business of Science (1-3). This course reviews techniques for effective communication of scientific proposals and presentations, both oral and written. For oral presentations, emphasis is on content organization and connecting with the audience. Assignments include the presentation and critical discussion of student research. For written presentations, the emphasis is on grant proposal development, as well as familiarization with the peer-review process. The course consists of lectures on all aspects of grant development (including budgets and protocols and compliance regulations for human and animal research), and student preparation of a grant proposal. An oral exercise includes the discussion of an NIH R01 proposal in a mock study section format. *P—POI.*

MMTS 781/782 – MMTS Graduate Program Journal Club (1). This course is designed to enhance students' ability to critique and present high-quality papers from current literature. The journal club will provide a forum for: 1) in-depth discussion of basic and translational research that reinforces the principles of multiple research approaches (including in vitro cell studies, animal models, human studies, "omics" studies and others); 2) practicing scientific presentation skills and developing skills to critically evaluate peer-reviewed high-impact research articles; and 3) discussing state-of-the-art technology in the field. The course will also include active audience (i.e., students, postdoctoral fellows, technicians, and faculty) discussion of results to stimulate learning effective presentation and discussion of scientific research findings.

MMTS 791/792 – Research (1-9). This course involves closely supervised research in various topics in molecular medicine, with a special emphasis on models of human disease, including research in preparation for the doctoral dissertation. *Satisfactory/Unsatisfactory.*

Other Electives:

In addition to the required courses, students in the PhD program may select, in consultation with their advisor, one or more other graduate-level science courses from a

range of other programs, including but not limited to: biochemistry and molecular biology (BAMB), biology (BIO), biomedical engineering (BMES), cancer biology (CABI), chemistry (CHM), comparative medicine (COMD), health and exercise science (HES), integrative physiology and pharmacology (IPP), mathematics and statistics (MST), microbiology and immunology (MICR), molecular genetics and genomics (MOGN), neuroscience (NEUR), physics (PHY), or translational and health system science (THSS). Students should complete these additional courses prior to the end of their third year.

NEUROSCIENCE (NEUR)

Program Director	Carol Milligan
Professors	Christos Constantinidis, Suzanne Craft, Paul Czoty, Waldemar Debinski, Osvaldo Delbono, Debra Diz, Eric Donny, Dwayne Godwin, Rob Hampson, Colleen Hanlon, Greg Hawkins, Allyn Howlett, Erik Johnson, Sara Jones, Paul Laurienti, Brian McCool, Carol Milligan, Michael Nader, Linda Porrino, Emilio Salinas, Carol Shively, Terry Stanford, Barry Stein, Joel Stitzel, Stephen Walker, Jeff Weiner, Chris Whitlow
Associate Professors	Evgeny Budygin, Rong Chen, Ryan Drenan, Christina Hugenschmidt, Timothy Hughes, Ken Kishida, Tao Ma, Heidi Munger Clary, Christopher Peters, Kimberly Raab-Graham, Ben Rowland, Rebecca Sappington, Hossam Shaltout, Sean Simpson, Stacey Wolfe
Assistant Professors	Jason Fanning, Mark Ferris, Sam Lockhart, Shannon Macauley-Rambach, Joost Maier, Miranda Orr, Johannes Plate, Jillian Urban
Adjunct Graduate Faculty	Katie Holleran

Overview

Neuroscience PhD training has been a component of graduate student training at Wake Forest University for approximately 30 years. The field of Neuroscience is at the cutting edge of scientific developments and the Wake Forest Neuroscience Program believes its long-term returns from student training will have positive consequences for our community and nation. Neurological disorders associated with trauma, an aging population, drug addiction, and neurodevelopmental and psychiatric disorders represent urgent local and national needs. As scientists and educators, we are at an ideal position to train individuals capable of pioneering research into both normal development and function of the nervous system and into the causes and mechanisms underlying neurological disease.

The training faculty represent a wide range of specific research interests, who employ diverse human and animal techniques and methodologies with major strengths in neuropharmacology, behavioral neurobiology, aging, sensory neurobiology, neurophysiology, pain mechanisms, and neurodegeneration. One of the rewarding features of research at Wake Forest University is the extent of collaborative interactions between investigators both within, and equally importantly, between departments and centers. These interactions provide the means by which the trainees in the Neuroscience Training Program can readily interact with investigators and students in other labs, departments, and across campuses.

The goal of our Neuroscience training program is to provide students with:

- A fundamental understanding of all levels of nervous system organization, from genetics, molecular, and cellular to systems and behavioral
- A skill set that includes extensive training in experimental design and interpretation, statistical and quantitative methodology
- Hands-on experience in state of the art laboratories that carry out meaningful and significant research in all areas of modern neuroscience
- A "bench to bedside" appreciation of how basic neuroscience research supports and translates into treatments for neurobehavioral pathologies

The program offers MS and PhD training. Competitive applicants to the neuroscience graduate program demonstrate proficiency in core disciplines such as biology, psychology, chemistry, physics, mathematics, statistics, computer programming, and have prior research experience.

Degree Requirements: As applicable, please see "Requirements for the Doctor of Philosophy Degree" of the "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: All students are required to take a core curriculum of neuroscience courses over the first 1.5 years as well as coursework in statistical and quantitative analysis.

MS students obtain hands-on research experience by participating in thesis research beginning in the first term.

PhD students obtain hands-on research experience by participating in laboratory rotations during the first year. Students begin thesis research by the end of the summer of the first year. Additional graduate coursework is tailored to provide advanced training and meet the research goals of each student.

Courses of Instruction

Core Courses

NEUR 701 – Introduction to Neuroscience I (6). Introduction to Neuroscience I is the first in a required three-course series for first-year neuroscience graduate students covering basic topics in the neurosciences. Introduction to Neuroscience I is offered only in the fall term. In the first section, Neuroanatomy, students will develop expertise in identification and understanding of neuroanatomical structures and pathways and proficiently apply that knowledge to normal and pathological nervous system function. The Neuroanatomy section includes both didactic and laboratory sessions. In the second section, Neurophysiology and Neuropharmacology, student will expand their understanding to basic cellular, molecular and physiological mechanisms mediating nervous system structure and function. Basic neuropharmacology will also be covered. The second section includes didactic and discussion based sessions. *For non-*

Neuroscience students, the sections can be taken individually as two three-credit-hour courses.

NEUR 702 – Introduction to Neuroscience II (6). Introduction to Neuroscience II is the second in the series of required courses for first-year neuroscience graduate students covering basic topics in the neurosciences. Topics covered include: developmental neuroscience, sensory, and motor systems. Class format is student-led discussion of course material with faculty guidance and facilitation. For non-Neuroscience students, the sections can be taken individually as three two-credit-hour courses. *P—NEUR 701.*

NEUR 703 – Introduction to Neuroscience III (2). Introduction to Neuroscience III is the third in the series of required courses for first-year neuroscience graduate students covering basic topics in neurosciences. Topics covered in this section include core concepts of cognitive neuroscience and psychology (e.g., attention, learning and memory, language, perceptual encoding, executive function, specialization, segregation, and lateralization) and basic computational concepts and models (e.g., associative networks, feature maps, learning algorithms). Class format is student-given lectures and student-mediated discussion of course material with faculty guidance. *P—NEUR 701; NEUR 702.*

NEUR 705/706 – Tutorial in Neuroscience (1). The Tutorial in Neuroscience runs during the fall, spring and summer terms. The format is one in which a faculty member or postdoc presents his/her research and a student presents a paper on a topic related to that research topic. Additionally, students must submit a manuscript or review paper related to his/her own research at the end of each term.

NEUR 707/708 – Research (1-9). Lab research in all areas of modern neuroscience, including studies done as part of the first-year research rotations and the requirements for the doctoral dissertation. *Satisfactory/Unsatisfactory.*

NEUR 711/712 – Seminars in Neuroscience (1). This is a weekly seminar given by students, postdocs, faculty and external speakers. It runs throughout the year and is structured so that each student presents one research seminar in a given year. First year students give a 30-minute seminar and senior students give an hour seminar. First year students are assigned seminar slots during the summer between first and second year. The remaining slots are used by postdocs, faculty, and visiting speakers. Departments and the WNCSfN Chapter take turns sponsoring the seminars by external speakers.

