

# **Graduate Student Handbook Master of Science in Biomaterials**

**Graduate School of Arts and Sciences (GSAS)  
New York University (NYU)**

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## 1 Foreword and Mission Statement

Welcome to the Master of Science Program in Biomaterials Science. The M.S. degree in Biomaterials Science is awarded by the Graduate School of Arts and Sciences (GSAS) of New York University with courses offered by the Department of Biomaterials and Biomimetics of the New York University College of Dentistry (NYUCD).

The mission of the program is to provide education and training in biomaterials science and state-of the art technology while ultimately contributing to improving human health through biomaterials-based treatment modalities.

The goals of this program are to:

- Provide students with state of the art knowledge and training in biomaterials science that will prepare them for careers in research and development in academia and industry;
- Enhance the students' understanding of biomaterials-based treatment modalities by providing them with a broad background in biomaterials structure, fabrication, function and interactions with cells and tissues; and
- Serve as a basis for further advanced studies, e.g., doctoral programs in biology, the physical and health sciences

Located at the New York University College of Dentistry, a world-class craniofacial research and healthcare institution and the largest dental school in the world, the Department of Biomaterials and Biomimetics is uniquely positioned to build upon its existing strengths in biomaterials fabrication, characterization, and testing to achieve the goal of the program and to bridge the gap between bench top research and clinical application.

This Graduate Student Handbook is designed to provide specific information on policies, procedures, courses, and timeframes for completion of requirements pertaining to the Master of Science program in Biomaterials Science.

## 2 The Program: An Overview

The program includes a study of basic properties and structure of a full range of biomaterials used in medicine and dentistry; of the biologic interactions of these materials related to their composition, surface, architectural features and function; and the methods employed to investigate structure, function, and biologic interactions.

The program represents a challenge to students in managing course work while designing and completing a thesis research project.

Completion of the M.S. program in Biomaterials Science requires 36 credit hours of course work as well as completion and acceptance of a research thesis based on the student's original work. Of the 36 required credit hours, 2-6 credit hours may be approved for the student's research work. The time required to complete the program is not specified and will vary as it is affected by time commitment, motivation and the uncertainties of research. *Most* of the didactic portion of the program for full time students can be completed over approximately three regular semesters (1.5 academic years). The research for the thesis will overlap with the didactic program. A full time student can complete the program, including research, in approximately two academic years

A part time student is required to register for 6 credits a semester and could complete the program in approximately 3 years. Students must be in continuous enrollment during the period of their participation in the program, either by course registration or by the maintenance of matriculation registration (G17.4747). All requirements must be satisfied within a period of 5 years from the time of original registration for courses.

The student is responsible for the selection of a mentor and for working with that mentor to develop a research protocol. The protocol must be presented to the faculty for approval before the research can commence. Students are free to propose their own research topic but final project selection must be approved by the faculty mentor. Constraints regarding feasibility, time, cost to the department, safety and regulatory issues, availability of materials, access to fabrication and investigation facilities, and mentor interest are all factors in project selection. The department will try to provide alternatives that are satisfactory to the student.

For more information contact the Program Administrator or consult the *Graduate School of Arts and Science Bulletin* at [www.nyu.edu/gsas](http://www.nyu.edu/gsas) or the department at [gsas.graduate.biomaterials@nyu.edu](mailto:gsas.graduate.biomaterials@nyu.edu).

## 3 Program Guidelines

### 3.1 Admission Requirements and Student Status

The Graduate School of Arts and Science (GSAS) M.S. program in Biomaterials Science offers admission to applicants who hold a Bachelors Degree (or equivalent foreign credentials, DDS, DMD or MD) and who show promise of superior scholarly achievement. Successful applicants will have: (1) distinguished academic records; (2)

strong recommendations from instructors or others qualified to evaluate academic ability; and (3) well articulated research goals. Applications for graduate study are accepted on a continuing basis. M.S. students may begin their study in the fall or spring semesters. However, some courses are full-year courses and must be started in the fall semester. All students must apply for fall admission by May 1<sup>st</sup> and by October 1<sup>st</sup> for the spring semester. Remedial work to make up any undergraduate deficiencies may be taken prior to, or concurrent with, the master's program, but in the latter case, must be completed within the first year.

**3.1.1 Graduate Record Examination (GRE).** The Graduate School of Arts and Science requires all applicants to take the Graduate Record Examination (GRE). The Admissions Committee of the Department of Biomaterials and Biomimetics will take the GRE scores into consideration when evaluating the application. One may obtain application forms and further detailed information regarding the admissions process and requirements from the GSAS Enrollment Services at One-half Fifth Avenue, New York, New York 10012, or consult the *Graduate School of Arts and Sciences Application for Admission and Financial Aid* available at [www.nyu.edu/gsas/Admissions/AdmApp.html](http://www.nyu.edu/gsas/Admissions/AdmApp.html).

**3.1.2 TOEFL.** All accepted applicants are expected to demonstrate the ability to understand and communicate in English, both in oral and in written forms. To evaluate proficiency, the school requires applicants whose native language is not English to take the test of English as a foreign language (TOEFL).

**3.1.3 Acceptance of Applicants.** The Admissions Committee will take all scores into consideration when evaluating the applicant. In some cases applicants may be required to take one or more semesters of English language instruction as a condition of acceptance to the program.

