Suggested Guidelines for Starting an Undergraduate Biophysics Program

A biophysics major explores the bridge between biology and physics, applying quantitative methods to solve problems in biology, medicine, and related fields. A biophysics program is interdisciplinary, drawing from coursework in physics, biology, chemistry, mathematics, and statistics. It combines a broad science curriculum with physical and mathematical rigor in preparation for diverse careers.

The need for STEM education is well documented. Studies including the influential 2007 National Academies report "Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future" have warned of potential weaknesses existing in the U.S. STEM education system, and how addressing it relates to national prosperity and power [1]. In the succeeding decade, positive efforts have been made over the entire educational spectrum. Still, there may be a need for over one million more college graduates in STEM fields above the current trajectory in the coming decade [2].

Documented trends indicate the need for interdisciplinary STEM options in particular. For example, the U.S. Department of Labor, Bureau of Labor Statistics projects, from 2014-2024, an increase in employment among interdisciplinary fields like biomedical engineering (23%), environmental science (11%), and biochemistry/biophysics (8%), above the projected increase for fields like microbiology (4%), physics (7%), and chemistry (3%) [3].

As an interdisciplinary STEM option, a biophysics program brings together faculty from across disciplines, encouraging interactions, and potentially leading research and funding opportunities. Further, an undergraduate biophysics program may have a relatively easy implementation, as much of the core coursework (physics, chemistry, biology, and mathematics) is already offered at most institutions.

Every situation is unique with institutions having different motivations for pursuing a biophysics program. Due to the broad science foundation provided by a biophysics program, graduates have diverse career options, including those related to biophysics, bioengineering, medicine, medical physics, and public health. Minors or tracks would provide guidance for students seeking particular options.

I. Getting started

Before designing and implementing a biophysics major, minor, focus, or course, first determine the procedure, requirements, and gauge the institutional support for undertaking such an endeavor. Engage colleagues, administrators, staff, and students in discussions about what and why a biophysics curriculum is important at your institution (See Appendix B for sample curriculum).

Determine Institutional Procedures

First, decide if the new program will be in an existing department or a new entity. For a new entity, discuss the procedure with an upper level administrator (e.g. Associate Dean of Sciences or Vice Provost for Education, etc.). Many institutions have curricular committees that approve courses and programs after a department has voted to support such changes. There are forms and procedures that are submitted and followed. Educate yourself on your institutions logistics. Informally, assess the enthusiasm for such a program. There are often unofficial policies that you are unaware of. For instance, there may be pressure to consolidate the curriculum and the likelihood of creating a new major is slim. Thus, you may need to establish the proposed biophysics program with an entity that already exists.

Educate yourself

Within your institution, it is important to find like-minded individuals who are interested in making reforms. Engage all stakeholders and determine what a common interest and focus will be for your program, what needs the program will address, and what institutional resources your program will leverage. Teaming up with interested people will build a cohort that you can use to develop and implement the proposed biophysics program. A team-based approach will also spread the workload around and make more people invested in the new program. Learning what works at your university and in your department will help your initiative be successful. Find out what new programs have recently been introduced to gain perspective. Meet with the people involved and listen to their thoughts and ideas about what was successful/challenging in their projects.

Gather Data

Determine what data you need to justify the proposed program. National, institutional, departmental, and course data can be very convincing to others to demonstrate that the proposed biophysics program is needed. At the national level, there are numerous reports for more interdisciplinary instruction (e.g. breaking down typical silos of instruction and teaching students to integrate knowledge) and research-based courses. Institutions have a database of course grades, race, gender, major, transfer information, and can follow a student's trajectory through a program or major by combining all of this information for each student. They may even have experiential information based on surveys like the Student Experience in the Research University sponsored by the Center for Studies in Higher Education. Beyond institutional data, you can acquire data yourself for a particular cohort of interest. The cohort could be the majors, students in introductory courses, or students in a specific course. The results of pre- and post-testing within a course or a set of courses is often very convincing data for colleagues. This data can assess what students are really learning, and can motivate fellow colleagues to support a new biophysics program.

II. Curriculum

A. Foundational courses

Since biophysics explores the domains between biology, physics, chemistry and mathematics, a solid foundation in each of these areas is required. Depending on the home department biophysics (or biophysical chemistry) majors may vary a little in their core foundation, but many allow a variety of upper level electives that depend on the student's interest. However, almost all biophysics majors will require at least a year of foundational coursework in biology, chemistry, mathematics and physics.

In general most biophysics or biophysical chemistry majors will require the following:

- one year of general chemistry including laboratories
- one year of introductory biology
- one year of physics including laboratories
- at least one year of calculus
- one year of organic chemistry including laboratories (recommended)
- mutivariate calculus and a course in differential equations and/or linear algebra (recommended)
- at least one semester of physical chemistry or a physical chemistry for the life sciences course (recommended)
- One year of cell and molecular biology and biochemistry courses (recommended)
- Many majors will include additional physics courses and courses such as advanced molecular biology and analytical chemistry. (recommended)

B. Upper Level Courses

Many majors will require capstone courses specific to the major such as biophysics or biophysical chemistry courses and associated laboratory courses. In addition to the foundational courses described in above in section 2A numerous upper level courses and electives can be available to biophysics majors. The upper level courses can allow students to better tailor their major to their interests. Students may want to enhance their training in any of the foundational disciples or work to gain additional experience at the interface of disciplines so that they may take materials science, bio-math, engineering or other computational courses of interest. The upper-level electives will most likely be dictated by the existing coursework at the institution, but there are often many interdisciplinary courses that are excellent additions to the foundation courses described in 2A. There can be many flavors for biophysics majors; Biophysics is an incredibly broad field, encompassing many disciplines (biology, chemistry, computer science, engineering, math, medicine, neuroscience, pharmacy, and physics). Some common "flavors" of biophysics are:

- Molecular Biophysics – nucleic acid or protein folding, transcription and translation, molecular motors, cytoskeletal proteins, lipids, channels, single molecule techniques, microscopy

- Computational or Mathematical Biophysics – protein folding, molecular dynamics, computational and mathematical methods, bioinformatics, modeling, algorithms, neural circuitry

- Biomechanics – muscle mechanics, structure, and regulation

- Channel Biophysics – channel structure or mechanism, channel dynamics, signaling, patch clamp techniques, electrophysiology, molecular and sensory neuroscience

- Engineering Biophysics – biosensors, biomaterials, biosurfaces, nanotechnology

- Cellular Biophysics – membrane folding and fusion, cellular motility or mechanosensing, rheology
- Structural Biophysics – protein folding, x-ray crystallography, NMR, mass spectrometry, biochemistry, molecular modeling
- Photosynthetic Biophysics – plant biology, quantum mechanics, optics

Many courses may reflect additional interests such as those described in section 2C under concentrations. Additional writing intensive and seminar courses may be required to give students familiarity with reading, searching, and citing literature as well as enhance their writing and presentation skills. Alternatively these topics and others such as scientific ethics, may be incorporated into courses required for the major. Undergraduate research experiences may be required by some institutions but others may not have the faculty power to require every major gain a typical undergraduate research experience. Institutions may also strive to incorporate research experiences into the required laboratories. For example, a year-long biophysical chemistry laboratory may be broken up into two parts: 1) first semester for project-oriented protein purification and basic characterization techniques and 2) second semester to focus on additional spectroscopic and biophysical characterization techniques. This year-long biophysical chemistry laboratory will be such that the majors have a year-long intensive research-like experience that requires them to plan, conduct and analyze experiments just as they would in a research setting.

Student research experience continues to become increasingly important to graduate and professional schools, as well as employers. Industrial employers are very interested in obtaining students with research experience and some companies will not consider hiring students without significant research experience. Many biophysical chemistry students may also be interested in medical or graduate school. Biophysics majors should aim to obtain undergraduate research experience in an active laboratory to help them achieve their career goals. The interdisciplinary nature of the major suggests that the students will work in a wide variety of research laboratories in chemistry, physics, mathematics, computer science and biology and will be dispersed among faculty in different departments. You can create a list of faculty that work on biophysical research (and are willing to work with biophysics students) and publish it on the program's website.

C. Concentrations

A concentration is a particular subset of courses within a major that allows students to tailor the courses in the major to a specific area of interest. There are several ways a concentration can be set up. For example: 1) students complete a concentration by taking a certain number of elective courses for the major in one area, 2) students have different required courses for the major based on the concentration that they choose. (Sometimes programs that are set up in this way are referred to as tracks instead of concentrations), and 3) students may have to complete a particular number of extra courses beyond the courses for the major in order to complete the concentration. Sometimes programs that are set up in this way are referred to as certificates. The choice of how to set up the concentration will depend on departmental resources and goals.

Setting up a concentration in biophysics is a great option. First, a concentration in biophysics allows departments that are interested in biophysics to experiment with the curriculum without the large investment in resources or logistics that it takes to set up a brand new department or major. If the biophysics concentration is successful, then the concentration can be converted to a major at a later time. Second, a concentration in biophysics allows students to major in a traditional department while also gaining interdisciplinary skills. Completing the requirements of the traditional major gives students the ability to apply to graduate school or to jobs with traditional requirements. Completing the requirements of the concentration in biophysics allows students to focus, giving them skills they need for interdisciplinary jobs and creating more career mobility. Finally, a concentration in biophysics may be particularly easy to set up since many of the foundational and upper level courses (see Section 2A and 2B) for the concentration may already be offered at your institution.