NEUR 741 – Quantitative Methods in Bioscience (3). An introduction to essential concepts and methods for the quantitative analysis of biological data, with a focus on descriptive and inferential statistics. General topics include basic concepts in statistics such as probability theory and chance models, samples and populations, analyses of the relationships between variables, analysis of normal data, analysis of non-normal data and non-parametric analyses, an introduction to Bayesian frameworks, clustering analysis, and multivariate analyses. Didactic lectures cover core frameworks,

analytic approach, and the mechanics and intuitive logic behind the methods. Laboratory sessions provide experience using a software platform (R) for data analysis and visualization using practical problems. *This course is cross-listed as IPP 741.*

NEUR 751 – Advanced Multivariate Analysis in Neuroscience (3). An advanced class focusing on the methods of complex data analysis for real biological datasets, complete with mixtures of fixed and random effects, missing entries, errors, and outliers. The course is centered on analytic projects that utilize combinations of linear/nonlinear regression, mixed models, and Bayesian estimation to explore best practice approaches to complex problems. Each project introduces a set of new concepts and challenges that are commonly encountered in the laboratory. The approach is comprehensive, taking each analysis from "start" (importing data from various sources) to "finish" (generating a report of the findings). Students collaborate in groups to decide on next steps at each stage of the analysis and identify potential caveats, then construct implementations/solutions individually, and reconvene at the next class period to discuss their results and next steps with expert faculty guidance. The over-arching goal is to simulate complex data analysis in real world collaborative environments. *P—NEUR 741.*

NEUR 771 – Clinical Neuroscience (3). Lectures and class discussions dealing with topics in neurobiology, pathophysiology, and treatment of patients with neurological and behavioral/psychiatric problems. Includes a brief introduction to major concepts of patient treatment and care with utilization of up-to-date methodology in clinical neuroscience. Students have the opportunity to observe and participate in patient evaluation and diagnostic testing in the clinical setting and to visit many of the neuroscience-related clinical research and treatment centers. Taught by both clinicians and basic science researchers. *P—NEUR 701; NEUR 702.*

Advanced Courses

Behavioral Neuroscience

NEUR 714 – Behavioral Neuroscience (3). Behavioral neuroscience is a relatively new and rapidly expanding discipline utilizing techniques of molecular biology, neurochemistry, neurophysiology, and psychology to investigate the neurobiological basis of behavior. A broad overview of the field and its relationship to these individual disciplines is presented. The course provides a survey of the field from the cellular level to the complexity of molar aspects of behavior including learning and memory. An introduction to lab models of human neurobiological disorders is included. *P—NEUR 701; NEUR 702; NEUR 703.*

NEUR 722 – Behavioral Pharmacology (3). Focuses on behavioral factors that influence the effects of drugs. Material presented provides a detailed review of the rate-dependent, reinforcing, and stimulating effects of drugs. Additional topics include behavioral factors related to tolerance and sensitization and a review of animal models

of drug action. *This course is cross-listed as IPP 722. P—NEUR 701; NEUR 702; NEUR 703.*

Computational Neuroscience

NEUR 723 – Computational Neuroscience (3). This course explores advanced topics in theoretical and computational neuroscience spanning multiple levels of abstraction, from models of ion channels and single neurons to decision-making and behavior. Major topics include models of individual neurons and populations, information theory, common network architectures involving oscillations and attractor dynamics, mechanisms of synaptic plasticity, neural encoding and decoding, and computation within large-scale neural networks. The course follows selected chapters from relevant textbooks to provide essential concepts and extends to discussions of recent literature. Classes consist of student-led lectures and discussion with faculty facilitation and commentary. Weekly take-home programming projects (MATLAB) reinforce concepts and provide practical hands-on experience with modeling neural systems. *P—NEUR 701; NEUR 702; NEUR 703.*

Structure and Function of Neurons

NEUR 721 – Advanced Molecular Approaches to Neuroscience (3). Introduces graduate and advanced undergraduate students to the basic principles of neurobiology as studied by cell and molecular biologists. Lectures introduce invertebrate and vertebrate model neuronal systems and the cellular and molecular methods to study them. *P—NEUR 701; NEUR 702; NEUR 703.*

NEUR 725 – Introduction to Neuroimaging (3). This course is a course for second-year and above neuroscience graduate students covering basic topics in neuroimaging acquisition, processing, and analysis. Topics covered in this section include basics of MRI image acquisition, fundamentals of structural and functional MRI, and an introduction to other commonly used imaging methods (PET, MEG, spectroscopy, ultrasound). Faculty will be primarily clinical research scientists using neuroimaging in their laboratories, and also clinicians who incorporate imaging into their practice and research. Class format will include didactic presentations of core concepts; hands-on data processing and analysis using online, publicly available data and example image analysis pipelines; and student-mediated discussion of course material with faculty guidance. Goal is for students to understand basic technical, experimental, and statistical methodology in neuroimaging, and gain quantitative skills through this understanding, as a gateway to potential future research work involving neuroimaging. *P—NEUR 701; NEUR 702; NEUR 703.*

NEUR 726 – Synaptic Physiology for Biologists (3). In this course, graduate students will be introduced to theory, techniques, and mechanisms of synaptic physiology. We will focus on molecular underpinnings of plasticity at the synapse - both pre- and post-synaptically, specifics of electrophysiological and electrochemical tools used to probe synaptic function, and how alterations of synaptic physiology contribute

to maladaptive states in the whole organism. In order to be adequately versed in basic synaptic physiology to take this course, students are required to have completed NEUR 701/702 coursework as a prerequisite to attending this course. *P—NEUR 701; NEUR 702*.

Development and Aging of the Nervous System

NEUR 742 – Development of the Nervous System (3). This is an advanced course to explore current topics regarding development of the nervous system. The course will rely on primary literature to delve into control of events that lay the foundation of the nervous system, regressive and progressive events, neural plasticity and regeneration, development of behavior, and developmental disorders. *P—NEUR 701; NEUR 702; NEUR 703*.

Sensory Neuroscience

NEUR 753 – Sensory Neuroscience I: Visual and Auditory Systems (3). This course is designed to introduce students to sensory neurobiology of visual, auditory, olfactory and gustatory systems from the cellular to systems level. Under each sensory system, the topics cover the receptors in the sensory organs, signal transduction, subcortical and cortical areas and higher order processing. The course also includes topics relevant to sensory perception such as attention, working memory, decision making and plasticity. The course is structured to enable the students to learn how individual sensory systems function and to recognize the parallels between sensory systems. *P—NEUR 701; NEUR 702; NEUR 703*.

NEUR 754 – Sensory Neuroscience II: Somatosensation and Multi-sensory Integration (3). This course is the second in a series that focuses on mammalian sensory systems. The course is designed to introduce students to somatosensory, pain and multisensory processing from the molecular to the systems level. The aim is to introduce key concepts of global organization that transcend individual modalities. Cellular, molecular, behavioral and pharmacological approaches will be covered against the backdrop of relevant model sensory systems. *P—NEUR 701; NEUR 702; NEUR 703; NEUR 753*.

NEUR 755 – Research Design in Sensory and Systems Neurobiology (3). This course combines didactic material with hands-on approaches so that students learn to properly design experiments in neurobiology and are able to analyze quantitatively the resulting experimental data. The didactic component provides a brief survey of fundamental mathematical and statistical concepts (e.g., probability, Bayesian inference, curve fitting, hypothesis testing, nonparametric statistics), which serves as a foundation for more advanced techniques used to analyze neuronal data (e.g., signal detection theory, cross-correlograms, information theory). Through computer-lab sessions and homework assignments tailored to each topic, students translate the theoretical knowledge to practical application as they learn to use the MATLAB programming environment. The specific quantitative methods covered, as well as the

sample data used for the hands-on analysis assignments, are tailored according to the students' backgrounds, programming experience, and research interests. *P—NEUR 701; NEUR 702; NEUR 703; NEUR 741.*

Substance Abuse and Addiction

NEUR 717 – Current Topics in Drug Abuse (2-3). Provides students with perspective on the problem of drug abuse. Defines the basic issues central to the field of drug abuse, including concepts of tolerance, physical dependence and reinforcement mechanisms, and relates these issues to the current problems of drug abuse in society. Describes how current research in drug abuse contributes to the design of rational treatment and prevention programs. *This course is cross-listed as IPP 717.*

