

# 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 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.

A program that combines a bachelor of science and masters of science in biochemistry or biophysics is offered.

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

*For the undergraduate curriculum leading to the degree bachelor of science, major in Agricultural Biochemistry in the College of Agriculture and Life Sciences, see Agricultural biochemistry.*

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	3-4
or BBMB 504 & BBMB 505	Amino Acids and Proteins and Bioenergetics and Metabolism	
BBMB 405	Biochemistry II	3-4
or BBMB 506 & BBMB 507	Membrane Biochemistry and Biochemistry of Nucleic Acids	
BBMB 411	Techniques in Biochemical Research	4
BBMB 461	Molecular Biophysics	2
or BBMB 561	Molecular Biophysics	
BBMB 561L	Laboratory in Molecular Biophysics	2-3
or CHEM 322L	Laboratory in Physical Chemistry	
BBMB 490	Independent Study (Elective) <sup>max. 9 cr. can be applied</sup>	arr +
BBMB 499	Undergraduate Research (Elective) <sup>highly encouraged</sup>	arr +
Take one of the following:		5-7
CHEM 201	Advanced General Chemistry	
or CHEM 177	General Chemistry I & CHEM 178 and General Chemistry II	
Take one of the following:		1
CHEM 201L	Laboratory in Advanced General Chemistry	
or CHEM 177	Laboratory in General Chemistry I	
or CHEM 177	Laboratory in General Chemistry II	
CHEM 211 & 211L	Quantitative and Environmental Analysis and Quantitative and Environmental Analysis Laboratory	4
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)	1-2
or CHEM 332L	Laboratory in Organic Chemistry II	

MATH 165	Calculus I	4	BBMB 201	Chemical Principles in Biological Systems	2
MATH 166	Calculus II	4	BBMB 404	Biochemistry I	3
MATH 265	Calculus III	3-4	or BBMB 420	Mammalian Biochemistry	
or MATH 266	Elementary Differential Equations		BBMB 411	Techniques in Biochemical Research	4
or MATH 267	Elementary Differential Equations and Laplace Transforms		BBMB 461	Molecular Biophysics	2
PHYS 221	Introduction to Classical Physics I	10	or BBMB 561	Molecular Biophysics	
& PHYS 222	and Introduction to Classical Physics II		BBMB 561L	Laboratory in Molecular Biophysics	2-3
BIOL 211	Principles of Biology I	6	or CHEM 322L	Laboratory in Physical Chemistry	
& BIOL 212	and Principles of Biology II		BBMB 490	Independent Study (Elective) <sup>max. 9 cr. can be applied</sup>	arr †
BIOL 211L	Principles of Biology Laboratory I	1	BBMB 499	Undergraduate Research (Elective) <sup>highly encouraged</sup>	arr †
or BIOL 212L	Principles of Biology Laboratory II		Take one of the following:		5-7
or BIOL 313L	Genetics Laboratory		CHEM 201	Advanced General Chemistry	
BIOL 313	Principles of Genetics	3	CHEM 177	General Chemistry I	
BIOL 314	Principles of Molecular Cell Biology	3	& CHEM 178	and General Chemistry II	
Biological Science electives <sup>from Biochemistry, Biology, Chemistry, Genetics, Microbiology</sup>		4	CHEM 201L	Laboratory in Advanced General Chemistry	1
Total Credits		80-88	or CHEM 177N	Laboratory in General Chemistry I	
		†	or CHEM 177L	Laboratory in General Chemistry I	

† Arranged with instructor.

**Communication Proficiency: A grade of C or better is required in ENGL 250. For students fulfilling the upper-level requirement with BBMB 411, a grade of 80% or better must be earned on two journal-style written reports.**

LIB 160	Information Literacy	1	CHEM 211	Quantitative and Environmental Analysis	4
ENGL 150	Critical Thinking and Communication	3	& 211L	and Quantitative and Environmental Analysis Laboratory	
ENGL 250	Written, Oral, Visual, and Electronic Composition	3	CHEM 324	Introductory Quantum Mechanics	3
One course from the following:			CHEM 325	Chemical Thermodynamics	3
BBMB 411	Techniques in Biochemical Research	4	CHEM 331	Organic Chemistry I	6
ENGL 305	Creative Writing: Nonfiction	3	& CHEM 332	and Organic Chemistry II	
ENGL 309	Proposal and Report Writing	3	MATH 165	Calculus I	4
ENGL 314	Technical Communication	3	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	Introduction to Classical Physics I	10
			& PHYS 222	and Introduction to Classical Physics II	

## General Education Area

Arts and Humanities	12	One course from the following:			
Social Sciences	9	MATH 481	Numerical Methods for Differential Equations		
International Perspectives	3	STAT 407	Methods of Multivariate Analysis		
U.S. Diversity	3	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		

## Biophysics undergraduate major program of study

Total Degree Requirement: 120 cr,

BBMB 101	Introduction to Biochemistry	1	BIOL 211	Principles of Biology I	6
BBMB 102	Introduction to Biochemistry Laboratory	1	& BIOL 212	and Principles of Biology II	

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		85-89

† Arranged with instructor.