When deciding what courses to include in a biophysics concentration, you will have to weigh the competing factors of resources, educational goals, and student interests at your institution in your decision. However, some guidelines here will be helpful:

- Since your department will only be requiring a small subset of the courses for the major to count toward the biophysics concentration, it may be advisable to just choose one "flavor" of biophysics to focus on. To have an effective concentration, your department may want to tailor the biophysics concentration to the particular strengths at your institution.
- Your students will need an interdisciplinary training to be successful biophysicists. To give them this interdisciplinary background, think about including courses from different departments or including courses that are cross-listed between several departments. Courses that touch on interdisciplinary topics or have students from a variety of backgrounds could also satisfy this need.

- Make sure that the courses you select for the concentration include some upper-level electives as defined in Section 2B, not just the foundational courses as defined in Section 2A. Ideally, the concentration would require some foundational courses outside of the home department and then some upper-level courses that build on those foundational courses. These upper-level courses could be in the home department or in an outside department. Some examples might include:

    i. Chemistry Department interested in a concentration in Molecular Biophysics – One foundational course outside of the home department could be introductory biology. An upper-level elective in the chemistry department that would build on this course might be biochemistry. An upper-level elective outside of the home department that would build on this course might be cellular biology, which is often taught in biology departments.

    ii. Biology Department interested in a concentration in Channel Biophysics – Two foundational courses outside of the home department could be two introductory physics courses. An upper-level elective in the biology department that would build on these courses might be neurophysiology. An upper-level elective outside of the home department that would build on these courses might be an electronics course, which is typically offered by physics departments.

    iii. Math Department interested in a concentration in Mathematical Biophysics – Four foundational courses outside of the home department could be three semesters of chemistry and one semester of biology. An upper-level elective in the math department that might build on these courses is differential equations for the life sciences. An upper-level elective outside of the home department might be biochemistry, which is often offered by the chemistry department.

- The number of courses for the concentration will depend on your institutional practices and the rigor that you select for your graduates. In practice, the number of courses in a concentration is typically one-third to one-half of the courses for the major. Increasing the number of required courses is likely to decrease the number of students who complete the concentration, so departments should be mindful of this when setting their requirements. To select the least number of courses, you should think about your departmental goals and the "flavor" of biophysics that you wish to impart to students. Another method is to select foundational courses that a large number of your student body takes anyway. These might be courses on the premed track if you are in a science department or courses in general engineering if you are in an engineering department. (See Appendix A for examples of minors and concentrations from a variety of intuitions).

D. Minors

Historically, a minor is a secondary subject that is subordinate to a student's major and requires fewer courses than the major to complete. However, in practice, students choose to have minors for all sorts of reasons and these minors might not actually be subordinate to the major. Biophysics minors are no different. First, biophysics minors can add specialization to a student's resume, identifying a particular area of interest within a chosen field. For example, a biophysics minor might be helpful for a math major trying to get a job at a genetics company. Second, biophysics minors can be attractive to students who have alternate interests, particularly if students do not know which interests to pursue after graduating. For example, an aspiring musician who is also interested in biophysics would likely want credentials in both fields. Third, biophysics minors are a good way to attract non-traditional, underprepared, or late-coming students to science. These students may only have time to complete the minor, but may wish to pursue biophysics after graduating. Finally, biophysics minors can also be useful to students who take many classes in the subject anyway, but are pursuing a different major. For example, an English major who is also a premed might be a good candidate for a biophysics minor since they would have taken many of the foundational courses and upper-level electives that a biophysics minor would require.

Typically, a minor in biophysics is offered by departments or programs who also offer a major in biophysics. Thus, we recommend that these departments think about the requirements for the major first. This will allow the department to think about their educational goals, as outlined in Sections 2A and 2B. Then, after choosing the requirements for the biophysics major, departments can choose a subset of these courses for the minor. In choosing the subset of courses for the minor, we suggest the following guidelines:

1) Keep in mind the reasons students tend to pursue biophysics minors, in addition to thinking about departmental constraints like resources, time, and logistics. To have a thriving biophysics minor, you will need to make sure it serves your students well.

2) We suggest you include some of the foundational courses and some of the upper-level courses in the requirements for the minor to prepare students for future work in the field. Just having the foundational courses is not recommended. The upper-level courses allow students to make the interdisciplinary connections that they will need if they choose careers in biophysics.

3) In addition, we suggest that you include a good mix of courses in different disciplines or ones that are interdisciplinary to keep students from just taking courses in one field.

4) The number of required courses for a minor varies from institution to institution. Some institutions have three years of requirements for a minor as opposed to four years of requirements for a major. Sometimes the requirements for a minor are only half the requirements for a major, perhaps only taking students two years to complete. Decreasing the number of required courses for the minor is likely to increase the number of students declaring the minor. We recommend that departments choose each required course for the minor with care.

III. Pedagogy

The pedagogical methods employed in courses can have a significant impact on the student's success, satisfaction and their learning. In turn, student success can affect the success of biophysics programs. Decades of research in education showed that effective pedagogical methods improve student learning and grades and reduce failure rates [5]. Familiarize yourself with these approaches and be sure to include them in any proposed curriculum. A list of sample resources is provided in Appendix A.

The American Physical Society, American Astronomical Society and the American Association of Physics Teachers offer bi-annual workshops on interactive engagement pedagogical techniques for new physics faculty [6]. Other workshops include Research Corporation for Science Advancement's Cottrell Scholar Collaborative New Faculty Workshop [7] and the Partnership for Undergraduate Life Sciences Education's Summer Institutes on Scientific Teaching [8].

IV. Sustaining a Biophysics Program

Starting a biophysics program requires a lot of work, however, so does sustaining and improving the program.

Gather Data

Institutions have a database of course grades, race, gender, major, transfer information, and can follow a student's trajectory through a program or major by combining all of this information for each student. They may even have experiential information based on surveys like the Student Experience in the Research University sponsored by the Center for Studies in Higher Education. Beyond institutional data, you can acquire data yourself for a particular cohort of interest. The cohort could be the majors, students in introductory courses, or students in a specific course.

The results of pre- and post-testing within a course or over a set of courses is often very convincing data for colleagues to assess what students are really learning, and can motivate them to support a new program.

Follow Best Practices and Recommendations

The American Physical Society surveyed thriving physics programs and published their findings and recommendations [4]. These recommendations may also help you create a thriving biophysics program.

V. Professional Development and Biophysics Resources

The Biophysical Society offers a number of educational and professional resources, along with ways to stay informed of new biophysical research and become more engaged in the larger biophysical community. Resources include webinars, a directory of biophysics programs from across the globe, a job board, high-school level lesson plans on basic biophysical concepts, and more. The Society's Annual Meeting brings together over 6,000 research scientists in the multidisciplinary fields representing biophysics each year. With more than 4,000 poster presentations, over 200 exhibits, and more than 20 symposia, the Annual Meeting is the largest meeting of biophysicists in the world. The Annual Meeting also includes an undergraduate poster competition session and an opportunity for undergraduates to rehearse their poster presentation. The Annual Meeting includes a Biophysics Education poster session and a "Teaching Science Like We Do Science" session focused on biophysics teaching.

Published twice a month, *Biophysical Journal* offers a way to stay updated on groundbreaking research happening in the field. Society members can also keep up with the latest developments in science policy and society news with BPS's monthly newsletter. For students, the Society offers travel awards to attend the Annual Meeting and will begin recognizing BPS Student Chapters in 2017. For more information on the resources and opportunities available through the Society, or to become a member, visit www.biophysics.org.

References Cited

1. Bureau of Labor Statistics, U.S. Department of Labor. Occupational Outlook Handbook, 2016-17 Edition, on the Internet at https://www.bls.gov/ooh/ (visited January 08, 2017).

2. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future. 2007. Washington, DC: The National Academies Press.

3. President's Council of Advisors on Science and Technology. Engage To Excel: Producing One Million Additional College Graduates With Degrees In Science, Technology, Engineering, And Mathematics. February 2012. www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf

4. Strategic Programs for Innovations in Undergraduate Physics. https://www.aapt.org/Programs/projects/ntfup/index.cfm

5. Active Learning increases student performace in science, engineering,and mathematics. http://www.pnas.org/content/111/23/8410.full

6. http://www.aapt.org/Conferences/newfaculty/nfw.cfm

7. Research Corporation for Science Advancement's Cottrell Scholar Collaborative New Faculty Workshop http://chem.wayne.edu/feiggroup/CSCNFW/

8. Partnership for Undergraduate Life Sciences Education http://www.pulsecommunity.org/

APPENDIX A: RESOURCES

Selected Publications:

Web

An undergraduate biophysics program: Curricular examples and lessons from a liberal arts context: http://scholarship.haverford.edu/cgi/viewcontent.cgi?article=1142&context=physics_facpubs

Vision and Change in Undergraduate Biology Education: A Call to Action
http://visionandchange.org/files/2011/03/Revised-Vision-and-Change-Final-Report.pdf

Discipline-Based Educational Research: Understanding and Improving Learning in Undergraduate Science and Engineering
http://www.nap.edu/catalog/13362/discipline-based-education-research-understanding-and-improving-learning-in-undergraduate

Print

Angelo, T.A. & Cross, K.P. (1993). *Classroom assessment techniques: A handbook for college teachers (2nd ed).* San Francisco: Jossey-Bass

Bonwell, C. C., & Eison, J. A. (1991). *Active learning: Creating excitement in the classroom (ASHE–ERIC Higher Education Rep. No. 1).*Washington, DC: The George Washington University, School of Education and Human Development.