NEUR 724 – Biology of Alcohol Abuse—Alcoholism (3). Designed to instruct graduate and postdoctoral students on the pharmacological, physiological, and behavioral effects of alcohol. Lectures cover topics ranging from the epidemiology and etiology of alcohol abuse and alcoholism to the basic biochemistry, metabolism, and pharmacokinetics of alcohol in the mammalian system. Lectures concerning effects of alcohol on specific organ systems include the hepatic system, the endocrine system, reproductive systems, the cardiovascular system, the gastrointestinal system, and the renal and pancreatic systems. Lectures focusing on the effects of alcohol on the nervous system include neuroreceptor interactions, ethanol's effects on intracellular signaling processes, neuroanatomical substrates for the actions of alcohol, systems electrophysiology, and mechanism of the behavioral effects of alcohol such as the reinforcing effects, anxiolytic effects, amnestic effects, and motor impairing effects. The neuroscience lectures provide the basis for an exploration of the conditions leading to tolerance and dependence, and how the brain adapts to prolonged exposure to alcohol. *This course is cross-listed as IPP 724.*

NEUR 740 – Neuropharmacology (3). General survey of neuropharmacology, emphasizing neurotransmitters, receptors and their interactions. Discusses general principles of drug action, including receptor binding, second messengers, and neurotransmitter metabolism. Surveys neurotransmitter function, including acetylcholine, biogenic amines, excitatory and other amino acids, and neuropeptides. *This course is cross-listed as IPP 740. P—NEUR 701; NEUR 702.*

Neurosciences Journal Clubs

NEUR 773/774 – Neuro-computational Approaches to Investigate Conscious Experience, Willful Choice, and Related Disorders Journal Club (1). In this journal club we will discuss literature relevant to computational neuroscience approaches used to investigate human consciousness and related mental health disorders.

NEUR 775/776 – Health Inequity in Neuroscience Journal Club (1). Roots of Health Inequity (ROHI) consists of an online curriculum with guided in person discussions to expand upon the online content in ways that are relevant to the WFSM

community within and outside the institution. This course will use the online component as a foundation and expand upon it with published reports from the literature exploring health inequities as they relate to neurological and related disorders.

NEUR 777/778 – Directed Journal Club in Pain and Anesthesiology (1). This journal club covers articles related to mechanisms of pain and somatosensory processing including cellular/molecular, pharmacological, behavioral, and anatomical studies of acute and chronic pain disorders. Students are encouraged to review current research findings from all aspects of pain research including basic science, translational and clinical studies. Each week a student presents an article providing a thorough review of relevant background information drawing upon seminal and related papers.

NEUR 780/781 – Directed Journal Club in Sensory Neuroscience (1). Correlates with the formal lecture courses in Sensory Neuroscience I-II. Students are required to read and critique papers chosen to complement the classroom lectures. Both seminal papers and current research are reviewed. The directed nature of the readings enhances the student's appreciation and understanding of the formal lectures. Students lead the presentation of the journal articles, thus providing opportunities for teaching in the area of sensory systems.

NEUR 783/784 – Directed Journal Club in Developmental and Molecular Neurobiology (1). Students are required to read and critique papers related to developmental, cell and molecular, or disease/pathological issues in the nervous system. Both seminal papers and current research are reviewed. The directed nature of the readings enhances the student's appreciation and understanding of the formal lectures. Students lead the presentation of the journal articles, thus providing opportunities for teaching in these areas.

NEUR 785/786 – Directed Journal Club in Network Science in Neuroimaging (1). This journal club covers articles related to network science and its application in biological systems, with a particular emphasis on the brain. Assigned reading will cover methodological foundation of network science, as well as the current literature on applications of network science in neuroimaging studies. Although the brain network will be of the main focus, readings may also include other types of networks such as biological, social and technological networks.

NEUR 787/788 – Memory, Cognition and Aging Journal Club (1). The topics in this journal club will cover all aspects of memory, cognition and cognitive aging from molecular and cellular/synaptic mechanisms to behavioral and imaging studies. Papers on basic research and translational science in any model system ranging from rodent, non-human primates to humans will be discussed. In the Journal Club course, each week a student will present a paper using a format indicated by the course director.

NEUR 789/790 – Translational Addiction Journal Club (1). The primary objective of this course is to provide a forum for students working in NIDA/NIAAA supported laboratories (or any students interested in addiction to present and discuss

the latest research breakthroughs in the field of addiction research with a major focus on studies with high translational significance. Students are encouraged to present cutting-edge manuscripts that cover topics ranging from molecular adaptations that contribute to the etiology of drug or alcohol use disorder to the latest clinical trials on addiction treatments. *Satisfactory/Unsatisfactory*.

Special Topics

NEUR 713/714 – Advanced Readings (2). Individualized instruction involving detailed review of literature pertaining to a specific area of interest in physiology and pharmacology.

NEUR 782 – Readings and Research in Neuropsychology (1-3). Allows the graduate student, working under the supervision of a faculty member, to pursue and receive credit for a special project in an area not covered by regular courses or a special research project not related to the master's thesis. Supervising faculty member and credit hours for the course are determined by graduate committee prior to registration. *This course is cross-listed as PSY 782*.

NEUR 791/792 – Readings and Directed Study in Neurobiology (1-2). Designed to provide an opportunity for graduate students to learn specific topics in the field that may not be covered by regular courses. Materials from the primary literature are presented to other participants, including at least one faculty member. The format is intended to generate in-depth discussion in a setting where each student acts as the lecturer. The supervising faculty member and the student will determine together the schedule and credit hours (either 1 or 2) for the course.

NEUR 793/794 – Special Topics in Developmental Neurobiology (2). Designed to focus on a specific theme each term, including such topics as cell death and regressive events, synaptogenesis, determination and differentiation, axonal guidance and pathway formation, neuroglia interactions, and neurotrophic agents.

NEUR 795 – The Development and Anatomy of Sensory Systems (2). Designed as an introduction to the structure and ontogeny of the sensory pathways. Provides a foundation for the subsequent advanced coursework in sensory systems, which provides one of the most fertile experimental areas in developmental biology. Topics include basic genetic control of developmental processes; embryonic development of the sensory nervous system; development and organization of subcortical sensory pathways; development of sensory cortices; role of the environment in neural development; and the genetics of neuronal ontogeny.

NEUR 796/797 – Special Topics in Sensory Neuroscience: Hearing and Multi-Sensory Integration (2). Emphasizes current topics in neuroscience pertaining to sensory systems. Topics cover neurobiology of individual sensory systems such as visual, auditory, somatosensory, olfactory, and gustatory systems. The importance of multi-sensory integration, i.e. how different sensory systems function

together to generate perception, is highlighted. Includes lectures, seminars, discussions, and reading assignments in the area of interest. *P—POI.*

NEUR 798 – Manuscripts, Seminars, and Posters (2). A highly interactive course with enrolled students receiving detailed feedback on all written assignments. Covers areas such as writing style, composing abstracts, constructing figures and legends, as well as simulating the e-submission process (text, figures, cover letter, etc.). In addition, previously published work is dissected for style, structure, and presentation. Didactic lectures cover a wide range of subjects, including but not limited to, EndNote (for Web); basics of Adobe Illustrator; authorship issues, and responses to reviewer's comments. *Background in neuroscience not required. Open to graduate students from all programs.*

TRANSLATIONAL AND HEALTH SYSTEM SCIENCE (THSS)