**3.1.4 Maintenance of Matriculation.** It is required that the student be continuously enrolled in each fall and spring semester until the degree is granted. A student who has matriculated in GSAS but then fails to register for any program courses or Maintenance of Matriculation (G17.4747) for at least three consecutive semesters must apply for readmission. Students who have completed all course work and are readmitted are responsible for payment of maintenance of matriculation fees for the lapsed semesters.

**3.1.5 Non-matriculating status.** In special cases, a student may be accepted by the Admissions Committee as a non-matriculate or non-degree student. A non-degree student may take up to twelve points from the regular program of the Department of Biomaterials and Biomimetics before applying for matriculated status in the Master of Science in Biomaterials program. The application for matriculation is only considered if the student has received a B or better in each course included in the twelve points. Deadlines for applying for non-matriculate status are the same as for the M.S. program.

**3.1.6 Health insurance.** Students who cannot show proof to GSAS of their own health insurance will be required to participate in a University Health Insurance Plan.

**3.1.7 Leave of absence.** A student in good standing who is obliged to withdraw temporarily for national service, serious illness, or compelling personal reasons may request from the Associate Dean of Academic Affairs of GSAS a leave of absence (normally up to one year). Due to the nature of visa status, foreign students should consult with the Office of International Students and Scholars in such cases.

**3.1.8 Maintenance of scholastic standing.** Students must maintain an average grade for each course of B (3.0) or better to remain in good standing in the program. Remedial and/or extension of course work approved by the instructor involved and the Director of Graduate Studies may, on a case by case basis, be allowed to improve course grades of less than B, IP or W. Students with three or more incomplete grades will not be considered to be in good standing.

**3.1.9 Tuition refunds.** Students are entitled to refunds on tuition according to the refund schedule published by the Office of the University Registrar. Non-attendance of a course does not constitute withdrawal. Students are liable for tuition charges if they do not formally drop a course. The student must consult program administration and the Director of Graduate Studies before dropping courses or applying for refunds.

## **3.2 Research Assistantships, Fellowships, Employment and Travel Awards**

**3.2.1 Research Assistantships and Fellowships** are sometimes arranged if available for advanced students from departmental faculty. Research Assistants receive a stipend, tuition remission for a limited number of credits and are required to work 20 hours per week on research assigned by the sponsoring faculty. Fellowships, when granted,

have similar benefits but require full time employment. Research Assistantships and Fellowships are generally not used to support the student's thesis research.

3.2.2 Student employment (20 hours a week or less) on projects outside the student's thesis research project may be available if in the case of foreign students their visa status allows employment.

3.2.3 Travel Awards to attend scientific meetings in Biomaterials Science are sometimes available through GSAS and NYUCD upon announcement. Biomaterials will help to defer meeting costs for *presenting students* if funds are available, but does not guarantee funding. All students are expected to take the initiative to apply for internal and external fellowships, scholarships, and loans. All students are urged to inquire at the Graduate Enrollment Services Office or the Office of Financial Aid early in the fall of the year before they wish to enter the graduate program for information regarding government, foundation, private, or overseas awards for support for graduate study.

A comprehensive list of University, Graduate School, and departmental fellowships, prizes, and travel awards appears in the *Financing Graduate Education section of the GSAS application for Admission and Financial Aid*

## 4 Degree Requirements

### 4.1 Overview

The M.S. degree in Biomaterials Science is awarded after: (1) completion of 36 points course work with grade of B or better; (2) satisfactory oral defense of a completed research effort; (3) submission of an approved research thesis. Of the 36 points required, 28 must be from the Department of Biomaterials and Biomimetics at New York University.

Only 8 points may be transferred from outside the University and other departments outside the Graduate School of Arts and Science. In these cases, no courses older than ten years may be transferred. All courses must be approved for transfer by the Associate Dean for Academic Affairs of GSAS. Application for transfer of courses must be within the first academic year of attendance as a matriculant. Courses for which a degree has already been awarded may not be transferred or applied to the Master's program. Permission must be received from the Director of Graduate Studies for any course work taken outside the department. As also mentioned above, it is anticipated that full time students (12 – 17 credits per semester) would finish the program in two academic years, depending upon research progress and summer semester attendance. It is anticipated that part time students (minimum of 6 pts per semester) should finish the program in three years. All students are required to complete the program within five years unless special permission is obtained from the Chair of the Department of Biomaterials and Biomimetics. However, in any case, continuous matriculation is required.

### 4.2 Requirements for the First Year

4.2.1 Research Methods: All beginning graduate students are required to register in their first Fall semester for the research course (2 credits) G17.2001, "Introduction to Research". There are three requirements for obtaining a grade of B (Pass) for this course: (1) Satisfactory attendance and participation in the course (2) Submission of a research protocol (not necessarily the thesis protocol), and (3) passing grade on final exam.

Students doing a *longer* program due to overlay or simultaneous PG program may be able to take Intro to Research in the second year -only with prior approval by Graduate Director.

Also as mentioned above, during the first year, the student must secure a faculty mentor from within the department who has formally agreed to supervise the thesis research. The student should eventually obtain three mentors for their committee; however one can be the department chairman who must sign off on all students regardless of whether he is on their committee or not. Upon approval by the Biomaterials and Biomimetics Department Chairman, a Co-mentor from another department in the University may be assigned to advise the student. A minimum of 2 committee members must be from the Biomaterials Department GSAS faculty.