Davis, B.G. (2009). *Tools for teaching (2nd ed).* San Francisco: Jossey-Bass Publishers.

Deslauriers L, Schelew E, Wieman C. (2011). Improved learning in a large-enrollment physics class. Science, 332, 862-864.

Felder, R.M. & Brent, R. (2009). Active learning: An introduction. *ASQ Higher Education Brief, 2*(4).

Grunert, Judith. The course syllabus: A learning-centered approach. Bolton, MA: Anker Publishing Co, Inc, 1997.

Prince, M. (2004). Does active learning really work? A review of the research. *Journal of Engineering Education. 93*(3). 223-231.

Topping, Keith and Ehly Stewart, Peer-Assisted Learning. Mahwah, NJ: Lawrence Erlbaum Associates, Inc., 1998

Evidence-based teaching recommendations and guidelines:

=> This section includes references to books or chapters, articles and websites, helpful tips on how to start transforming your courses according to research-based best practice guidelines

Website of the **Carl Wieman Science Education Initiative (CWSEI)** at the UBC in Vancouver.

- http://www.cwsei.ubc.ca/resources/index.html
- http://www.cwsei.ubc.ca/resources/course_transformation.htm

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- particularly, we recommend downloading the free "Course transformation guide" which some of us have successfully used: http://www.cwsei.ubc.ca/resources/files/CourseTransformationGuide_CWSEI_CU-SEI.pdf
- As well as the "instructor guidance"- resources, as they do not only provide guidance on how to apply the recommended methods, but also such invaluable advice of what to avoid:
- http://www.cwsei.ubc.ca/resources/files/WhatNotToDo_CWSEI.pdf

Other teaching recommendations and resources on evidence based teaching:

o Active Learning Toolbox collated by McMaster University
https://library.mcmaster.ca/instruction/libtoolbox.htm
o Carleton College's very practically oriented collection of active learning strategies:
http://serc.carleton.edu/sp/index.html
o National Center for Case Study Teaching in the Sciences
http://sciencecases.lib.buffalo.edu/cs/
o iBiology's scientific teaching videos
http://www.ibiology.org/scientific-teaching.html
o The Center for Integrated Research on Teaching and Learning (CIRTL) organizes free, open online courses for faculty on how to improve undergraduate STEM education.
http://stemteachingcourse.org/

Publications on educational research (+/- discipline based) & scholarly teaching observation reports, and resource collections and journals

=> This section includes links to formal, hypothesis driven educational research studies, as well as anecdotal reporting of educational observations

o CWSEI's featuring of their own educational research studies, papers and presentation:
http://www.cwsei.ubc.ca/resources/papers.htm
http://www.cwsei.ubc.ca/SEI_research/index.html
Eric Mazur's educational research areas
o http://mazur.harvard.edu/education/educationmenu.php

(CBE) Life Science Education
one of the hallmark journals for educational scholarship across the life science disciplines, with contributions addressing all aspects of instruction in undergrad and graduate science education:
http://www.lifescied.org/

Resources on collaborative learning:
o an overview:
http://www.cwsei.ubc.ca/resources/files/Group_work_SEI_8-08.pdf
o Eric Mazur's Peer Instruction research
http://mazur.harvard.edu/research/detailspage.php?ed=1&rowid=8

Online discussion groups and education communities

=> Where educators exchange views and experiences on evidence-based teaching techniques:

- **Evidence Based Teachers Network:** http://www.ebtn.org.uk/
- **Team-based learning Collaborative:** http://www.teambasedlearning.org/

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- **Science's Education Forum:** http://www.sciencemag.org/site/feature/misc/webfeat/educationforum/

Biophysics Minor and Concentration Examples

=> Several colleges and universities offer either Minors or Concentrations in biophysics:

http://www.marquette.edu/physics/minor_biophysics.shtml

http://catalog.drexel.edu/undergraduate/collegeofartsandsciences/biophysics/

http://bulletin.gwu.edu/arts-sciences/physics/minor-biophysics/

https://www.clarkson.edu/engineering/minors_concentrations/Minor%20in%20Biophysics.pdf

https://physics.wustl.edu/undergraduate/biophysics-requirements

http://www.physics.upenn.edu/biophysics/biophpages/Minor.html

Appendix B: Sample Curriculum

B.S. in BIOPHYSICAL CHEMISTRY

Typical Schedule ***(TENTATIVE - Expect changes, consult with your advisor)***

Freshman Fall (14-17 cr) Chem 131[ap, pph] (Gen Chem I) [3] Chem 135L[pph] (Special Gen Chem Lab I) [1] Math 235 [pph] (Calc I) [4] GenEd Cluster 1 [3] GenEd WRTC 103 &/or other GenEd [3-6] [ap]If AP Chem = 3-5, Chem 131/132 [6]	**Freshman Spring (16 cr)** Chem 132[ap, pph] (Gen Chem II) [3] Chem 136L[pph] (Special Gen Chem Lab II) [2] Math 236 (Calc II) [4] Bio 140[pph] (Foundations I) [4] GenEd Cluster 1 [3] [ap]If Chem 131/132 is complete, consider Chem 270 [3]
Sophomore Fall (15-17 cr) Chem 241[pph] (Organic I) [3] Chem 287L[pph] (Inor/Org lab I) [2] Phys 240[pph] (University Phys I) [3] Phys 140L[pph] (Phys lab I) [1] GenEd &/or electives[e,pph] [6-8] [e]Suggestions: Research, BIO 150[pph] (Fndtns II) [4]	**Sophomore Spring (16 cr)** Chem 242[pph] (Organic II) [3] Chem 270 (Inorganic) [3] Chem 288L (Inor/Org lab II) [2] Bio 240 (Genetics) [4] Phys 250[pph] (University Phys I) [3] Phys 150L[pph] (Phys lab I) [1]
Junior Fall (15-18 cr) Bio 480 (Adv Molecular Bio) [4] Chem 351 (Analytical) [4] Chem 361[pph] (Biochem) [3] Math 237 (Calc III) [4] Electives[e] [0-3] [e]Suggestions: Research [1-2], Math 220[pph] [3]	**Junior Spring (15-17 cr)** Chem 331 (PChem I) [3] Chem 336L (Appl Pchem Lab) [2] Mat 238 (Linear Algebra with Diff Eq) [4] GenEd &/or electives[e] [6-8] [e]Suggestions: Research [1-2]
Senior Fall Chem 363 (Biophys Chem w/Lit&Sem) [3] Chem 367L (Biochem Lab) [2] Chem 432 (PChem II) [3] Approved elective[e] [3-4] GenEd &/or electives[e] [3-6] [e]*Suggestions*: Research, more Bio[pph]	**Senior Spring** Chem 368L (Biophys Chem Lab) [2] Approved elective[e] [3-4] GenEd &/or electives[e] [10-12] [e]*Suggestions*: Research, more Bio[pph]

[e]**Approved elective courses include**: Research (390, 497-499), Chem Hazards (Chem 325 -F,even), Environmental Chem (353 –Sp,odd), Environmental Field Camp (Chem 354, Su), Geochem (Chem 355 -F), Biochem II (Chem 362, 366L -Sp), Materials (Chem 375 -F), Intermediate Organic (Chem 440-F,even), Polymers (Chem 445,445L -F,odd), Lasers (Chem 455 -V), Inorganic II (Chem 470 –F), Human Genetics (Bio 324 -F), Neurobiology (Bio 445 -V), Math. Models in Bio (Bio/Math 342-Sp), Biometrics (Bio/Math 454 -Sp), Prob & Stats (Math 318), Biophysics (Phys 326), Physics III (Phys 260), Modern Physics (Phys 270), Materials Characterization (Phys/Mats 381), etc. [See Undergrad Catalog]

[pph]**Most pre-Professional health (pre-med, pre-pharm, etc) programs require**: BIO 140-150, CHEM 131-132, CHEM 135L-136L, CHEM 241-242, CHEM 242L or 287L, MATH 220, MATH 235, PHYS 240-250, PHYS 140L-150L. Recommendations include CHEM 361 and additional Bio courses.
Pre-med: GenEd recommendations include PHIL 120 (C1), SOCI 110 (C4), PSYC 101 (C5).
Pre-Pharm: GenEd recommendations include PHIL 150 (C1), SCOM 122 (C1), ECON (C4), PSYC 101 or 160 (C5). [See Undergrad Catalog]

Updated April 2016

Department of Biochemistry and Molecular Biophysics

B.S. Molecular Biophysics Track

The following courses are required by the Biochemistry and Molecular Biophysics Department for the B.S. degree in Biochemistry, Molecular Biophysics Track. Additional College of Arts & Sciences requirements and K-State 8/UGE requirements are listed below the Departmental requirements.