Program Co-directors	Capri Foy, Janet Tooze
Professors	Walter Ambrosius, William Applegate, Nancy Avis, Ronny Bell, Alain Bertoni, Werner Bischoff, Don Bowden, Greg Burke, Haiying Chen, Ralph D'Agostino Jr., Suzanne Danhauer, Debra Diz, Doug Easterling, Matthew Edwards, Mark Espeland, Metin Gurcan, Mark Hall, Kathleen Hayden, David Herrington, Jason Hoth, Denise Houston, Tom Houston, Tim Howard, Fang-Chi Hsu, Nancy King, Dalane Kitzman, Stephen Kritchevsky, Carl Langefeld, Paul Laurienti, David Miller, Michael Miller, Barb Nicklas, Mary Claire O'Brien, Katherine Poehling, Sara Quandt, Steve Rapp, Dave Reboussin, Scott Rhodes, Gary Rosenthal, John Sanders, Avi Shetty, Sally Shumaker, Sean Simpson, Joey Skelton, Beverly Snively, Elsayed Soliman, John Spangler, Erin Sutfin, Mara Vitolins, Lynne Wagenknecht, Lynne Wagner, Kathryn Weaver, Jeff Williamson, Mark Wolfson
Associate Professors	Daniel Beavers, Holly Brower, Laura Coker, Sabina Gesell, , Elizabeth Jensen, Iris Leng, Michael McCrory, Justin Moore, Nicholas Pajewski, John Salsman, , Joseph Yeboah
Assistant Professors	Mike Bancks, Ajay Dharod, Capri Foy, Morgana Mongraw-Chaffin, Chandylen Nightingale, Nate O'Connell, Lindsay Reynolds, Jennifer Ross, Anna Snavely, Stephanie Sohl, Jaime Speiser
Adjunct Graduate Faculty	Manny Ramirez

Overview

The Master of Science degree in Translational and Health System Science (THSS) is hosted by the Division of Public Health Sciences and the Clinical and Translational Science Institute. The THSS program is open to individuals who already hold or are pursing advanced degrees, such as the MD, DVM, ScD, PhD, DDS, DSN, MMS (Physician Assistant), or MSN who are seeking training in the clinical and population aspects of translational research or improving the health system. The program also may be appropriate for qualified applicants with at least a BA or BS in a social science, public health, or other health-related field, although additional post-baccalaureate coursework may be required. For applicants without an advanced degree, previous experience in a health-related field is required.

The purpose of this program is to assist students in developing competencies (theoretical/conceptual, methodology, statistics) required for the conduct of clinical and population research and the translation of knowledge gained from such research into improved human health through dissemination and implementation in the health system. Development of translational research skills is vital for the future success of researchers in the basic science and health professions. Translational research includes two areas of translation. One area involves the process of applying discoveries generated during laboratory research, and in preclinical studies, to the development of trials and studies in humans. The second area of translation concerns research aimed at enhancing the adoption of best practices in the health system and the community. This program focuses on clinical research and the second area of translational research described above, as well of implementation of evidence-based research in the learning health system. (Of note, the graduate program in Molecular Medicine and Translational Science focuses on the first area of translation described above.) There are two tracks which students may pursue in addition to completion of core coursework: Clinical and Translational Investigation (CTI), and Learning Health System Science (LHSS).

Translational and health system research comprises studies and trials in human participants including:

- Patient-oriented research – Research conducted with human participants (or on material of human origin such as tissues, specimens, and cognitive phenomena) for which an investigator (or colleague) directly interacts with human participants
- Epidemiologic and behavioral studies
- Outcomes research and health services research
- Implementation science

While a minimum of twelve months of full-time work or its equivalent in residence is required for the master's degree, this program normally requires two years. In addition to coursework, all students complete a capstone project under the direction of a committee. Students may initiate original data collection or analyze existing data sets or develop a career development award application, dependent on the track. It is feasible to extend the program from two to three years or to enroll as a part-time student. Students may matriculate only at the beginning of the fall term each year.

The Master of Science degree in Translational and Health System Science was initiated in the fall of 2020. It is one of a small number of similarly structured Master's degree programs in the U.S., placing it on the cutting edge of graduate education.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: All students are required to take a minimum of 32 graduate course credit hours, with 6 hours in capstone courses. All students are required to take the following set of courses: THSS 703, 704, 720, 730, 731, 736. 740, 741, 748, and 749.

For the CTI track, 732, 742, and 751 are also required; for the LHSS track, 733, 735, 737, 738, 739, and either 751 or 752 are required.

Certificate Requirements: In addition to the Master of Science degree, two abbreviated THSS graduate certificates corresponding to the two tracks are also available for students who do not have time to complete a capstone project. The purpose and entrance requirements are identical to the Master's program. Although capstone coursework is not required, students who seek a certificate will need to complete at least 15 hours of specified THSS coursework, complete research ethics training requirements and demonstrate competency in basic biostatistics.

Courses of Instruction

THSS 703 – Ethics and Responsibility in Translational and Health System Science I (1). Provides students with an overview of topics related to ethics and the responsible conduct of human subjects research. Students utilize a case-based format to address such topics as: study oversight and research design, informed consent, selection of subjects, conflicts of interest, the social effects of research, the use of embryos, fetuses and children in research, genetic research, and authorship and publication of study findings. Students are required to complete the Collaborative Institutional Training Initiative (CITI) Human Research On-Line Curriculum as part of this course. *P—POI; Satisfactory/Unsatisfactory*.

THSS 704 – Ethics and Responsibility in Translational and Health System Science II (1). Provides students with an overview of topics related to ethics and the responsible conduct of human subjects research. Students utilize a case-based format to address such topics as: study oversight and research design, informed consent, selection of subjects, conflicts of interest, the social effects of research, the use of embryos, fetuses and children in research, genetic research, and authorship and publication of study findings. Students are required to complete the Collaborative Institutional Training Initiative (CITI) Human Research On-Line Curriculum as part of this course. *P—THSS 703 or POI; Satisfactory/Unsatisfactory*.

THSS 720 – Epidemiology (4). This course is designed to provide students with an introduction to the concepts and methods of epidemiology. Foundational elements covered throughout the course include study design, measurement of disease frequency and disease association, and threats to validity in epidemiologic and clinical research. Topics and concepts discussed in the context of these elements include critical review of scientific literature, systematic bias, random error, confounding, interaction, sensitivity and specificity, regression and survival analysis, causal inference, interpretation of data, and policy implications. *P—POI*.

THSS 722 – Antimicrobial Stewardship (3). The Antimicrobial Stewardship (AMR) course will expose candidates to the challenges and opportunities faced by the healthcare epidemiology community and provide the understanding and tools to mitigate the threat of infectious pathogens present in patient care settings. This course

will provide students with the competency regarding antimicrobials to reduce the occurrence of AMR in diverse healthcare settings through surveillance, research, new product development, and prevention and control. This course is mandatory for students pursuing the Antimicrobial Stewardship & Infection Prevention Concentration. *Typically offered in the spring term. P—THSS 720 or BMSC 713; POI.*

THSS 723 – Infection Prevention and Health System Epidemiology (3). This course will provide the knowledge base to apply epidemiological principles and determine appropriate infection prevention measures to reduce the occurrence of hospital associated infections and spread of communicable diseases in healthcare settings. The proposed training program will expose candidates to the challenges and opportunities faced by the healthcare epidemiology community and provide the understanding and tools to mitigate the threat of infectious pathogens present in patient care settings. This course is mandatory for students pursuing the Antimicrobial Stewardship & Infection Prevention Concentration. . *Typically offered during the summer term. P—THSS 720; POI.*

THSS 725 – Global Health Seminar Series (1). The Global Health Seminar Series will teach the interaction between a pathogen, host, and environment, transmission modes and dynamics, and disease elimination pathways, with focus on issues affecting global populations. The course will address the causes and consequences of morbidity and mortality related to infectious diseases that cross regional or national boundaries, with emphasis on research and implementation of public health interventions in low and middle-income countries. *Typically offered in the fall term. P—POI.*

THSS 730 – Introduction to Biostatistics (4). This course provides an introduction to statistical concepts and basic methodologies that are prevalent in biomedical literature. It includes discussion topics such as descriptive statistics, probability, sampling distributions, hypothesis testing, simple linear regression, correlation, one-way analysis of variance, categorical data analysis, survival analysis, sample size and power analysis, and nonparametric methods. *Access to SAS/STAT required. P—POI.*

THSS 731 – Introduction to Biomedical Informatics for the Learning Healthcare System (2). The Introduction to Biomedical Informatics for the Learning Healthcare System course provides an introduction to the core domains of biomedical informatics, including bioinformatics, medical/healthcare informatics, public health informatics, imaging informatics, and the evolving role of biomedical informatics in the "Big Data" era. Course content is provided using didactic lectures, group discussions, selected readings, directed self-study and classroom demonstrations. *P—POI.*

THSS 732 – Statistical Modeling (4). The topics of the course include statistical concepts and basic methodologies related to the general linear model and its extensions. The basic statistical procedures discussed in the course include simple and multiple linear regression, analysis of variance and covariance, logistical regression, and repeated

measures analysis. Emphasis is given to proper application and interpretation of statistical methods and results. *Access to SAS/STAT required. P—THSS 730 or POI.*