4.2.2 Thesis research protocol. The thesis proposal (protocol) for the completion of original research must be: (1) approved by the mentor, (2) filed with the Director of Graduate Studies and the Laboratory Manager, and (3) presented and approved at a department research meeting. The student must have received a grade of B in the Introduction to Research in Biomaterials course.

The plan of study and the thesis research are formulated in consultation with the faculty mentor(s). The thesis must represent original, independent research in a significant area of biomaterials and biomimetics at a level comparable to research published in recognized journals or as professional monographs. When the thesis is completed and has been approved by the mentor(s) and by a research advisory committee (readers) assigned by the

Director of Graduate Studies, the candidate defends the results of the research before a faculty committee. No more than twelve months should lapse between the approved proposal and the thesis defense. Exceptions requiring time extension must be approved by the Chair of the Department of Biomaterials and Biomimetics.

#### **4.3 Special Program**

Special Program Emphasis may be arranged by the Department Chair for students desiring to participate in a Special Emphasis research study (e.g., concentration in another department of the University, but still related to Biomaterials and Biomimetics (physics, chemistry, biology, etc.)). Students working with a Special Program Emphasis may, in consultation with the Director of Graduate Studies, be required to take courses in addition to the 36 points mentioned above.

#### **4.4 Departmental Meetings and Seminars**

Mandatory attendance is required of all graduate students to periodic (usually weekly) departmental seminars and/or research group meetings and various sessions of Laboratory Safety (see section "Requirements for Participation in Research"). At these seminars and research group meetings, students, faculty and scholars from other institutions discuss their research plans and findings. In addition, the department and the Linkow Implant Research program co-sponsor special seminars throughout the year for which attendance is also mandatory unless specifically excused by the Director of Graduate Studies..

#### **4.5 Meetings with Program Administrator**

All students are required to schedule regular meetings with the Program Administrator in order to keep current regarding course requirements, regulatory status, research requirements, research progress, thesis defense preparations, and if applicable, visa status.

#### **4.6 Graduation information**

Information concerning GSAS graduation dates and participation in GSAS graduation ceremonies can be obtained from the Program Administrator and GSAS administration. Information concerning NYU College of Dentistry graduation dates and ceremonies can be obtained through program administration.

## **5 Courses Offered**

Each course consists of a series of lectures (and laboratory sessions when indicated), mid-term and final examinations. **Courses indicated by an asterisk (\*) are required.** Announcements of available courses, schedule changes and other information are posted on the Graduate Students Bulletin Board in the hall of 804S.

**Principles of Biomaterials Science** G17.1000. [3 Points. Course Director: Department Faculty]. Covers the scientific principles underlying the area of materials science, including concepts of kinetics, thermodynamics, diffusion, and quantum mechanics, etc., as they relate to the structure and properties of materials. Also discussed are the role of interfaces on absorption, nucleation, phase diagrams of interest to materials scientists, the role of dislocation so and other defects in the macroscopic formation associated with materials, the solidification of metals and alloys, and mechanisms of strengthening alloys.

**\*Metal and Ceramic Biomaterials** G17.1001. [3 points. Course Director: Y. Zhang]. Covers the structure and properties of metals, alloys, ceramics and composites generally used in dentistry and medicine and their criteria for clinical applications. Also discussed are fundamental processes involving deformation, precipitation, order-disorder transformations, and synthesis; principles involving phase diagrams, recent advances in the development of advanced metal alloys and ceramic composites for dental and orthopedic implants; materials properties including defects, fracture, fatigue, and failure.

**\*Polymers & Biopolymers** G17.1002. [3 points. Course Director: H. Upton]. Covers the chemistry, structure, and properties of polymers used in dentistry and medicine, both inorganic and organic. Topics include the science of large macromolecules, molecular weights and measurements, polymerization mechanisms, mechanical properties of polymers, thermoplastic and thermosetting resins, chemistry of poly-siloxanes, emulsion and suspension polymerization, polymers associated with restorative materials, ionic polymers, silicones, polymethyl-methacrylate, BIS-GMA, reinforced polymers, composites, etc.

**\*Bioceramics** G17.1003. [3 points. Course Directors: R.Z. LeGeros, Y. Zhang]. Covers the preparation, structure, chemical compositions, and thermal and mechanical properties of bioinert (alumina, zirconia, carbon) and bioactive (silica- and phosphate-based special glasses, calcium carbonate, calcium sulfate, calcium phosphates) ceramics, cements, scaffolds used in dentistry and medicine.

**Testing Methods in Biomaterials** G17.1004. *Lecture and laboratory [2 points. Course Directors: M. Pines, J. Ricci].* Covers the principles governing tensile tests, compressive tests, creep tests, thermal and setting expansions, corrosion and tarnish tests, microstructural examination, and familiarization with the testing and use of instruments.

**\*Biomaterials-Tissue Interface I, II** G17.1005, 1006 [3 points per semester. *Course Directors: R.Z LeGeros, J. Ricci].* Provides background knowledge on the response of cells *in vitro* and tissues *in vivo* to different types of biomaterials used in dentistry and medicine. Covers surface chemistry of biomaterials, protein interaction with surfaces, effects of surface chemistry and microstructure on cell and tissue response, and other topics.