Departmental requirements

Suggested Term Semester Chart (/bmb/docs/degrees/BiochemPhysBS_Table_031915.pdf) (pdf)

Biochemistry courses

BIOCH 110 - Biochemistry & Society (3 credits)
BIOCH 521 - General Biochemistry (3 credits)
BIOCH 755 - Biochemistry I (3 credits)
BIOCH 756 - Biochemistry I Laboratory (2 credits)
BIOCH 765 - Biochemistry II (3 credits)
BIOCH 775 - Molecular Biophysics (3 credits)

Chemistry courses

CHM 210 - Chemistry I (4 credits)
CHM 230 - Chemistry II (4 credits)
CHM 371 - Chemical Analysis (4 credits)
[CHM 220 & 250 - Honors Chemistry I & II (10 credits) may be substituted for CHM 210, 230 & 371.]

CHM 350 - General Organic Chemistry (3 credits)
CHM 351 - General Organic Chemistry Laboratory (2 credits)
[CHM 531, 532 & 550 - Organic Chem I, Organic Chem Lab & Organic Chem II (8 credits) may be substituted for CHM 350 & 351]

CHM 500 - General Physical Chemistry (3 credits)

Biology courses

BIOL 198 - Principles of Biology (4 credits)
BIOL 450 - Modern Genetics (4 credits)
BIOL 455 - General Microbiology (4 credits)
BIOL 541 - Cell Biology (3 credits)

Physics courses

Choose from the following two options:

PHYS 213 - Engineering Physics I (5 credits)
PHYS 214 - Engineering Physics II (5 credits)
Or
PHYS 223 - Physics I (5 credits)
PHYS 224 - Physics II (5 credits)

AND

PHYS 325 - Physics III (4 credits)

AND one of the following:
PHYS 664 - Thermodynamics & Statistical Physics (3 credits)
PHYS 775 - Biological Physics (3 credits)

Mathematics courses

MATH 220 - Analytic Geometry and Calculus I (4 credits)
MATH 221 - Analytic Geometry and Calculus II (4 credits)
MATH 222 - Analytic Geometry and Calculus III (4 credits)

Statistics course

STAT 703 - Statistical Methods for Natural Sciences (3 credits)

Research

BIOCH 799 - Problems in Biochem (Variable)*

*3 Credit hours required. At least one hour MUST come from BIOCH 799, though two hours of Advanced Biochemistry Labs (BIOCH 757, 758, 766, 767) MAY be applied toward the research requirement. Please contact your advisor.

Upper-division electives

5 Credits of BIOCH, BIOL, CHM, CIS, OR STAT 500 to 799,
or MATH 240 Differential Equations,
or MATH 515 Introduction to Linear Algebra

GPA requirement in science and mathematics courses

To graduate, a student must have a grade of C or better in all science and mathematics courses required for the degree, including transfer courses, as specified below. In addition, to graduate a student must have a 2.2 GPA in required science and mathematics courses taken at K-State.

Note: The courses in the above list satisfy the natural sciences and quantitative reasoning requirements shown in the general requirements for the B.S. degree.

College of Arts & Sciences course requirements

English and Communication courses

Three courses, 8 credit hours minimum. Purpose: to give students practice in oral presentation and in writing and analyzing expository and argumentative prose.

ENGL 100 - Expository Writing I (3 credits)
ENGL 200 - Expository Writing II (3 credits)

AND

COMM 105 - Public Speaking IA (2 credits)
Or
COMM 106 - Public Speaking I (3 credits)

Humanities courses

Four courses, one course for each section, 11 credit hours minimum:

Fine arts (one course)
Philosophy (one course)
Western heritage (one course)
Literary or rhetorical arts (one course)

Consult Course Catalog (http://courses.k-state.edu/catalog/) for specific courses in each of these areas.

Social sciences courses

Four courses, 12 credit hours minimum, from at least three disciplines. A wide range of choices available. One of these courses often satisfies the International studies overlay requirement.

Consult Course Catalog (http://courses.k-state.edu/catalog/) for specific courses in each of these areas.

Additional requirements for B.S. degree in Biochemistry

K-State 8 (http://www.k-state.edu/kstate8/) (or UGE requirements (http://www.k-state.edu/kstate8/uge/) for enrollment prior to fall 2011)

Course requirement guidelines

Each student must successfully complete credit-bearing courses/experiences to cover all of the K-State 8 areas (or UGE requirements). Some of the K-State 8 areas/courses may be covered in the student's major.

Note: The humanities and social sciences requirements of the College of Arts & Sciences along with our Biochemistry Major requirements will usually meet the K-State 8 and/or the UGE requirements.

Total hours required for graduation = 124 credit hours

Note: This differs from the University-wide requirement of 120 credit hours.

BIOCHEMISTRY AND BIOPHYSICS

The department of Biochemistry, Biophysics & Molecular Biology (http://www.bbmb.iastate.edu) offers majors in biochemistry or biophysics in the College of Liberal Arts and Sciences and a major in agricultural biochemistry (http://catalog.iastate.edu/collegeofagricultureandlifesciences/biochemistry_biophysics_andmolecularbiology) in the College of Agriculture and Life Sciences.

Biochemists and biophysicists seek to understand life processes in terms of chemical and physical principles. They conduct research in the frontiers of biology such as metabolic networking; structure and function of enzymes, membranes, and hormones; computational approaches; genomic and proteomic technology; protein engineering; plant biotechnology; muscle structure and function; and the design and evaluation of drugs for the treatment of disease. Biochemistry, biophysics and molecular biology provide the basis for much of modern biotechnology. Graduates have opportunities in industry, especially the biotechnology sector, in universities, veterinary and medical schools, and government laboratories. Students who meet the necessary high scholastic standards have the opportunity to continue their education to pursue advanced degrees in graduate school, medicine, pharmacy or veterinary medicine.

Graduates of biochemistry, agricultural biochemistry and biophysics understand the chemical principles of biological systems including molecular biology. They have developed laboratory expertise in modern biochemical techniques, including the ability to analyze data and prepare scientific reports. Most have participated in undergraduate research and have developed the skills necessary for both written and oral presentations at a level that will serve the student both within the university and in postgraduate professional life. Graduates have the experience of interacting with persons of different disciplines and cultures. Students have the training in biological and physical science and mathematics to solve problems of broad scope in biological, biomedical and environmental sciences and to provide leadership in diverse scientific and technological arenas.

Biochemistry or Biophysics Majors in the College of Liberal Arts and Sciences

For the undergraduate curriculum leading to the degree bachelor of science, see College of Agriculture, Agricultural biochemistry (http://catalog.iastate.edu/collegeofagricultureandlifesciences/biochemistry_biophysics_andmolecularbiology).

Biochemistry and biophysics are recommended to students whose career interests involve advanced graduate or medical study or employment in biochemistry or biophysics, or in related areas of the biological or medical sciences.

Biochemistry undergraduate major program of study

Total Degree Requirement: 120 cr.

BBMB 101	Introduction to Biochemistry	1
BBMB 102	Introduction to Biochemistry Laboratory	1
BBMB 201	Chemical Principles in Biological Systems	2
BBMB 404	Biochemistry I	3
or (4 credits)		
BBMB 504	Amino Acids and Proteins	
BBMB 505	Bioenergetics and Metabolism	
BBMB 405	Biochemistry II	3
or (4 credits)		
BBMB 506	Membrane Biochemistry	
BBMB 507	Biochemistry of Nucleic Acids	
BBMB 411	Techniques in Biochemical Research	4
BBMB 461	Molecular Biophysics	2
or BBMB 561	Molecular Biophysics	
BBMB 490	Independent Study (Not required)	1-3
BBMB 499	Undergraduate Research (Not required but strongly encouraged)	1-5
Take one of the following:		5-7
CHEM 201	Advanced General Chemistry	
or CHEM 177 & CHEM 178	General Chemistry I and General Chemistry II	
Take one of the following:		
CHEM 201L	Laboratory in Advanced General Chemistry	
or CHEM 177N	Laboratory in General Chemistry I	
or CHEM 177L	Laboratory in General Chemistry I	
CHEM 211 & 211L	Quantitative and Environmental Analysis and Quantitative and Environmental Analysis Laboratory	4
BBMB 561L	Laboratory in Molecular Biophysics	2-3
or CHEM 322L	Laboratory in Physical Chemistry	
CHEM 324	Introductory Quantum Mechanics	3
CHEM 325	Chemical Thermodynamics	3
CHEM 331 & CHEM 332	Organic Chemistry I and Organic Chemistry II	6
CHEM 333L	Laboratory in Organic Chemistry I (for Chemistry and Biochemistry Majors)	1-2
or CHEM 331L	Laboratory in Organic Chemistry I	
CHEM 334L	Laboratory in Organic Chemistry II (for Chemistry and Biochemistry Majors)	2
or CHEM 332L	Laboratory in Organic Chemistry II	
MATH 165	Calculus I	4
MATH 166	Calculus II	4
MATH 265	Calculus III	3-4
or MATH 266	Elementary Differential Equations	
or MATH 267	Elementary Differential Equations and Laplace Transforms	
PHYS 221 & PHYS 222	Introduction to Classical Physics I and Introduction to Classical Physics II	10
BIOL 211 & BIOL 212	Principles of Biology I and Principles of Biology II	6
BIOL 211L	Principles of Biology Laboratory I	1
or BIOL 212L	Principles of Biology Laboratory II	
or BIOL 313L	Genetics Laboratory	
BIOL 313	Principles of Genetics	3
BIOL 314	Principles of Molecular Cell Biology	3
Biological Science electives from Biology, Genetics, Microbiology, Biochemistry or Chemistry		4
Total Credits		**82-93**