THSS 733 – Learning Health System Team Science Practicum (0.5-2). The Learning Health System Team Science Practicum is an experiential activity in which course participants are embedded in an interdisciplinary team at Wake Forest Baptist Health working to implement evidence-based strategies to improve healthcare quality, access, or costs. The goals of the Practicum are to enhance participants' 1) competency in working in interdisciplinary team; 2) awareness of the complexity of implementing organizational change in the complex milieu of a large integrated delivery system; 3) understanding of potential patient, provider and system level barriers to change; and 4) understanding of the marketplace challenges faced by healthcare delivery systems in rapidly changing environments. Trainees will develop a literature review that will describe 1) the significance of the issue that is being addressed by the team; 2) challenges or barriers that have to be overcome to address the issue; 3) interventions to address the issue that have been described in the literature; and 4) potential metrics to measure the impact of interventions to address the issue. *P—POI.*

THSS 735 – Building Successful Teams (0.5). This course provides an introduction to building successful teams, with a focus on building translational research teams in the health system. It will consist of two sessions that will provide an introduction to concepts of team building and leading teams, including team development, developing team charters, holding team members accountable, team dynamics, working in multi-disciplinary teams, minimizing conflict, and holding effective meetings. Students will be asked to write reflections of team building concepts addressed after completing each session. *P—POI.*

THSS 736 – Principles of Improvement and Implementation Science (2). The Principles of Improvement and Implementation Science course provides an introduction to dissemination and implementation (D&I) science and a theoretical foundation to translate evidence into clinical practice, health policy, or public health. Participants will be introduced to the foundations of implementation science and will explore a broad range of implementation research in health and healthcare. Topics include: D&I research terminology, efficacy and effectiveness research, quality improvement methods, evidence-based interventions, D&I measures and analytic strategies, fidelity, developing sustainable partnerships, and evaluating and adapting D&I strategies. *P—POI.*

THSS 737 – Organizational Change in Health Systems (2). This course provides an introduction to models for leading effective change and open systems thinking. Students will not only study models for effective change leadership, but will apply knowledge to cases, a simulation and practical projects in the Health Care setting. *P—POI.*

THSS 738 – Learning Health System Colloquium (0.5-1). The Colloquium brings together faculty, mentors, and trainees and utilizes two formats. The first format

involves the discussion of emerging methods in health systems research using a "flipped classroom" design in which students are asked to read original studies using the methods being discussed and pose two questions about the topic on the Colloquium website. The second format involves student presentations of drafts of manuscripts or 'Chalk Talks' of research projects they are developing. The primary goal of these sessions is to teach skills in critical review and the features of well-written research. The format promotes a lively pre-class exchange of ideas and ensures that the presenter covers issues identified by trainees. The intimate nature of the Colloquium also enables presenters to learn about the interests of the students and mentors. Colloquium content will be well integrated and aligned with the course content to complement or reinforce learning competencies for the Translational and Health System Science MS and Learning Health System Science certificate programs in the area of development of research questions, review of the scientific literature, study design, statistical analysis, research ethics, scholarly communication, team science, implementation science, health system operations, and systems theory. *P—POI*.

THSS 739 – Leading Successful Teams (0.5). This course provides an introduction to leading successful teams, with a focus on leading translational research teams in the health system. It will consist of three sessions that will address the essential leadership skills for leading successful teams, including communication, negotiation, building trust, decision making, and problem solving. Students will be asked to write reflections of leadership concepts addressed after completing each session. *P—POI*.

THSS 740 – Scientific Writing for Papers and Proposals (2). This course provides students in the Translational and Health System Science MS or certificate programs with the knowledge and skills to develop a grant proposal to pursue funding in their areas of interest. It represents the second in a series of capstone courses for the MS degree. The course will be taught over 6 weeks in the summer session with weekly 2.5 hour sessions. Topics covered include: Human Subjects, Clinical Trials, Investigator, and Resource components of grant proposals; NIH review process; How to write a grant critique; mock study section; and how to revise a grant proposal. Sessions will be led by faculty and research staff with expertise in writing, developing, and critiquing grant proposals. *P—POI*.

THSS 741 – Research Grant Preparation (1). Provides students with the knowledge and skills to develop grant proposals to pursue funding in their areas of interest. Topics covered include: the role of external funding in biomedical research; how to identify public and private sources of funding; required components of grant submission; and human subjects and budgeting considerations. Students develop a research proposal for peer review and critical discussion. *P—THSS 740; POI*.

THSS 742 – Clinical Trial Methods (3). Provides students with knowledge of clinical trials methodology from Phase I through Phase IV and beyond. Topics include: why trials are needed; specification of the trial question(s); basic trial designs; identification of the appropriate study population, interventions, and response

variables; the randomization process; masking; sample size; data analysis; recruitment/retention/adherence; trial monitoring and interim analyses; assessing/reporting adverse effects; and interpreting trial results. *P—POI.*

THSS 747 – Topics in Cancer Survivorship Research (1). Provides students with an overview of topics related to cancer survivorship. Topics include: epidemiology of cancer survivorship, quality of life issues, cancer and the family, disparities in morbidity and mortality, late effects of cancer treatment, ethical issues, complementary and alternative medicine, symptom management, behavioral and lifestyle issues post-treatment, health services research, and special populations. *Course may be repeated for credit. P—POI.*

THSS 748 – Translational Research Methods I (2). The course will focus on the development of integrated aims, literature reviews, and conceptual frameworks that provide the necessary foundation for successful community and health delivery translational research. To provide students with the opportunity to expand their ability to develop and communicate research concepts, the course will include numerous in-class activities and several written assignments. *Typically offered in the fall term. P—POI.*

THSS 749 – Translational Research Methods II (3). The course examines how study designs are selected and examines specific application of these designs within the community and health delivery settings. The latter part of the course focuses on measurement, with emphasis on the development of data collection forms and surveys. To provide students with the opportunity to expand their ability to develop and communicate research concepts, the course will include in-class activities plus a presentation and written assignments. *Typically offered in the spring term. P—THSS 748; POI.*

THSS 751 – Research Paper (1-9). The Research Paper is a capstone project for the Translational and Health System Science (THSS) MS program, and is required for the Clinical and Translational Investigation track. The goal of the paper is to apply the knowledge and skills gained from coursework to the development of a research paper suitable for publication in a peer-reviewed journal. Students will work individually on the paper, and will be the first author on the manuscript. The Research Paper course is intended to be taken after or concurrently with coursework. The Research Paper will be assessed by a Research Paper Committee comprised of the student's advisor, a statistician, and an additional member with subject area expertise. *P—POI.*

THSS 752 – Career Development Award Application (1-9). The Career Development Application is a capstone project for the Translational and Health System Science (THSS) MS program. The goal of the course is to apply the knowledge and skills gained from coursework to the development of a training grant suitable for submission to a funding agency. The Career Development Award Application course is intended to be taken after, or concurrently with coursework. The career development award application will be assessed by a Capstone Committee comprised of the student's advisor

and two additional members with subject area expertise. The student is expected to select a scientifically relevant, feasible topic, in the area of clinical, translational, or health system science. Students are expected to develop a training plan and a research plan, as well as put together other essential elements of a career development award application. Students are expected to draft all sections of the training plan and research plan. *P—POI; Satisfactory/Unsatisfactory*.

THSS 761 – Detecting and Understanding Health Disparities (1). This course will define and measure health disparities, evaluate landmark reports, and examine the social determinants and health systems determinants of healthcare disparities. Professional skills developed in this course will include evaluation of implicit bias, critical thinking in health care ethics, adjusting to group dynamics, and practice in public speaking. *P—POI*.

THSS 762 – Promoting Health Equity (1). This course will address organizational and community points of interventions to reduce health disparities, strategies for policy intervention to address health disparities, development of platforms for community engagement, and incorporating service learning projects into the educational structure. Professional skills developed in this course will include problem-solving skills, adjusting to group dynamics, and written communications. *P—POI*.

THSS 766 – Individual Study in Translational and Health System Science (1-6). Provides students with opportunities to pursue advanced topics in their individual areas of interest with guidance from expert faculty. *May be repeated for credit. P—POI*.