**Degradation of Biomaterials** G17.1007. [2 points. *Course Directors: M. Pines, J. Ricci].* Covers the principles and testing of *in vivo* and *in vitro* corrosion. Describes electrochemical mechanisms, corrosion tendency and electrode potentials polarization and corrosion rates, passivity, and crevice corrosion. Also discussed are testing methods involving anodic potentiostatic and potentiodynamic polarization techniques, stress corrosion cracking, intergranular corrosion, corrosion fatigue, oxidation and tarnish phenomena, and principles governing corrosion resistant alloy development.

**Introduction to Electron Microscopy** G17.1008, *Lecture and laboratory. [3 points. Course Directors: M. Pines, J. Ricci].* Covers the physical construction of scanning electron microscope and the theory of its use, the signals emitted when a high velocity beam of electron is allowed to scan a specimen target, and principles of resolution and contrast. The principles and uses of backscattered electron imaging and x-ray microanalysis are also covered. Students will become familiar with specimen preparation, instrumental use for microstructural examination, and interpretation. The course provides hands on experience.

**\*Physical & Chemical Methods in Biomaterials** G17.1011, *Lecture and Laboratory. [3 points. Course Directors: J. LeGeros, J. Ricci, M. Pines].* Introduces students to the principles and techniques used in the study of materials and hard tissues, including x-ray diffraction, infrared spectroscopy, inductive coupled plasma, and mechanical testing. The course provides hands on experience.

**\*Experimental Design in Biomaterials Research I & II** G17.1012 and G17.1013 [3 points first semester and 2 points the second semester. *Course Director: J. LeGeros].* Covers mathematical and statistical tools that are useful in biomaterials research. Students are trained to (1) evaluate the technical and economic feasibility of a study; (2) design research protocols taking into account required statistical power and sample size; (3) use appropriate statistical analysis tools; and (4) interpret the significance of the experimental results. Reliability, Live Testing, and Weibull Analysis are also covered.

**Seminars in Biomaterials** G17.1015. [3 points *Course Director: Department Faculty].* Covers aspects of the materials used in clinical dentistry and medicine including restorative materials, alloys, cements, impression materials, gypsum products, and cell-biomaterial interactions.

**Readings in Biomaterials and Biomimetics** G17.2000. [1 to 4 points, normally 1 credit per semester, *Course Director: E. Clark for Critical Review of Scientific Literature (or Department Faculty for other Readings)].* Covers reviews of scientific literature related to biomaterials and biomimetics. Requires students to prepare reviews of selected topics.

**Research in Biomaterials** G17.3000. [*Course Director: Department Faculty. 2 to 4 points.*]  
The student *may* use these additional credits (2 to 4 points) for thesis research.

**\*Introduction to Research** G17.2001 [2 points. *Course Directors: R. LeGeros and E. Clark]*  
Covers basics of what is needed to prepare research protocols and conduct research. Lecture topics include: research tool, literature search, experimental models and scientific writing and presentations. **Imaging**

**Science:** G17.1016. [4 points. *Course Directors: T. Bromage, E. Clark].* This course will highlight basic principles of preparation and imaging relevant to biomaterials research, particularly as they relate to 2D and 3D transmitted and reflected light microscopy and scanning electron microscopy, with an emphasis on bone and tooth microanatomy. Students will be exposed to and perform digital processing, analysis, and measurements of images acquired from their samples investigated by them for a Research Project.

**Complex Materials:** G17.1017. [3 points. *Course Director Y Zhang].* This course offers graduate students a comprehensive study of structure–function–property relationships in composites across a range of applications. A background in composite materials design is provided, including multiphase metal, ceramic and polymer systems. This background is supplemented by study of the interactions between micro, meso and macro structures within several biological structures as a basis for biomimetic materials design. *Prerequisite:* Metal and Ceramic Biomaterials.

**Additional courses are available through arrangement with GSAS and Polytechnic University.**

## 6 Requirements for Participation in Research

All students must complete a series of training modules in order to start a research project in the Department of Biomaterials. Students must take lab safety training from the Environmental Services Department at NYUCD or from qualified laboratory personnel at the Department of Biomaterials and Biomimetics. The student must provide documentation of this training to the Department before starting activity in the department laboratories. All students are also required to take the Laboratory Orientation session offered by the department before starting activity in the laboratories. Additionally, Bloodborne Pathogen training, Hazardous waste, and Chemical handling are all required, and are available as online tutorials.

If the student's proposed research project involves contact with any human material, patient contact, or patient information; the student will be required to take the Human Subjects and HIPAA tutorials and submit documentation indicating completion of tutorials to the Program Administrator before initiating any research project. In addition, the student must submit through the Lab Manager and the Dean of Research a copy of an approved thesis proposal and will likely have to submit an application to conduct research on human material to the Institutional Review Board (IRB).

All students, as part of their overall training, must take IRB training, HIPAA training, and the human subjects tutorial during the course of their program. However, if the student does not directly need these modules to start their research project, they may take these training sessions when available at any time during the program.

## 7 Guidelines for Completing Research Requirements

The following section outlines a stepwise process for completion of the Master's Thesis research, dissertation, and defense.