Communication Proficiency (Minimum grade C-)

LIB 160	Information Literacy	1
ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
One course from the following:		
ENGL 305	Creative Writing: Nonfiction	3
ENGL 309	Proposal and Report Writing	3
ENGL 314	Technical Communication	3
BBMB 411	Techniques in Biochemical Research Minimum grade C	4

General Education Area

Arts and Humanities	12
Social Sciences	9
International Perspectives	3
U.S. Diversity	3

Biophysics undergraduate major program of study

Total Degree Requirement: 120 cr,

BBMB 101	Introduction to Biochemistry	1
BBMB 102	Introduction to Biochemistry Laboratory	1
BBMB 201	Chemical Principles in Biological Systems	2
BBMB 404	Biochemistry I	3
or BBMB 420	Mammalian Biochemistry	
BBMB 411	Techniques in Biochemical Research	4
BBMB 461	Molecular Biophysics	2
or BBMB 561	Molecular Biophysics	
Take one of the following:		5-7
CHEM 201	Advanced General Chemistry	
CHEM 177 & CHEM 178	General Chemistry I and General Chemistry II	
CHEM 201L	Laboratory in Advanced General Chemistry	1
or CHEM 177N	Laboratory in General Chemistry I	
or CHEM 177L	Laboratory in General Chemistry I	
CHEM 211 & 211L	Quantitative and Environmental Analysis and Quantitative and Environmental Analysis Laboratory	4
BBMB 561L	Laboratory in Molecular Biophysics	2
or CHEM 322L	Laboratory in Physical Chemistry	
CHEM 324	Introductory Quantum Mechanics	3
CHEM 325	Chemical Thermodynamics	3
CHEM 331 & CHEM 332	Organic Chemistry I and Organic Chemistry II	6
MATH 165	Calculus I	4
MATH 166	Calculus II	4
MATH 265	Calculus III	4
MATH 266	Elementary Differential Equations	3
MATH 207	Matrices and Linear Algebra	3
or MATH 317	Theory of Linear Algebra	
PHYS 221 & PHYS 222	Introduction to Classical Physics I and Introduction to Classical Physics II	10
One course from the following:		
MATH 481	Numerical Methods for Differential Equations	
STAT 407	Methods of Multivariate Analysis	
STAT 430	Empirical Methods for the Computational Sciences	
COM S 207	Fundamentals of Computer Programming	3
STAT 305	Engineering Statistics	3-4
or STAT 231	Probability and Statistical Inference for Engineers	
BIOL 211 & BIOL 212	Principles of Biology I and Principles of Biology II	6
BIOL 211L	Principles of Biology Laboratory I	1
or BIOL 212L	Principles of Biology Laboratory II	
Additional 300+ or higher level courses in biochemistry, biophysics, biological sciences, chemistry or physics.		7
Total Credits		**85-88**

Communication Proficiency (Minimum grade C-)

LIB 160	Information Literacy	1
ENGL 150	Critical Thinking and Communication	3
ENGL 250	Written, Oral, Visual, and Electronic Composition	3
One course from the following:		
ENGL 305	Creative Writing: Nonfiction	3
ENGL 309	Proposal and Report Writing	3
ENGL 314	Technical Communication	3
BBMB 411	Techniques in Biochemical Research minimum grade C	4

General Education Area

Arts and Humanities	12
Social Sciences	9
U.S. Diversity	3
International Perspectives	3

Biochemistry minor is offered in both the College of Liberal Arts and Sciences and Agriculture and Life Sciences

BBMB 404	Biochemistry I	3
BBMB 405	Biochemistry II	3
BBMB 411	Techniques in Biochemical Research	4
One course from the following:		2-3
BBMB 461	Molecular Biophysics (2 crs)	
BBMB 561	Molecular Biophysics (2 crs)	
CHEM 325	Chemical Thermodynamics	
300+ level courses in BBMB or CHEM to 15 cr total		3-4
Total Credits		**15-17**

These lists of courses should not be regarded as statements of fixed requirements or as complete outlines of the work necessary for the major. They are given solely for the convenience of students or advisers who wish to estimate the amount of basic study that may be needed.

See also the B.S./M.S. program under Graduate Study.

Biochemistry, B.S.

Freshman

Fall	**Credits**	**Spring**	**Credits**
BBMB 101	1	BBMB 102	1
CHEM 201*	5	CHEM 211	2
CHEM 201L*	1	CHEM 211L	2
MATH 165**	4	MATH 166	4

ENGL 150[1]	3	BIOL 211	3
LIB 160[1]	1	BIOL 211L[2]	1
		LAS General Education requirement	3
	15		**16**

Sophomore

Fall	Credits	Spring	Credits
CHEM 331	3	BBMB 201	2
CHEM 331L or 333	1-2	CHEM 332	3
MATH 265 or 266	3-4	CHEM 332L or 334L	1-2
BIOL 212	3	PHYS 222	5
PHYS 221	5	ENGL 250[1]	3
	15-17		**14-15**

Junior

Fall	Credits	Spring	Credits
BBMB 404[3]	3	BBMB 405[3]	3
BIOL 313	3	BIOL 314	3
LAS General Education Requirement[1]	3	LAS General Education Requirement[1]	3
LAS General Education Requirement[1]	3	LAS General Education Requirement[1]	3
LAS World Language Requirement[1]	4	LAS World Language Requirement[1]	4
	16		**16**

Senior

Fall	Credits	Spring	Credits
BBMB 411	4	BBMB 461	2
CHEM 324	3	Biological Science Elective[5]	4
LAS General Education Requirement[1]	3	CHEM 325	3
LAS General Education Requirement[1]	3	BBMB 561L or CHEM 322L[6]	2-3
BBMB 490 or 499	1-5	BBMB 490 or 499[4]	1-5
	14-18		**12-17**

Total Credits: 118-130

* General Chemistry I and II (177, 177N or 177L and 178) are acceptable substitutes for CHEM 201 and 201L. Chemistry assessment required for placement into CHEM 201.

** Math assessment is required. Students not ready for calculus will be enrolled in MATH143.

1 Liberal Arts and Sciences (LAS) General Education requirements include:
12cr. Arts and Humanities, 9 cr. Social Sciences and 11 cr. Natural Sciences (8 cr.) and Math (3 cr.).
Students in all ISU majors must complete a 3 cr. course in U.S. Diversity and a 3 cr. course in International Perspectives. Discuss with your adviser how the two courses you select can be applied to address general education requirements. Check for a list of approved courses at: http://www.registrar.iastate.edu/students/div-ip-guide

2 One Biology laboratory course is required. Choose Biol 211L, 212L or 313L.

3 Students have the option of choosing the senior level biochemistry sequence for 6 credits (BBMB 404 nd BBMB 405) or the graduate-level biochemistry sequence for 8 credits (BBMB 504, 505 and BBMB 506, 507).

4 Undergraduate study or research, BBMB 490 or 499, is recommended but not required. Credit value is variable.

5 Four credits of electives in Biological Sciences are required.

6 CHEM322L may be taken as a substitute for BMB 561L.

Biophysics, B.S.

Freshman

Fall	Credits	Spring	Credits
BBMB 101	1	BBMB 102	1
CHEM 201*	5	CHEM 211	2
CHEM 201L*	1	CHEM 211L	2
MATH 165**	4	MATH 166	4
ENGL 150[1]	3	BIOL 211	3
LIB 160[1]	1	BIOL 211L[2]	1
		COM S 207	3
	15		**16**

Sophomore

Fall	Credits	Spring	Credits
CHEM 331	3	CHEM 332	3
MATH 265	4	MATH 266	3
BIOL 212	3	PHYS 222	5
PHYS 221	5	ENGL 250[1]	3
	15		**14**

Junior

Fall	Credits	Spring	Credits
BBMB 404[3]	3	CHEM 325	3
CHEM 324	3	CHEM 322L[6]	3
LAS Foreign Language Requirement[1]	4	MATH 307 or MATH 317	3-4
Science Elective 300+[5]	3	LAS General Education Requirement[1]	3
		LAS Foreign Language Requirement[1]	4
	13		**16-17**

Senior

Fall	Credits	Spring	Credits
BBMB 411	4	BBMB 461 (BBMB 561L optional)	2
Science Elective 300+[5]	3	Biological Science Elective[5]	3
STAT 305 or STAT 231	4	LAS General Educaton Requirement[1]	3
LAS General Education Requirement[1]	3	LAS General Educaton Requirement[1]	3
LAS General Education Requirement[1]	3	LAS General Education Requirement[1]	3
BBMB 490 or 499[7]		BBMB 490 or 499[7]	
	17		**14**

Total Credits: 120-121

* General Chemistry I and II (177, 177n or 177l and 178) are acceptable substitutes for CHEM 201 and 201L.
Chemistry assessment required for placement into CHEM 201.