Joint Degrees, Certificates, and Concentrations

JOINT DEGREES

The School of Medicine-based office administers the following joint degrees in conjunction with other university professional schools (Medicine and Business): PhD/MMS (in Molecular Medicine & Translational Science), PhD/MD (in all PhD programs), PhD/MBA (in all PhD programs), MS/MD (in Translational and Health System Science), and the MS/BA or BS (in Neuroscience). For information on the degree requirements for all other joint graduate degrees, please consult the Graduate Bulletin maintained and administered through the Reynolda campus.

PhD/MMS (Molecular Medicine and Translational Science)

Program Co-Directors — Gayle Bodner (Interim), John Parks

Overview

The PhD/MMS is a 5- to 7-year program that combines a PhD in Molecular Medicine and Translational Science (MMTS) with a Master of Medical Science (MMS) in Physician Assistant (PA) Studies and is offered in conjunction with the Wake Forest School of Medicine Physician Assistant Program. The program targets students interested in clinical research, community research, and the translation of knowledge into improved human health. Graduates with the PhD/MMS will be basic scientists trained to function successfully in clinical environments and will have considerable professional flexibility. Graduates can work as clinician scientists on teams conducting clinical trials, for example, or they can teach and conduct research within academic health centers.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin. The PhD degree is conferred in the term in which all requirements for that degree are met. The MMS degree shall be awarded upon completion of the PA program.

Program Requirements: Applicants for the PhD/MMS dual degree program must be accepted first into the PhD program through the Graduate School's admission process. Students can apply for admission to the PA program during the first, second, or third year of study in the PhD program and will begin PA program studies after completing the dissertation defense.

Potential applicants should note the following:

- Students interested in the PhD/MMS program must meet the PA program course prerequisites to be eligible for admission to the PA program

- Students with the MMTS PhD who were involved with translational research and attached to a physician mentor are considered to have met the PA program admission requirement of 1,000 patient/clinical contact hours
- Because students with the MMTS PhD have completed a doctoral thesis, they are also considered to have met the PA program requirement to complete a graduate project

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PhD/MD

Program Director Chris Whitlow

Overview

A PhD/MD degree offers graduates outstanding opportunities in the new era of biomedical research of the 21st century. The invaluable perspective of a PhD/MD graduate positions the physician scientist as a crucial link in translating scientific research into improving human health and reducing disease. During the past decade, 62 percent of Nobel prizes in medicine and physiology were awarded to MD or PhD/MD researchers.

With the increasing sophistication of research tools, MDs without extensive formal research training rarely have the depth of knowledge needed to progress rapidly as a research scientist. The increasing pace of research, the need for knowledge in specific techniques, and the competition in funding have made it more difficult for MD clinicians to succeed in a research-intensive career. Optimal training is provided by combining an MD with a PhD academic program.

The PhD/MD program, a combined effort between the Graduate School of Arts and Sciences and the School of Medicine, is an integrated program where neither the MD nor the PhD degree is compromised. The student gains the full perspective for identification and analysis of problems related to human health while receiving rigorous training in a basic or translational research discipline: training which provides the depth of knowledge of scientific logic and techniques for an effective, exciting, and successful career in medical research.

The program seeks outstanding students who have already shown aptitude and enthusiasm for research.

Degree Requirements: Please see “Requirements for the Doctor of Philosophy Degree” in the “Degree Requirements” section of the Graduate Bulletin. The PhD degree is conferred in the term in which all requirements for that degree are met. The MD degree shall be awarded upon completion of the MD program.

Program Requirements: The duration of the program typically is seven years. Prior to entry into MD program, students are required to explore available research

opportunities. A research rotation is conducted with a selected member of the participating graduate faculty. This research rotation (and subsequent ones, if needed) familiarize students with faculty and their fields of expertise; usually one of these faculty are chosen as the student's graduate (PhD) advisor.

Years 1 and 2: The first two academic years are dedicated to the MD program. Phase I (seven months) introduces core biochemical knowledge, including development and structure of the human body (gross, microscopic, embryological, and radiological anatomy) and basic cellular functions (biochemistry, molecular biology and genetics, immunology, introduction to pathology).

Phase II (months 8-20) includes courses in systems pathophysiology (physiology, pharmacology, microbiology and pathology), and a two-month period for a second rotation in a lab of the selected graduate program in the summer after the first year.

Medicine as a profession, clinical decision making, and epidemiology studies are included in both Phases I and II.

During these years, the student usually attends a graduate seminar course. The seminar meets once a week and provides a continuing in-depth introduction to the chosen graduate discipline in addition to social and intellectual contact with other graduate students and faculty.

If possible, the student chooses a graduate adviser by the end of Phase II of the medical curriculum. Otherwise, the summer after Phase II may be used for another laboratory rotation, prior to choosing an adviser.

At the beginning of year three students will remain with their medical school class for a three month clinical experience. These three months are spent learning basic clinical skills on internal medicine rotations and introduce the students to the practice of medicine providing basic skills in completing the history and physical exam experience during the graduate school years in an out-patient clinic. These three months of training will also increase the flexibility for returning to medical school upon completion of the graduate degree. After completion of the three clinical months the students will then join the graduate school with the new cohort of graduate students.

Years 3 through 5: During the graduate school years, the student participates in a monthly outpatient clinical experience. Students rotate at a clinic for the underserved, working with faculty and private practice physicians. Participation in this clinic not only helps to maintain clinical skills but gives the student experience with balancing research and clinical responsibilities.

The third year is spent taking advanced basic science courses and conducting research. Didactic coursework is intended to supplement the biomedical knowledge base built in the medical school curriculum. Program or departmental courses also provide a more discipline-specific focus and, therefore, depend on the chosen graduate program.

The duration of the dissertation research may vary but typically is completed in years three-to-five and, if needed, a portion of year six. The PhD dissertation is completed and defended prior to returning to clinical studies.

Years 6 and 7: The student completes eighteen months of required clinical rotations (Phase III of the clinical curriculum) which include internal medicine, surgery, pediatrics, obstetrics, women's health, neurology, psychiatry, radiology, anesthesiology, family and community medicine, and emergency medicine. Four months of elective time are spent in other clinical experiences or may be used for completion of graduate studies prior to returning to the medical curriculum. This part of the schedule is tailored to the individual student with the approval of the graduate advisor, MD/PhD program director, and the Associate Deans for medical education and student services.

Both the Graduate School and the School of Medicine evaluate the applicant's credentials. The MCAT is the required standardized test for all applicants. All biomedical PhD programs participate in the joint degree plan.

Initial application is through the American Medical College Application Service (AMCAS). When the School of Medicine receives AMCAS applications, students are sent supplemental forms for application to the School of Medicine. The applicant should indicate interest in the combined PhD/MD program on the supplemental application. The School of Medicine supplemental packet requests an evaluation by the applicant's premedical advisory committee. For the PhD/MD program, the applicant should also include letters of evaluation specifically addressing his or her research experience and abilities.

This is a highly competitive, limited program. Students who matriculate receive tuition scholarships throughout the program. In addition to outstanding grades and MCAT scores, the applicant should provide evidence of enthusiasm and aptitude for research, with prior research experience beyond that of college courses. This is an important factor in evaluation of the application.

After the supplemental application packet, MCAT scores, and letter(s) of evaluation are received, the completed application is reviewed by the committees on admissions of the MD/PhD program. Competitive applicants are scheduled for interviews.

PhD/MBA

Program Director — Dwayne Godwin

Overview

In addition to intensive doctoral training, the PhD/MBA program incorporates core knowledge of business and managerial skills to provide the student with a marketable, competitive advantage, whether the student finds employment in industry or academia. Graduates choosing to pursue a traditional tenure-track faculty position will have the managerial and business training to initiate and operate their own research laboratories

and to collaborate more effectively with the private sector. Graduates choosing a non-traditional career path will be prepared to exercise their research training in management positions in the pharmaceutical industry, private foundations, government agencies, or university research and technology transfer offices.

Degree Requirements: Please see "Requirements for the Doctor of Philosophy Degree" in the "Degree Requirements" section of the Graduate Bulletin. The PhD degree is conferred in the term in which all requirements for that degree are met. The MBA degree shall be awarded during the same term as the PhD.