### 7.1 Formulation of a Thesis Proposal

The first step in this process is formulation of a preliminary proposal for a research project. This project can be based on the student's background or interests, literature review, or consultation with potential mentors or with peers. The student should conduct a preliminary literature survey on the proposed thesis project, and then compose this preliminary proposal as a concise document (variable page number (decided by mentor, chairmen, and lab manager), single spaced, 12 pt type) containing **introduction**, **rationale**, and **specific aims** sections. This must be submitted to the Mentor, Chairman, or the laboratory manager (LM).

### 7.2 Selection of a Thesis Mentor

Based on the area of interest of the preliminary proposal, the student should select a committee and a thesis mentor who heads the committee. The committee comprises the mentor and a minimum of two additional faculty mentors. The primary mentor must be selected from department faculty. One of the committee members, may be from outside the department or from another institution. Faculty from outside of the department are encouraged to be involved in the mentoring process. Students should consult the department faculty, and the laboratory manager (LM) if they need assistance in identifying the faculty appropriate for the proposed project. Upon selection of a thesis mentor and committee the student must notify departmental Chairman of the selections. The selections must be approved by the Chairman.

### 7.3 Preparation of the Thesis Proposal

Once the preliminary proposal and thesis mentor selections have been approved by department administration, the student must prepare a formal thesis proposal. This proposal comprises a detailed plan for the student's thesis research and, if it is composed properly, it will become the introductory and technical (Materials and Methods) basis of the thesis. This proposal is in a format similar to those used for industrial and basic science research proposals and preparation of this document is part of the training process for the degree. The thesis proposal must have the following sections and content:

*Abstract* — As would be submitted to a conference, but without results and discussion/conclusion.

*Introduction* — Must contain the background (critical review of the literature on the research subject), significance of and rationale for the proposed research project, a summary of the specific aims, and the hypothesis (working hypothesis and null hypothesis) of the proposal.

*Materials and Methods* — Must contain the specific technical procedures, experimental plan, and statistical analysis methods to be used in the project. Whenever applicable, a statistical power analysis should be included to ensure that adequate statistical power is incorporated into the proposed work. Materials and devices that are required from corporate sponsors must be specified here.

*Expected Outcome* – **Should contain a summary of the specific expected outcomes of the proposed research. It should also include potential problems and suggested solutions to those problems.**

*Budget* — Cost analysis of all necessary products and equipment not already available.

*Proposed Timeline*— A proposed timeline for the research should be included. This will include timelines for specific experiments, expected milestones related to specimen preparation, analysis, data analysis, and thesis preparation.

#### **7.4 Submission of the Thesis**

Research Protocol. Students are strongly encouraged to submit intermediate stages of this proposal to their mentors. A thesis proposal should never be submitted in its expected final form. Program administration, in particular the Laboratory Manager, must be involved with formulation of the proposal in order to ensure that all student training, laboratory safety, animal protocol, and institutional review (for human clinical studies) requirements are met. In addition, it is extremely important that the LM reviews all protocols to ensure that the proposed work can be conducted in an efficient and timely manner within the department and college facilities. The finished thesis proposal must be approved by the mentor(s) and program administration before further work is conducted.

#### **7.5 Presentation of the Thesis Research Protocol**

The last stage in thesis proposal preparation is presentation of the proposal at one of the Biomaterials Group Meetings. This represents both a valuable training exercise for public presentation of research as well as a way to get feedback from faculty and students regarding all aspects of the project.

#### **7.6 Conducting Thesis Research**

The student's thesis research comprises the most technically difficult aspect of the Master's program. There are several aspects of this work that deserve consideration:

7.6.1 Clinical studies, or studies that; (a) utilize any human tissue or fluids, (b) utilize biomaterials, devices, or instrumentation that has come in contact with human patients are subject to Institutional Review Board (IRB) approval. Students conducting this type of research must have special training for Blood Borne Pathogens, HIPAA, and human subjects (see Section 2.2) and submit appropriate protocols to IRB before the research commences. Students must work closely with the Laboratory Manager and program administration to make sure these requirements are met. IRB applications must be prepared in coordination with the LM and submitted to the Associate Dean for Research for approval before being submitted to the IRB. IRB approval must be documented with the LM prior to project initiation.

7.6.2 Animal studies, or studies that utilize any animal tissue or fluids, are subject to Institutional Animal Care and Use Committee (IACUC) approval. Students conducting this type of research must complete special training, and submit appropriate protocols to IACUC before the research commences. Students must work closely with the LM to make sure these requirements are met.

7.6.3 Use of laboratory facilities. Students are responsible for learning to properly use the laboratory facilities necessary to conduct their research. In many cases this will require special instruction from laboratory faculty and staff. Students should be prepared to arrange appointments with appropriate personnel for this training, and must be prepared to arrange and keep appointments for use of laboratory facilities. In many cases it is necessary to use a sign-in schedule or log. It must be anticipated that some facilities will be over utilized, so facilities scheduling must be arranged and strictly followed in order to optimally utilize existing facilities and available time.

When using laboratory facilities the student is responsible for the care of those facilities. This means using the facilities in a proper and safe manner, keeping the facilities clean and in working condition, and reporting any and all malfunctioning or broken equipment to the laboratory manager. The department recognizes that malfunction and breakage are a normal part of facilities use and wear. All malfunctions and breakage must be immediately reported to keep the facilities safe and working properly.