** Math assessment is required. Student not ready for calculus will be enrolled in MATH 142.

1 Liberal Arts and Sciences (LAS) General Education Requirements include a minimum of: 12 cr. Arts and Humanities, 9 cr. Social Sciences and 11 cr Natural Sciences (8 cr.) and Math (3 cr.)
Students in all ISU majors must complete a 3-cr. course in U.S. Diversity and a 3-cr. course in International Perspectives. Discuss with your adviser how the two courses you select can be applied to address general education requirements. Check for a list of approved courses at: http://www.registrar.iastate.edu/courses/div-ip-guide.html
Foreign Language Requirement: (www.las.iastate.edu/academics/learning_goals.shtml (http://catalog.iastate.edu/collegeofliberalartsandsciences/biochemistry_biophysics_andmolecularbiology/www.las.iastate.edu/academics/learning_goals.shtml))

2 One Biology laboratory course is required. Choose BIOL 211L, 212L, or 313L.

3 Students have the option of choosing the senior level biochemistry sequence for 5 credits (BBMB 404 and BBMB 405) or the graduate-level biochemistry sequence for 8 credits (BBMB 501 and BBMB 502).

4 Undergraduate study or research, BBMB 490 or 499, is recommended but not required. Credit value is variable.

5 Four credits of electives in Biological Sciences is required.

6 CHEM 321L + BBMB 561L may be taken as a substitute for CHEM 322L.

Graduate Study

The department offers work for the degrees master of science and doctor of philosophy with majors in biochemistry and biophysics and with interdepartmental majors in bioinformatics and computational biology, genetics and genomics, immunobiology, molecular, cellular, and developmental biology, neuroscience, plant biology, and toxicology. Minor work is offered to students taking major work in other departments.

Prerequisite to graduate work is a sound undergraduate background in biology, chemistry, mathematics, and physics.

All graduate students are required by the department to teach as part of their training for an advanced degree.

The department offers a B.S./M.S. program in biochemistry and biophysics that allows students to obtain both the B.S. and M.S. degrees in five years. The program is open to students in the College of Liberal Arts and Sciences and in the College of Agriculture and Life Sciences. Students interested in this program should contact the department office for details. Application for admission to the Graduate College should be made near the end of the junior undergraduate (third) year. Students would begin research for the M.S. thesis during the summer semester after their junior year and are eligible for research assistantships.

Courses primarily for undergraduates:

BBMB 101: Introduction to Biochemistry
(1-0) Cr. 1. F.
Research activities, career opportunities in biochemistry and biophysics, and an introduction to the structure of biologically important compounds. For students majoring in biochemistry, agricultural biochemistry or biophysics or considering one of these majors.

BBMB 102: Introduction to Biochemistry Laboratory
(0-2) Cr. 1. S.
Prereq: Credit or enrollment in CHEM 177 and CHEM 177L or CHEM 201 and CHEM 201L
Topics in the scientific background of biochemistry, such as macromolecules, metabolism, and catalysis. Laboratory experimentation covers biochemical concepts and the study of bio-molecules including proteins, lipids and nucleic acids. A significant component is practice in scientific communication. For students majoring in biochemistry, agricultural biochemistry or biophysics or considering one of these majors.

BBMB 201: Chemical Principles in Biological Systems
(2-0) Cr. 2. S.
Prereq: Credit or enrollment in CHEM 332
Survey of chemical principles as they apply in biological systems including: water, organic chemistry of functional groups in biomolecules and biochemical cofactors, weak bonds and their contribution to biomolecular structure, oxidation-reduction reactions and redox potential, thermodynamic laws and bioenergetics, chemical equilibria and kinetics, inorganic chemistry in biological systems, data presentation. The subjects will be taught using molecules from biological systems as examples. Intended for majors in biochemistry, biophysics or agricultural biochemistry.

BBMB 221: Structure and Reactions in Biochemical Processes
(3-0) Cr. 3. F.S.
Prereq: CHEM 163, CHEM 167, or CHEM 177
Fundamentals necessary for an understanding of biochemical processes. Primarily for students in agriculture. Not acceptable for credit toward a major in biochemistry, biophysics, or agricultural biochemistry. Credit for both BBMB 221 and Chem 231 may not be applied toward graduation.

BBMB 301: Survey of Biochemistry
(3-0) Cr. 3. F.S.SS.
Prereq: CHEM 231 or CHEM 331
A survey of biochemistry: structure and function of amino acids, proteins, carbohydrates, lipids, and nucleic acids; enzymology; metabolism; biosynthesis; and selected topics. Not acceptable for credit toward a major in biochemistry, biophysics, or agricultural biochemistry.

BBMB 316: Principles of Biochemistry
(3-0) Cr. 3. F.
Prereq: CHEM 231 or CHEM 331; BIOL 212; BIOL 313 and BIOL 314 strongly recommended.
Understanding biological systems at the molecular level; chemistry of biological macromolecules, enzyme function and regulation, metabolic pathways; integration of metabolism in diverse living systems. For students in biology and related majors who do not require the more rigorous treatment of biochemistry found in BBMB 404/405. Not acceptable for credit toward a major in biochemistry, biophysics, or agricultural biochemistry.

BBMB 404: Biochemistry I
(3-0) Cr. 3. F.
Prereq: CHEM 332
A general overview for graduate and advanced undergraduate students in agricultural, biological, chemical and nutritional sciences. Chemistry of amino acids, proteins, carbohydrates, and lipids, vitamins; protein structure; enzymology; carbohydrate metabolism. Credit for both BBMB 420 and the BBMB 404 - 405 sequence may not be applied toward graduation.

BBMB 405: Biochemistry II
(3-0) Cr. 3. S.
Prereq: BBMB 404
A general overview for graduate and advanced undergraduate students in agricultural, biological, chemical, and nutritional sciences. Metabolism of carbohydrates, amino acids, nucleotides and lipids; formation, turnover, and molecular relationships among DNA, RNA, and proteins; genetic code; regulation of gene expression; selected topics in the molecular physiology of plants and animals. Credit for both BBMB 420 and the BBMB 404 - BBMB 405 sequence may not be applied toward graduation.

BBMB 411: Techniques in Biochemical Research
(2-8) Cr. 4. F.
Prereq: Credit or enrollment in BBMB 404 or BBMB 504 and BBMB 505; CHEM 211
Laboratory experimentation and techniques for studying biochemistry, including: chromatographic methods; electrophoresis; spectrophotometry; enzyme purification; enzyme kinetics; and characterization of carbohydrates, proteins, lipids, and nucleic acids. Scientific communication and technical writing are emphasized.

BBMB 420: Mammalian Biochemistry
(3-0) Cr. 3. F.
Prereq: CHEM 332, BIOL 314
Structure and function of proteins; enzymology; biological oxidation; chemistry and metabolism of carbohydrates, lipids, amino acids and nucleic acids; protein synthesis and the genetic code; relationship of biochemistry to selected animal diseases. Biochemistry of higher animals emphasized. Not acceptable for credit toward a major in agricultural biochemistry or biochemistry. Acceptable for credit toward a major in biophysics. Credit for both BBMB 420 and the BBMB 404 - 405 sequence may not be applied toward graduation.

BBMB 430: Procaryotic Diversity and Ecology
(Dual-listed with BBMB 530). (Cross-listed with MICRO). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: MICRO 302, MICRO 302L
Survey of the diverse groups of procaryotes emphasizing important and distinguishing metabolic, phylogenetic, morphological, and ecological features of members of those groups.

BBMB 440: Laboratory in Microbial Physiology, Diversity, and Genetics
(Cross-listed with MICRO). (2-6) Cr. 4. F.
Prereq: MICRO 302, MICRO 302L, CHEM 332, BIOL 313L
Fundamental techniques and theory for studying the cellular mechanisms and diversity of microbial life. Experimental techniques will include isolation and physiological characterization of bacteria that inhabit different environments. Also included are techniques for phylogenetic characterization, measuring gene expression, and genetic manipulation of diverse species of bacteria. Essential components for the effective communication of scientific results are also emphasized.