Program Requirements: The program is a synthesis of curricula from the Graduate School and the Evening MBA Program of the Wake Forest University School of Business, with specialized course-work and opportunities for industrial and business internships. The joint program is open to all PhD-granting programs across all Wake Forest campuses. It has taken students approximately 5 years to complete the joint program, depending on the nature of the graduate research undertaken in the home program. The first year of the curriculum provides students with a core base of knowledge in biomedical sciences and includes training in the core competencies of the home graduate program. At the same time students begin to be exposed to issues related to research and design, career development, and journal clubs. Laboratory rotations usually occur in this first year in accord with Program or Track requirements. The students typically begin their dissertation research during the second year. At the end of the second year and before beginning MBA course-work, the student is required to take and pass a qualifying exam that will admit him or her to candidacy for the PhD.

A student enrolling in the PhD/MBA program will have 5-6 terms of evening MBA courses added to his or her graduate degree requirements. Opportunities for industrial projects and internships are possible after as-cent to PhD candidacy and during the MBA coursework phase. The PhD and MBA degrees are awarded simultaneously at the completion of all requirements for both degrees.

Admissions are administered through the Graduate School of Arts and Sciences. Students wishing to enroll in the program must apply to both programs and meet the respective admissions requirements of the Graduate School of Arts and Sciences and the Wake Forest University School of Business. Admission to the MBA portion of the program can occur separately after gaining admission to the home graduate program and after securing appropriate release from the home program for participation in the joint program (this is in the form of a letter from the thesis advisor cosigned by the program director). In addition to the application a copy of the letter should be submitted to Dr. Dwayne Godwin, Dean, Graduate School of Arts and Sciences and Director, PhD/MBA program. The Graduate Record Exam is accepted for admission to the joint program. Prospective students should also submit a one-page statement of interest indicating future plans for use of the joint degree, official transcripts from each college or university attended, and three completed recommendation forms.

Before admission to the program, the applicants are required to complete a personal interview with the PhD/MBA program director and the Wake Forest University School of Business. After the interview phase, the top applicants may be offered admission to the joint program.

MS/MD (Translational & Health System Science)

Program Co-Directors — Capri Foy, Janet Tooze

Overview

Those interested in the MS/MD degree may choose to complete training in clinical research after the third year of medical school. Medical students may apply for admittance to the MS graduate program in the fall of their third year. The MS/MD in Translational and Health System Science is designed to develop competencies in clinical researchers interested in conducting translational or health system research as a physician scientist.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin. The MS degree is conferred in the term in which all requirements for that degree are met. The MD degree shall be awarded upon completion of the MD program.

Program Requirements: Students apply to the MS program through the Graduate School during their enrollment in the MD program. Accepted applicants enroll full-time in the MS program during their fourth year of study and complete required coursework for the MS degree within that year. Upon completion of the MS curricula and their capstone project, students return to the MD program to complete the MD degree. In rare cases, students may request to continue work towards completion of the capstone project concurrently with their MD degree pursuit.

In addition to the Master of Science degree, two abbreviated certificates in THSS (Clinical and Translational Investigation, Learning Health System Science) are also available for medical students who for various reasons choose not to complete a full MS degree. Admissions requirements for the certificates are identical to that to gain admittance into the master's program. Please see the section on Certificates for additional information on the certificate requirements.

MS/BS-BA (Neuroscience)

Program Director — Carol Milligan

Overview

This program offers Wake Forest University, or partner school, undergraduates pursuing a BS or BA degree in a Neuroscience discipline the opportunity to earn a

research-oriented MS degree in Neuroscience with one additional year of study. The program builds on the existing Neuroscience Minor and utilizes existing course and research opportunities associated with the Graduate School's Neuroscience Program.

The goal is to provide highly motivated undergraduate students with sophisticated training in neuroscience, and the opportunity to build critical thinking and research skills. Students will gain graduate course credit and an enhanced research experience that will provide them with a competitive edge to apply to graduate or professional schools, or to pursue non-academic careers that require research expertise in the life sciences and Neuroscience.

Degree Requirements: Please see "Requirements for the Master of Science Degree" in the "Degree Requirements" section of the Graduate Bulletin.

Program Requirements: Wake Forest University undergraduate students wishing to enter the program are required to declare and pursue the Neuroscience minor, and should identify a mentor in order to apply to the program. The minor requires a minimum of 17 hours, 9 of which must include the Neuroscience courses (200, 201 300, 391). At least one term of research in neuroscience is required for the minor (NEU 391). The research can be conducted on the Reynolda campus or with investigators at the Wake Forest University School of Medicine. The research project must be approved by a member of the Neuroscience Minor faculty. 8 hours must come from elective courses. One of the elective courses must come from outside the student's major department. Requirements for students entering from partner schools will be specified in an articulation agreement between the program and the partner school.

GRADUATE CERTIFICATES

The School of Medicine-based office administers the following graduate certificates: Clinical and Translational Investigation, and Learning Health System Science. For information on all other graduate certificate offerings, including Bioethics (BIE), Curriculum, Instruction, and Assessment (CIA), Interpreting and Translation Studies (ITS), Medieval and Early Modern Studies (MDV), Structural and Computational Biophysics (SCB), and Sustainability (SUS), please consult the Graduate Bulletin maintained and administered through the Reynolda campus.

Clinical and Translational Investigation

Certificate Co-Directors — Capri Foy, Janet Tooze

Overview

The objective of this certificate program is to provide training in epidemiology, biostatistics, and applied clinical and translational research methods to health professionals, research professionals, and health sciences students, residents, and fellows. Students trained in the program will develop skills to: 1) develop meaningful and feasible research questions, 2) critically appraise the scientific literature, 3) design and implement studies to answer clinical and translational research questions, 4) communicate scientific concepts orally and in writing, 5) perform and interpret basic biostatistical analyses, and 6) collaborate productively in multidisciplinary scientific teams. Courses are primarily taught by faculty within the Division of Public Health Sciences and are held on Tuesdays and Thursdays.

Certificate Requirements

Although a capstone project is not required, students are required to complete 15 credit hours of instruction of coursework from the Translational and Health System Science (THSS) program, including at least 6 hours from THSS 720, THSS 742, THSS 748, and THSS 749; complete ethics training requirements and demonstrate competency in basic biostatistics. A 3.0 GPA is required.

Learning Health System Science

Certificate Co-Directors — Capri Foy, Janet Tooze

Overview

The objective of this certificate program is to provide training to integrate research with practice to create and develop learning health systems. Students trained in the program will develop skills to: 1) critically appraise the scientific literature, 2) design and implement studies in health system settings, 3) utilize system science and organizational change management, 4) perform and interpret basic biostatistical analyses, and 6) lead multidisciplinary teams. Courses are primarily taught by faculty within the Division of

Public Health Sciences and the Clinical and Translational Sciences Institute and are held on Mondays, Tuesdays and Thursdays.

Certificate Requirements

Students are required to complete 15 credit hours of instruction of coursework from the Translational and Health System Science (THSS) program or other approved courses, including at least 10 hours from THSS 731, THSS 733, THSS 735, THSS 736, THSS 737, THSS 738, and THSS 739; complete ethics training requirements; and demonstrate competency in basic biostatistics. A 3.0 GPA is required.

CONCENTRATIONS

The School of Medicine-based office administers the following graduate concentrations: Antimicrobial Stewardship and Infection Prevention, Cancer Biology, Integrative Physiology and Pharmacology, Neuroscience (discontinued and only available to students who were enrolled on 4/23/19 or earlier), and Regenerative Medicine. Pursuit of a concentration is open to any student and requires no application. Successful completion of a concentration results in a note on the transcript that indicates the completed concentration at the awarding of the degree. Concentrations are not awarded without a completed degree. For information on all other graduate concentrations, including Religion and Public Engagement and Women's, Gender, and Sexuality Studies, please consult the Graduate Bulletin maintained and administered through the Reynolda campus.

Antimicrobial Stewardship and Infection Prevention

Concentration Director — Werner Bischoff

Overview

The Antimicrobial Stewardship and Infection Prevention concentration provides the knowledge base to apply epidemiological principles and determine appropriate antimicrobial stewardship and infection prevention measures to reduce the occurrence of healthcare associated infections and spread of communicable diseases. The concentration exposes candidates to the challenges and opportunities faced by the global healthcare epidemiology community and provide the understanding and tools to mitigate the threat of infectious pathogens present in patient care settings. The collaboration with colleagues from diverse backgrounds will promote the exchange of different approaches to universal antimicrobial stewardship and infection prevention problems and open up opportunities to find and implement novel solutions.