7.6.4 Research materials and contract research. Many projects involve the use of components, devices, materials or parts provided by companies or entities outside of NYU. All arrangements for funding or use of materials from outside the department MUST be made through the program administration and not directly between the student and the company. In this way, the administration can make sure that contract studies are properly funded, can track the contributions of suppliers, and prevent conflict of interest problems.

7.6.5 Research record keeping. Students must keep a detailed laboratory notebook of all research conducted in the laboratories. This includes thesis research as well as preliminary projects and side projects that do not

become part of the thesis. Laboratory notebooks can be obtained from the LS. The laboratory notebook(s) must be kept in the laboratory, and all observations, data, and statistical analysis must be documented here.

### **7.7 Preparing the Master's Thesis**

While conducting the thesis research project, the student should begin writing the Master's dissertation. The thesis proposal should represent the starting document for this effort. A summary of the final format of the thesis is included in the appendix section of this document. All students are encouraged to read dissertations available in the department library as examples of proper thesis format.

Students must submit drafts of sections of the dissertations to their primary mentor for review. They are encouraged to get significant input from their mentor at every stage of thesis writing. The mentor will assist in editing the thesis and will determine when the thesis is ready for distribution to the other thesis committee members. Along with the thesis committee, the final thesis must be submitted to the GSAS Director of Graduate Studies and to the department chair. At this time the Master's Degree Checklist must be completed (see Appendix). The committee will not sign final documentation for graduation without the completion of this checklist.

### **7.8 Setting the Thesis Defense Date**

A date acceptable to the student, the mentor, and the committee will be scheduled for the thesis defense by the program administrator. This date must be at least three weeks after the semi-final thesis is submitted to the department faculty. Announcement of the defense will be posted within the school.

### **7.9 The Thesis Defense**

The thesis defense is public and will follow this format: the student, after being introduced by the GSAS Director of Graduate Studies, or primary mentor will present an oral presentation summarizing the thesis research. This should be conducted using the same organizational format as the dissertation, and should take approximately 40-50 minutes. This will be followed by a question and answer period in which the audience can participate. After this period the audience will be excused and the committee members will question the student. After this period the student will be excused and the thesis committee will consider which of the following grades should be awarded to the student: 'pass without revisions', 'pass with revisions', or 'fail'. In the case of a 'pass without revision' grade, the committee will sign the final documents for submission to the Graduate School of Arts and Science for graduation. The 'pass with revisions' option means the committee will sign the final documentation only when revisions acceptable to the committee are submitted. In the case of a failing grade, the committee may or may not propose an optional plan for the student to conduct additional thesis research. A student accepting the plan may be considered for thesis defense at a later date.

### **7.10 The Final Steps**

The student who has passed the thesis defense and completed the checklist must provide a minimum of six (6) bound (at the time this document was revised electronic copies are being *considered* for almost all purposes) copies of the thesis: one each for the graduate school library, the mentors, and the student, and 2 for the department library. Additional bound copies may be ordered at the student's discretion. All bound copies must be identical and comprise the final form of the dissertation.

## **8 Time Frame for Degree Completion**

This time frame is based on a two-year completion plan for full time students for the Master's Degree. It is anticipated that the student will complete most of the course requirement in the first academic year and the research requirements in the second year. Those students approved for a longer program time will follow same sequence but at an expanded amount of time.

### **8.1 First Semester**

Begin coursework. Begin selection process for thesis research project as well as mentor and committee selection at end of first semester.

### **8.2 Second Semester**

At this time the mentor and committee should be selected and a preliminary proposal should be prepared. By the end of this semester the student should have submitted their first draft of a thesis proposal.

### **8.3 Third Semester**

By the beginning of the third semester of graduate study, the student should have an approved thesis proposal and be starting their thesis research. The student should also begin writing the final dissertation. The bulk of the thesis work and data acquisition should be conducted during this semester.

### **8.4 Fourth Semester**

Work in the fourth semester should revolve around completion of thesis research, writing of the final dissertation, and completion of the Master's Degree Checklist. At the middle of this semester arrangements should be made for submission of the final dissertation and arrangement of the thesis defense date. By the end of the semester, all thesis requirements should be completed so the student can graduate.

## **9 Department Faculty and Facilities**

### **9.1 Faculty Mentors**

Students may conduct research with investigators listed below whom are working on a variety of topics:

**Timothy Bromage**, MA PhD *Professor, Department of Biomaterials and Biomimetics and Department of Basic Science and Craniofacial Biology*. Comparative bone and tooth development and morphology, craniofacial development and architecture, skeletal response to environmental change, light and scanning electron microscopy, digital image processing, human paleontology, African Pilo-Pleistocene and Mediterranean Pleistocene fieldwork.

**Elizabeth A. Clark**, MS, *Adjunct Assistant Professor, Department of Biomaterials and Biomimetics*. Cell and molecular biology, cell and tissue response to biomaterials, and general dental biomaterials testing and application. Bone scaffold, and 3D printing research.

**John P. LeGeros**, MS, PhD, *Adjunct Professor, Department of Biomaterials and Biomimetics*; Co-Director, Calcium Phosphate Research Laboratory. Implant coating technology (plasma-spray, electrochemical deposition); implant or device surface modifications; calcium-phosphate based biomaterials (bioceramics) and implant coatings.