BBMB 461: Molecular Biophysics
(Dual-listed with BBMB 561). (2-0) Cr. 2. S.
Prereq: Credit or enrollment in MATH 166 and CHEM 178 and PHYS 222 or PHYS 112.
Physical methods for the study of molecular structure and organization of biological materials. X-ray diffraction, nuclear magnetic resonance, hydrodynamics and fluorescence spectroscopy. Registration for the graduate credit commits the student to graduate-level examinations, which differ from undergraduate-level examinations in the number and/or difficulty of questions.

BBMB 490: Independent Study
Cr. 1-3. Repeatable. F.S.SS.
Prereq: College of Agriculture: junior or senior classification and permission of instructor; College of Liberal Arts and Sciences: permission of instructor.
Independent study with a faculty mentor. No more than 9 credits of BBMB 490 may count toward graduation.

BBMB 490H: Independent Study, Honors
Cr. 1-3. Repeatable. F.S.SS.
Prereq: College of Agriculture: junior or senior classification and permission of instructor; College of Liberal Arts and Sciences: permission of instructor
Independent study with a faculty mentor. No more than 9 credits of BBMB 490 may count toward graduation.

BBMB 499: Undergraduate Research
Cr. 1-5. Repeatable. F.S.SS.
Prereq: Permission of faculty member with whom student proposes to work.
Independent research under faculty guidance.

Courses primarily for graduate students, open to qualified undergraduates:

BBMB 504: Amino Acids and Proteins
(2-0) Cr. 2. F.
Prereq: CHEM 332 or equivalent
Review of amino acids and proteins, including atomic interactions, thermodynamics, structure and properties of amino acids, post-translational modifications, protein expression, purification and analysis, protein secondary, tertiary and quaternary structure, protein folding, oxygen transport and hemoglobin, models for equilibrium binding, elementary reactions and enzyme kinetics, biosynthesis of amino acids: pathways and mechanisms.

BBMB 505: Bioenergetics and Metabolism
(2-0) Cr. 2. F.
Prereq: CHEM 211, CHEM 332; a previous course in biochemistry is strongly recommended
Examination of catabolic pathways involved in the oxidation of organic and inorganic molecules, and energy metabolism involving inputs from light or other non-light sources. Central metabolism and glycolysis, fermentation, aerobic and anaerobic respiration, photosynthesis.

BBMB 506: Membrane Biochemistry
(2-0) Cr. 2.
Prereq: CHEM 332 or equivalent
Analysis of the structure, function, and synthesis of membranes. Bacterial and eukaryotic membrane characteristics. Membrane transport and signaling mechanisms. Analysis of the structure and function of lipids and membrane proteins.

BBMB 507: Biochemistry of Nucleic Acids
(2-0) Cr. 2. S.
Prereq: CHEM 332 or equivalent
Analysis of the chemical structure, function, synthesis, and metabolism of nucleic acids. Chemical characterization of nucleotides, polynucleotides, DNA, and RNA. Analysis of transcription, translation, and the genetic code.

BBMB 530: Procaryotic Diversity and Ecology
(Dual-listed with BBMB 430). (Cross-listed with MICRO). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: MICRO 302, MICRO 302L
Survey of the diverse groups of procaryotes emphasizing important and distinguishing metabolic, phylogenetic, morphological, and ecological features of members of those groups.

BBMB 542: Introduction to Molecular Biology Techniques
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. F.S.SS.
Sessions in basic molecular biology techniques and related procedures. Offered on a satisfactory-fail basis only.

BBMB 542A: Introduction to Molecular Biology Techniques: DNA Techniques
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. F.S.
Includes genetic engineering procedures, sequencing, PCR, and genotyping. Offered on a satisfactory-fail basis only.

BBMB 542B: Introduction to Molecular Biology Techniques: Protein
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, VDPAM). Cr. 1. Repeatable. S.SS.
Prereq: Graduate classification
Techniques. Includes: fermentation, protein isolation, protein purification, SDS-PAGE, Western blotting, NMR, confocal microscopy and laser microdissection, Immunophenotyping, and monoclonal antibody production. Sessions in basic molecular biology techniques and related procedures. Offered on a satisfactory-fail basis only.

BBMB 542C: Introduction to Molecular Biology Techniques: Cell Techniques
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. F.S.
Includes: immunophenotyping, ELISA, flow cytometry, microscopic techniques, image analysis, confocal, multiphoton and laser capture microdissection. Offered on a satisfactory-fail basis only.

BBMB 542D: Introduction to Molecular Biology Techniques: Plant Transformation
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. S.
Includes: Agrobacterium and particle gun-mediated transformation of tobacco, Arabidopsis, and maize, and analysis of tranformants. Offered on a satisfactory-fail basis only.

BBMB 542E: Introduction to Molecular Biology Techniques: Proteomics
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. F.
Includes: two-dimensional electrophoresis, laser scanning, mass spectrometry, and database searching. Offered on a satisfactory-fail basis only.

BBMB 542F: Introduction to Molecular Biology Techniques: Metabolomics
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. F.
Includes: metabolomics and the techniques involved in metabolite profiling. For non-chemistry majoring students who are seeking analytical aspects into their biological research projects. Offered on a satisfactory-fail basis only.

BBMB 542G: Introduction to Molecular Biology Techniques: Genomic
(Cross-listed with B M S, EEOB, FS HN, GDCB, HORT, NREM, NUTRS, V MPM, VDPAM). Cr. 1. Repeatable. S.
Offered on a satisfactory-fail basis only.

BBMB 552: Biomolecular NMR Spectroscopy
(2-0) Cr. 2. Alt. F., offered even-numbered years.
Prereq: CHEM 325 or permission of instructor
Advanced solution state Nuclear Magnetic Resonance spectroscopy as applied to biological systems. Topics include theoretical principles of NMR, practical aspects of experimental NMR, methodologies for protein structure determination, NMR relaxation, recent advances in NMR spectroscopy.

BBMB 561: Molecular Biophysics
(Dual-listed with BBMB 461). (2-0) Cr. 2. S.
Prereq: Credit or enrollment in MATH 166 and CHEM 178 and PHYS 222 or PHYS 112.
Physical methods for the study of molecular structure and organization of biological materials. X-ray diffraction, nuclear magnetic resonance, hydrodynamics and fluorescence spectroscopy. Registration for the graduate credit commits the student to graduate-level examinations, which differ from undergraduate-level examinations in the number and/or difficulty of questions.

BBMB 561L: Laboratory in Molecular Biophysics
(1-3) Cr. 2. S.
Prereq: Credit or enrollment in BBMB 461/BBMB 561
Practice in methods of X-ray diffraction, nuclear magnetic resonance, hydrodynamics and fluorescence spectroscopy as applied to macromolecules.

BBMB 569: Bioinformatics III (Structural Genome Informatics)
(Cross-listed with BCB, COM S, CPR E). (3-0) Cr. 3. F.
Prereq: BCB 567, BBMB 316, GEN 409, STAT 430
Algorithmic and statistical approaches in structural genomics including protein, DNA and RNA structure. Structure determination, refinement, representation, comparison, visualization, and modeling. Analysis and prediction of protein secondary and tertiary structure, disorder, protein cores and surfaces, protein-protein and protein-nucleic acid interactions, protein localization and function.

BBMB 590: Special Topics
Cr. arr.
By arrangement.

BBMB 593: Workshop in Biochemistry and Biophysics
Cr. 1. Repeatable. F.S.
Prereq: Permission and signature of course administrator required.
Workshops in selected topics in biochemistry and biophysics. Credit in this course does not meet the requirement for advanced graduate electives in Biochemistry. Spring only: BBMB Undergraduate Research Symposium participation. Scheduled class meetings are required in addition to attending the symposium.

Courses for graduate students:

BBMB 607: Plant Biochemistry
(2-0) Cr. 2. Alt. F., offered even-numbered years.
Prereq: BBMB 405 or BBMB 506 and BBMB 507
Description of unique aspects of plant biochemistry including lipid metabolism, cell wall structure, secondary metabolism, phytoalexin biosynthesis, and plant defenses.

BBMB 615: Molecular Immunology
(Cross-listed with MICRO, V MPM). (3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: BBMB 405 or BBMB 506 and BBMB 507
Current topics in molecular aspects of immunology: T and B cell receptors; major histocompatibility complex; antibody structure; immunosuppressive drugs and viruses; and intracellular signaling pathways leading to expression of genes that control and activate immune function.

BBMB 622: Carbohydrate Chemistry
(2-0) Cr. 2. Alt. S., offered even-numbered years.
Prereq: BBMB 404 or BBMB 504 and BBMB 505
Structure, occurrence, properties, function, and chemical and enzymatic modifications of monosaccharides, oligosaccharides, polysaccharides, and glycoproteins.

BBMB 632: Kinetics of Enzyme Action
(2-0) Cr. 2. Alt. F., offered even-numbered years.
Prereq: BBMB 504 and BBMB 505
Fundamental and advanced enzyme kinetics. Topics include integrated rate equations, methods for deriving initial-rate equations, inhibition, product effects, methods for verifying kinetic mechanisms, allostery, hysteresis, isotope effects, and complex kinetic mechanisms.