The concentration in Antimicrobial Stewardship and Infection Prevention offers an opportunity for medical professionals to expand their field of study to the emerging threat of resistant pathogens and their successful reduction in global healthcare settings. The concentration therefore meets the needs and desires of students interested in Antimicrobial Stewardship and Infection Prevention and also provides a base of peers with similar interests and goals. The Antimicrobial Stewardship and Infection Prevention concentration also offers a value-added component, and competitive advantage, for students who choose to pursue careers that are not in the traditional academic career path, a frequent choice for current medical professionals.

Concentration Requirements:

- Epidemiology (THSS 720) OR Applications of Epidemiology (BMSC 713)
- Antimicrobial Stewardship (THSS 722)
- Infection Prevention (THSS 723)

- Global Health Seminar Series (THSS 725)
- Capstone project or thesis research completed in Antimicrobial Stewardship and Infection Prevention under the guidance of faculty members of the Section on Infectious Diseases and Global Health (for international students, the project will be selected on a relevant research topic executed in their home country)

Cancer Biology

Concentration Director Steve Kridel

Overview

The Cancer Biology concentration defines the unique educational and research experience for students pursuing an MS or PhD in the Cancer Biology Program, Molecular and Cellular Biosciences and all other tracks. The concentration will cover the topics in cancer research outlined by the Cancer Biology Training Consortium (CABTRAC) as being essential for students pursuing graduate degrees in cancer research.

Cancer Biology is a field of study that uses interdisciplinary approaches to understand the basic, clinical, and translational aspects of cancer. The Cancer Biology concentration would therefore meet the needs and desires of students interested in Cancer Biology and also provide a base of peers with similar interests and goals. The Cancer Biology concentration could also provide a value-added component, and competitive advantage, for students who choose to pursue careers that are not in the traditional academic career path, a frequent choice for current PhD students across the country.

Concentration Requirements:

MS students

- Basics Concepts in Cancer Biology (MCB 721)
- Basic Concepts in Cancer Research (MCB 722)
- Topics in Cancer Biology (MCB 723)
- Cancer Biology Seminar Series (CABI 701 & CABI 702)
- Thesis research completed in the laboratory of Cancer Biology Program faculty (6 hours)

PhD students

- Students must complete coursework with a B grade of higher, pass their written proposal, and advance to candidacy.
- Basics Concepts in Cancer Biology (MCB 721)
- Basic Concepts in Cancer Research (MCB 722)
- Topics in Cancer Biology (MCB 723)
- Cancer Biology Seminar Series (CABI 701 & CABI 702)

- Dissertation research completed in the laboratory of Cancer Biology Program faculty

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Integrative Physiology and Pharmacology

Concentration Director Paul Czoty

Overview

The Concentration in Integrative Physiology and Pharmacology is an integrated course of study under the sponsorship and direction of the Integrative Physiology and Pharmacology program. This concentration embraces the principles of pharmacology, and systems physiology and pharmacology, a unique educational experience that can enhance the program of MS students seeking application to medical school, MS or PhD students in non-biological (e.g., physical) sciences who plan to seek employment in the pharmaceutical or biotech industries, or MS students in a variety of biomedical programs who plan careers in the innovation or science support structures of academic or commercial organizations. The Concentration in Integrative Physiology and Pharmacology will not involve teaching faculty that are outside the IPP graduate program.

Concentration Requirements:

The concentration requires a minimum of 9 credit hours of IPP Graduate Program coursework, selected from the following courses:

- Principles of Pharmacology (IPP 701) OR Foundations of Pharmacology (IPP 601)
- Systems Physiology & Pharmacology (IPP 702, 4 or 6 credits)
- Any IPP Elective courses (to achieve no fewer than 9 credit hours)

Neuroscience (discontinued and only available to students who were enrolled on 4/23/19 or earlier)

Concentration Director Carol Milligan

Overview

The Neuroscience Concentration defines the unique educational experience obtained by students pursuing an MS or PhD in the Neuroscience program. All faculty members for the Concentration in Neuroscience are members of the Neuroscience program.

Neuroscience is a field of study devoted to understanding the brain and nervous system. Our Neuroscience training program is based on the belief that neuroscience broadly conceived provides a fundamental framework for understanding the biological basis of behavior and is critical for revealing the causes of neurological and psychiatric disorders. Accordingly, the major goal of our program is to provide a strong foundation

in all disciplines of neuroscience. With this foundation in place, students train to be able to carry out meaningful and significant research in all areas of modern neuroscience. The program provides an appreciation of the importance of all levels of organization, from genetics and molecular approaches to behavioral and physiological aspects, with an understanding of how basic neuroscience research is key to finding treatments for neurobehavioral pathologies and translating this information to the clinic.

Concentration Requirements:

MS students (MS/BA-BS joint degree)

- Introduction to Neuroscience I (NEUR 701)
- Introduction to Neuroscience II (NEUR 702)
- Seminars in Neuroscience (NEUR 711 and NEUR 712)
- Quantitative Methods in Bioscience (NEUR 741)
- Approved Elective (2-3 hours)
- Any Neuroscience Journal Club sequence (fall/spring pair)
- Thesis research completed in the laboratory of Neuroscience program faculty

MS students

- Introduction to Neuroscience I (NEUR 701)
- Introduction to Neuroscience II (NEUR 702)
- Clinical Neuroscience (NEUR 771) (or an approved elective)
- Thesis research completed in the laboratory of Neuroscience program faculty

PhD students

- Students must pass their preliminary examination, and advance to candidacy
- Introduction to Neuroscience I (NEUR 701)
- Introduction to Neuroscience II (NEUR 702)
- Clinical Neuroscience (NEUR 771) (or an approved elective)
- Thesis research completed in the laboratory of Neuroscience program faculty

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Regenerative Medicine

Concentration Co-Directors Anthony Atala, Joan Schanck

Overview

Regenerative Medicine is a highly interdisciplinary field which aims to repair diseased or damaged tissues using biological, engineering, and cell-based approaches and technologies. It is a rapidly growing area of biomedical research that encompasses many fields of science and medicine. The field encompasses numerous strategies including stem cell research, tissue engineering (TE), cellular therapies, gene therapy, and biomedical devices to address tissue/organ insufficiency. The concentration in

Regenerative Medicine (RM) offers a unique educational and research experience for students pursuing a MS or PhD drawn primarily from four graduate school tracks (Biomedical Engineering, Integrative Physiology & Pharmacology, Molecular & Cellular Bioscience, and Neuroscience); students in all biomedical sciences graduate programs are eligible to pursue the concentration. The RM concentration will provide multi-disciplinary education and research training in the scientific principles and clinical applications of RM including stem cell biology, biomaterials, gene therapy, nanotechnology, imaging, and enabling technologies and tissue/organ engineering. The RM concentration offers a balanced combination of theory and practice; and can serve either as a preparation for a PhD or as a self-contained advanced qualification in its own right.

Concentration Requirements:

MS Students

- Regenerative Medicine Immersion - Fundamentals, Principles, and Clinical Applications (MMTS 721)
- Introduction to Regenerative Medicine I (BMES 631)
- Advanced Topics in Regenerative Medicine (MCB 753)
- Regenerative Medicine Journal Club (IPP 785/786)
- Additional Requirements - Select one of the options below:
    - Option 1: Regenerative Medicine concentration with Research Thesis completed in the laboratory of Regenerative Medicine program faculty (6 credits)
    - Option 2: Regenerative Medicine concentration with Capstone Project or Internship completed in the laboratory of Regenerative Medicine Program faculty. Projects should take two terms to complete. Credit hours based on length of internship (GRAD 702/703).

PhD Students

- Students must complete coursework with a B grade or higher, pass their written proposal, and advance to candidacy.
- Regenerative Medicine Immersion - Fundamentals, Principles, and Clinical Applications (MMTS 721)
- Introduction to Regenerative Medicine I (BMES 631)
- Advanced Topics in Regenerative Medicine (MCB 753)
- Regenerative Medicine Journal Club (IPP 785/786)
- Thesis research completed in the laboratory of Regenerative Medicine program faculty