**Racquel Zapanta LeGeros**, MS, PhD, *Professor; Associate Chair, Department of Biomaterials and Biomimetics; Director, Calcium Phosphate Research Laboratory; Leonard Linkow(endowed) Professor of Implant Dentistry*. Calcium phosphates associated with normal (enamel, dentin, bone) and pathological calcifications (e.g., dental calculus, vascular calcifications) or diseased states (e.g., dental caries, osteoporosis); preparation and characterization of calcium phosphate-based biomaterials (bioceramics, composites, cements, scaffolds, implant coatings); implant surface modifications; biomineralization; tissue engineering.

**Mitchell S. Pines**, DDS. *Clinical Professor, Department of Biomaterials and Biomimetics*; Dental implants; dental restorative materials; dental casting alloys.

**Dianne Rekow**, MS, ME, MBA, DDS, PhD, *Director, Translational Research; Professor, Department of Basic Sciences and Craniofacial Biology, and Department of Orthodontics*; Performance and properties of brittle materials; tissue response to scaffolds, machinable ceramics — optimizing performance and properties Performance and properties of brittle materials; tissue response to scaffolds, machinable ceramics — optimizing performance and properties.

**John L. Ricci**, PhD, *Associate Professor, Department of Biomaterials and Biomimetics, Co-Director of Graduate Studies*; Cell and tissue response to permanent and resorbable biomaterials and medical devices; effects of surface microstructure and other surface modifications on cell and tissue response; bone and soft tissue repair and regeneration.

**Cristina M. C. Teixeira**, DDS, DMD, MSc, PhD, *Assistant Professor, Departments of Orthodontics, Craniofacial Biology, and Basic Science*; Cell and molecular biology of growth plate chondrocyte differentiation, maturation and apoptosis, Mechanism of Pi induced apoptosis in chondrocyte and the role of mitochondria in this process, nitrous oxide in chondrogenesis, endothelial nitric oxide synthase (eNOS) in knockout mouse with marked limb defects. Studies of overexpression of nitric oxide synthesis affecting endochondral bone formation, and tissue engineering of endochondral bone.

**Van P. Thompson**, DDS, PhD, *Professor; Chairman, Department of Biomaterials and Biomimetics, Director of Graduate Studies*; Materials and design research in fixed restorative dentistry; resin bonded bridges and prostheses;

damage accumulation in dental crowns; crown design; properties of enamel and dentin; tissue engineering and tissue response to scaffolds.

**Yu Zhang**, MS, PhD, *Assistant Professor, Department of Biomaterials and Biomimetics*, Functionally graded ceramic structures with improved damage resistance and functionalities for dental and orthopedic applications; damage accumulation in biomechanical structures—dental and orthopedic prostheses; relationship between microstructures and mechanical properties of ceramics and composites; biodegradable ceramic/polymer scaffolds for bone regeneration; ceramics processing, develop materials and design research in dental ceramics, bioactive glass materials.

## **9.2 Faculty Co-mentors**

**Gary Robert Goldstein**, DDS, *Professor, Department of Prosthodontics, and Department of Biomaterials and Biomimetics*; Dental implants, restorative materials, biotechnical devices.

**Bapanaiah Penugonda**, MS, DDS, *Associate Professor, Department of General Dentistry*; Clinical research; evaluation and development of dental restorative biomaterials.

**Teresita Salgado**, DDS, MS, *Adjunct Clinical Assistant Professor, Department of Biomaterials and Biomimetics*; Titanium surface modifications; tooth surface modifications.

**Hanna Lujon Upton**, PhD, *Adjunct Assistant Professor, Department of Biomaterials and Biomimetics*; Polymer synthesis, hydrogels, dental restorative materials research.

## **10 Department Facilities**

The following research facilities of the Department of Biomaterials and Biomimetics and the Calcium Phosphate Laboratory are available for graduate student research projects: Instron mechanical testing system; Alexandra I instrumented indenter with Romulus IV universal material tester, including breaking point platform and shear module; Chatillon tensile tester with bencor mult-t attachment; 4 EnduraTEC-Bose Elf 3300 biaxial fatigue testing systems, 2 with mouth motion wear simulation; a thermocycling device; Hitachi S3500 Scanning Electron Microscope (SEM) with energy dispersive X-ray analysis (EDAX) and backscattered electron imaging systems; Zeiss EVO50 environmental SEM with energy dispersive X-ray analysis (EDAX) and backscattered electron imaging systems, Scanco40 micro computed tomography system, Philips X'PERT X-ray diffraction (XRD) unit; BioQuant and other Image analysis systems; Confocal microscope; Fourier transform infrared (FTIR) spectroscopy with ATR; Fourier Transform Infrared Spectrometer (Nicolet 500); Thermodyne Inductive Coupled Plasma (ICP); Texas-Instrument Thermogravimetry (TGA/DTA); Micromeritics Flowsorb Specific Surface Analyzer; Micromeritics AccuPic density analyzer; Profilometer and various metallographic and SEM, TEM sample preparation equipment and wet chemical synthesis apparatus (pH stat systems, electrochemical deposition system, auto titrations, refrigerated centrifuges, etc.). The Department's Hard Tissue Research Unit has a fully equipped digital imaging facility, containing a variety of 2D and 3D light microscopy techniques.

The NYUCD library is located on the second floor of the VA hospital.