BBMB 642: Mechanisms of Enzymatic Catalysis
(2-0) Cr. 2. Alt. S., offered odd-numbered years.
Prereq: BBMB 404 or BBMB 420; or BBMB 504 and BBMB 505
The chemical basis of enzymatic catalysis with emphasis on mechanisms of substrate recognition, general acid-base catalysis and stereo-electronic factors.

BBMB 645: Molecular Signaling
(2-0) Cr. 2. Alt. S., offered odd-numbered years.
Prereq: BBMB 405 or BBMB 420; or BBMB 506 and BBMB 507
Molecular mechanisms of cellular signaling including receptor activation, desensitization and cross talk, signal transduction pathways, and nuclear receptors. Discussion includes a variety of cell surface receptors and their hormone; growth factor and extracellular matrix activators; protein kinases; caspase and transcription factor downstream signals; lipids, gases and cyclic nucleotides as regulators of cell signaling. Course content includes current literature, student and instructor presentations and research proposal writing.

BBMB 652: Protein Chemistry - Chemical Methods
(2-0) Cr. 1. Alt. F., offered odd-numbered years.
Prereq: BBMB 404 or BBMB 504 and BBMB 505
First 8 weeks. Chemical reactions as a means of determining protein structure and biological function.

BBMB 653: Protein Chemistry - Physical Methods
(2-0) Cr. 1. Alt. F., offered odd-numbered years.
Prereq: BBMB 404 or BBMB 504 and BBMB 505
Second 8 weeks. Protein structure determination as a means of understanding biological function.

BBMB 660: Membrane Biochemistry
(2-0) Cr. 2. Alt. F., offered even-numbered years.
Prereq: BBMB 405 or BBMB 506 and BBMB 507
Protein and lipid constituents of biological membranes. Structure and topography of membrane proteins. Selected topics concerning the membrane proteins involved in diverse biochemical processes, such as energy transduction transport across membranes, neurotransmission and signal transduction.

BBMB 661: Current Topics in Neuroscience
(Cross-listed with GDCB, NEURO). (2-0) Cr. 2-3. Repeatable. Alt. S., offered even-numbered years.
Prereq: NEURO 556 (or comparable course) or permission of instructor
Topics may include molecular and cellular neuroscience, neurodevelopment, neuroplasticity, neurodegenerative diseases, cognitive neuroscience, sensory biology, neural integration, membrane biophysics, neuroethology, techniques in neurobiology and behavior.

BBMB 675: Nucleic Acid Structure and Function
(2-0) Cr. 2. Alt. F., offered even-numbered years.
Prereq: BBMB 405 or BBMB 506 and BBMB 507
In-depth discussion of nucleic acid properties, structures and structure/function relationships. Interactions between nucleic acids and proteins will be emphasized.

BBMB 676: Biochemistry of Gene Expression in Eucaryotes
(Cross-listed with MCDB). (2-0) Cr. 2. Alt. S., offered even-numbered years.
Prereq: BBMB 404 and BBMB 504; and BBMB 506 and BBMB 507; or BBMB 405 or BBMB 505 and or GDCB 511
Analysis of the biochemical processes involved in expression of eucaryotic genes and the regulation thereof, including RNA polymerase, transcriptional regulatory proteins, enhancers and silencers, chromosome structure, termination, RNA processing, RNA transport, RNA turnover, small RNAs, translational regulation, protein turnover.

BBMB 681: Advanced Seminar
Cr. 1. Repeatable. F.S.
Prereq: Permission of instructor
Student presentations.

BBMB 682: Departmental Seminar
Cr. R. F.S.
Prereq: Permission of instructor
Faculty, staff and invited guest research seminar.

BBMB 696: Research Seminar
(Cross-listed with AGRON, FOR, GDCB, HORT, PLBIO). Cr. 1. Repeatable. F.S.
Research seminars by faculty and graduate students. Offered on a satisfactory-fail basis only.

BBMB 698: Seminar in Molecular, Cellular, and Developmental Biology
(Cross-listed with GDCB, MCDB, MICRO, V MPM). (2-0) Cr. 1-2. Repeatable. F.S.
Student and faculty presentations.

BBMB 699: Research
Cr. arr. Repeatable. F.S.
Prereq: Permission of instructor

Curriculum for a B.S. degree in Biochemistry, Molecular Biophysics Track

Year	Term	BIOCH		CHM		BIOL		PHYS		MATH		STAT	
1	Fall	110 Biochem Society	3	210 Chemistry I	4					220 Calc I	4	703 Statistical Methods for Natural Scientists *A&S requirements*	3 *32*
	Spr			230 Chemistry II	4	198 Prin Biology	4			221 Calc II	4		
2	Fall			350 Gen Org Chem 351 Gen Org Lab *Optional* 531 Org Chem I (3) 532 Org Lab (2) 550 Org Chem II (3)	3 2	450 Modern Genetics 455 General Microbiology 541 Cell Biology	4 4 3	213 Eng Phys I or 223 Physics I	5 5	222 Analytic Geometry and Calculus III Electives: 240 Elementary Differential Equations 515 Introduction to Linear Algebra	4 (4) (4)		
	Spr	521 Gen Biochem	3	371 Chemical Analysis	4			214 Eng Phys II or 224 Physics II	5 5				
3	Fall	755 Biochem I 756 Biochem I Lab	3 2					325 Physics III, Relativity, Quantum Physics 664 Thermodynamics and Statistical Physics or 775 Biological Physics	4 3 3				
	Spr	765 Biochem II (757/758/766/767) Biochem II Lab	3 (2)[1]	500: General Physical Chemistry	3								
4	Fall	799 Biochem Research	(1-3)[1,2]										
	Spr	775 Molecular Biophysics	3										
Total			20		20		15		17		12		35

Total credit hours of required courses	119
Electives[3]	5
Total	124

[1] Either Biochem II laboratory (757/758/766/767) or 2 credits of Biochemistry Research (799)

[2] BIOCH 799 (Biochemistry Research) may be taken for 1-3 credits in any year of the degree plan

[3] MATH 240 or 515 or any upper division (>500 level) course in the following departments: BIOCH, BIOL, CHM, CIS, MATH, STAT

Biophysical Science, BA

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Faculty

John M. Belote, Mark Bowick, Samuel H.P. Chan, Scott E. Erdman, Martin B. Forstner, Kenneth Foster, Edward D. Lipson, M. Lisa Manning, M. Cristina Marchetti, Alan Middleton, Liviu Movileanu, Ramesh Raina, John M. Russell, Peter Saulson, Eric A. Schiff, Jennifer Schwarz, Roy Welch

The B.A. in biophysical science is designed to serve students with strong interests in physical and mathematical aspects of the life sciences. The signature of the program is an exceptionally broad training in physics, biology, and chemistry. There are excellent scientific and professional opportunities for students who have acquired this broad grounding; bioinformatics, proteomics, and cell signaling are examples of subfields that benefit from a broad background in biophysical science. In conjunction with the other elements of the liberal arts core, graduates of the program are very well prepared to pursue careers in many sectors of the economy. The major is also well suited to students interested in graduate work in the health professions or in the biophysical sciences.

B.A. Degree Requirements

The B.A. in biophysical science requires a minimum of 61 credits of classwork, including 55 credits of specified courses. 18 credits of upper-division coursework in biology and physics are required, as are 3 credits of upper-division laboratory work in biology or physics.

- BIO 121 - General Biology I

- BIO 123 - General Biology II and
- BIO 124 - General Biology II Laboratory

- PHY 101 - Major Concepts of Physics I and
- PHY 102 - Major Concepts of Physics II

- CHE 106 - General Chemistry Lecture I and
- CHE 107 - General Chemistry Laboratory I

- CHE 116 - General Chemistry Lecture II and
- CHE 117 - General Chemistry Laboratory II

- MAT 285 - Life Sciences Calculus I and
- MAT 286 - Life Sciences Calculus II

- PHY 211 - General Physics I and
- PHY 221 - General Physics Laboratory I

- PHY 212 - General Physics II and
- PHY 222 - General Physics Laboratory II

- CHE 275 - Organic Chemistry I and
- CHE 276 - Organic Chemistry I Laboratory

- BIO 326 - Genetics and
- BIO 327 - Cell Biology

- PHY 315 - Biological and Medical Physics
- PHY 361 - Introduction to Modern Physics
- Upper-division biology electives
- Upper-division laboratory elective

Footnotes

1. Courses required for medical college admission; students who will apply to medical college must take CHE 325/CHE 326.
2. CHE 109/CHE 119 and CHE 129/CHE 139, Chemistry for Honors and Majors, may be substituted.
3. MAT 295, MAT 296, Standard Calculus, may be substituted (8 credits).
4. PHY 215, PHY 216, Physics for Honors and Majors, may be substituted.
5. BIO 355, BIO 407, BIO 409, BIO 422, BIO 425 , BIO 462, BIO 463, BIO 465, BIO 475, BIO 501, BIO 503 and BIO 565 are recommended upper-division biology electives.
6. Three credits of either a biology or a physics upper-division laboratory class, including experimental research, are required; the requirement for 6 elective credits of upper-division biology may be satisfied simultaneously.

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