The Elmer Holmes Bobst Library, covering a full square block and the east corner of Washington Square and housing more than 3.3 million volumes, 20 thousand journals, and over 3.5 million microforms, is one of the country's largest open – stack reference, journal, and circulating collections. Many of the most commonly used journals are available on-line through the library.

## **11 Appendix**

### **11.1 Research and Laboratory Use: Guidelines and Policies**

After the student's research protocol has been approved, a laboratory space will be assigned by the Laboratory Manager.

Students are expected to adhere to the following policies and guidelines:

- **Laboratory notebook:** Proposed and actual Materials and Methods used in the student study and results obtained should be recorded in your laboratory notebook. The laboratory notebook will be kept in the laboratory at ALL times.
- **Chemicals:** A list of chemicals required for your study should be presented to the Laboratory Manager. When using chemicals, it is important that proper procedures be observed to prevent contamination of

chemical stocks. Leftover chemicals should be disposed of appropriately (cf. Laboratory Training information). You should be familiar with the MSDS of the chemicals that you use. In many cases standard operating procedures (SOPs) are in place for use of hazardous chemicals. These should be followed at all times. Chemical waste and handling procedures must also be followed.

- Glassware and plastic ware: If your study requires special glassware, consult the Laboratory Manager. For ordinary glassware and plastic ware, you are expected to clean them properly after your use. Disposable plastics should be disposed of appropriately. (cf your Laboratory Training session).
- Use of minor equipment (e.g., balances, pH meters, ovens): Appropriate weighing devices should be used. The balance and the weighing area should be cleaned after use. pH electrodes should be stored in appropriate buffers. Cutting and grinding areas MUST be cleaned after use.
- Use of major equipment (e.g., Instron, IR, XRD, SEM, etc): The use of the major equipment will be on a schedule basis that should be arranged with your mentor and/or the Laboratory Manager. Your mentor will decide when you can use the equipment without supervision.
- Working hours: No one will be allowed to work in the lab without the presence of faculty or research/administration personnel.
- Consultations: Other members of the faculty and research personnel are available for consultation, by appointment, on your project (e.g., use of specific equipment, statistical analysis, etc).
- Problems: The Laboratory Manager should be notified immediately in case of equipment problems, damage or breakage of equipment or supplies, or accidents.
- Scientific Honesty and Integrity is expected in the conduct of your research and in the presentation and interpretation of your results.
- Interpersonal relationships: Common courtesy, mutual respect and professionalism are expected from and among students, research and administration personnel, and faculty.

## **11.2 Components of a Research Thesis**

Dissertations should be composed in Microsoft Word using EndNote for references.

### **Opening pages:**

**Title page**

**Dedication** (optional)

**Table of Contents**

**Abstract** (limit to one page)

### **A. Introduction and Specific Aims**

Background (critical literature review)

Identification of the research problem

Previous reported studies addressing the problem

Objectives of the research.

Significance of proposed study

Specific Aims: Include when applicable null hypothesis and (working) research hypothesis, and detailed specific aims

### **B. Materials and Methods**

Materials used in the research

All Methods (synthesis, analytical methods, test methods)

Data management and statistical analysis

### **C. Results**

Detailed descriptions, accounts, and results of each experiment

Results should include preliminary data and data not used as in final version or versions of experiments. This should include justify for exclusion of data.

Tables and graphs of results

Figures and appropriate legends (see figure caption document)

### **D. Discussion**

Data interpretation addressing each specific aim

Comparison of results obtained with results reported in the literature (if any, or in part as they apply)

Significance of findings and limitations of findings related to specific aims as appropriate

#### **E. Summary and Conclusion**

Brief summary of results

Significance of results

Clinical relevance (if any)

Detailed conclusions resulting from the studies

#### **F. Recommendations for Further Studies**

Proposed next steps in the research and rationale for the proposed studies

#### **G. References**

These should be included in the text and in the reference list in a consistent format (numbered or alphabetical) using the reference format in the *Journal of Dental Research*.

#### **H. Acknowledgements**

#### **I. Appendix (optional)**

### **11.3 Master's Degree Checklist**

The following requirements must be met before the degree is granted.

1. Student's lab notebook must be complete, legible, and detailed enough for someone to understand and reproduce research and data. Notebook must be submitted to thesis mentor. The notebook must contain all lab notes and raw data, as well as statistically processed data.
2. All electronic files (including digital images) and non-electronic data (print and slide film photographs and micrographs) from instrumentation and all other raw and processed data must be turned in to mentor in electronic format (on CD or DVD). All graphics, digital images, and data files must be removed from instrumentation computers. Data storage is available through the department in the NYU digital archive.
3. A summary list of the above data must also be supplied to the mentor.
4. Students must empty all lab space and drawers of samples and equipment. All relevant to study materials should be turned in to the mentor, with documentation. Materials and instrumentation that can be recycled (i.e., SEM stubs) or of further use in the laboratories should be turned in to the LM or mentor after cleaning.
5. All materials that are no longer of use to the student or mentor and are not recyclable should be disposed of in the appropriate manner.
6. Student must submit the final version of the printed thesis and an electronic copy to each mentor and the department chair.
7. The thesis with the signature first page must be bound. A minimum number of six bound copies are required: one each for the department, the graduate school, and each mentor (usually 3), and the student. The student is responsible for all costs and arrangements for binding.