**Communication Proficiency: A grade of C or better is required in ENGL 250. For students fulfilling the upper-level requirement with BBMB 411, a grade of 80% or better must be earned on two journal-style written reports.**

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:		
BBMB 411	Techniques in Biochemical Research	4
ENGL 305	Creative Writing: Nonfiction	3
ENGL 309	Proposal and Report Writing	3
ENGL 314	Technical Communication	3

## 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 cr)	
BBMB 561	Molecular Biophysics (2 cr)	
CHEM 325	Chemical Thermodynamics (3 cr)	
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	3	BIOL 211	3
LIB 160 <sup>1</sup>	1	BIOL 211L <sup>3</sup>	1
		LAS General Education requirement <sup>2</sup>	3
			15
			16

### Sophomore

Fall	Credits	Spring	Credits
CHEM 331	3	BBMB 201	2
CHEM 331L or 333L	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 <sup>1</sup>	3
			15-17
			14-15

### Junior

Fall	Credits	Spring	Credits
BBMB 404 <sup>4</sup>	3	BBMB 405 <sup>4</sup>	3
BIOL 313	3	BIOL 314	3
LAS General Education Requirement <sup>2</sup>	3	LAS General Education Requirement <sup>2</sup>	3
LAS General Education Requirement <sup>2</sup>	3	LAS General Education Requirement <sup>2</sup>	3
LAS World Language Requirement <sup>8</sup>	4	LAS World Language Requirement <sup>8</sup>	4
			16
			16

### Senior

Fall	Credits	Spring	Credits
BBMB 411 <sup>1</sup>	4	BBMB 461	2
CHEM 324	3	Biological Science Elective <sup>6</sup>	4
LAS General Education Requirement <sup>2</sup>	3	CHEM 325	3
LAS General Education Requirement <sup>2</sup>	3	BBMB 561L <sup>7</sup>	2

BBMB 499 <sup>5</sup>	var BBMB 499 <sup>5</sup>	var
	13	11

Total Credits: 116-119

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

\*\* ALEKS assessment determines math placement.

<sup>1</sup> Communication Proficiency: A grade of C or better is required in ENGL 250. For students fulfilling the upper-level requirement with BBMB 411, a grade of 80% or better must be earned on two journal-style written reports.

<sup>2</sup> 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>

<sup>3</sup> One Biology laboratory course is required. Choose Biol 211L, 212L or 313L.

<sup>4</sup> Students have the option of choosing the senior level biochemistry sequence for 6 credits (BBMB 404 and BBMB 405) or the graduate-level biochemistry sequence for 8 credits (BBMB 504, 505 and BBMB 506, 507).

<sup>5</sup> Undergraduate study or research, BBMB 490 or 499, is recommended but not required. Credit value is variable.

<sup>6</sup> Four credits of electives in Biological Sciences are required.

<sup>7</sup> CHEM322L may be taken as a substitute for BBMB 561L.

<sup>8</sup> World Language Requirement

## Biophysics, B.S.

### Freshman

Fall	Credits Spring	Credits
BBMB 101	1 BBMB 102	1
CHEM 201 <sup>*</sup>	5 CHEM 211	2
or CHEM 177 and CHEM 178	CHEM 211L	2
CHEM 201L or 177L <sup>*</sup>	1 MATH 166	4
MATH 165 <sup>**</sup>	4 BIOL 211	3
ENGL 150	3 BIOL 211L <sup>3</sup>	1
LIB 160 <sup>1</sup>	1 COM S 207	3
	15	16

### Sophomore

Fall	Credits Spring	Credits
CHEM 331	3 BBMB 201	2
MATH 265	4 CHEM 332	3
BIOL 212	3 MATH 266	3
PHYS 221	5 PHYS 222	5
	ENGL 250 <sup>1</sup>	3
	15	16

### Junior

Fall	Credits Spring	Credits
BBMB 404 <sup>4</sup>	3 CHEM 325	3
CHEM 324	3 BBMB 461	2
LAS World Language Requirement <sup>8</sup>	4 BBMB 561L <sup>7</sup>	2
Science Elective <sup>6</sup>	3 MATH 317	4
	LAS General Education Requirement <sup>2</sup>	3
	LAS World Language Requirement <sup>8</sup>	4
	13	18

### Senior

Fall	Credits Spring	Credits
BBMB 411 <sup>1</sup>	4 Science Elective <sup>3</sup>	
Science Elective 300+ <sup>5</sup>	3 LAS General Education Requirement <sup>2</sup>	3
LAS General Education Requirement <sup>2</sup>	3 LAS General Education Requirement <sup>2</sup>	3
STAT 231 or 305	4 LAS General Education Requirement <sup>2</sup>	3
LAS General Education Requirement <sup>2</sup>	3 BBMB 499 <sup>5</sup>	var
BBMB 499 or 490 <sup>5</sup>	var	
	17	9

Total Credits: 119

\* General Chemistry I and II (177, 177n or 177L and 178) are acceptable substitutes for CHEM 201 and 201L.

\*\* ALEKS assessment determines math placement.

<sup>1</sup> Communication Proficiency: A grade of C or better is required in ENGL 250. For students fulfilling the upper-level requirement with BBMB 411, a grade of 80% or better must be earned on two journal-style written reports.

- <sup>2</sup> 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>
- <sup>3</sup> One Biology laboratory course is required. Choose BIOL 211L or 212L.
- <sup>4</sup> Students have the option of choosing BBMB 405 or BBMB 420.
- <sup>5</sup> Undergraduate study or research, BBMB 490 or 499, is recommended but not required. Credit value is variable.
- <sup>6</sup> Seven additional science elective credits 300+; biochemistry, biophysics, biological sciences, chemistry or physics.
- <sup>7</sup> CHEM 322L can substitute for BBMB 561L.
- <sup>8</sup> World Language Requirement

## Graduate Study

### Introduction

Biochemistry and Biophysics are the science and technology used to understand the mechanisms underlying biological processes at the molecular level, with an emphasis on the fundamental relationships among the chemical, physical, and biological sciences. The Roy J. Carver Department of Biochemistry, Biophysics, and Molecular Biology (BBMB) administers Doctor of Philosophy (Ph.D.), Master's (M.S.), and Graduate Certificate programs that lead to an advanced degree or certificate in these disciplines. The prerequisite to graduate study is a sound undergraduate background in biology, chemistry, mathematics, and physics.

BBMB offers Doctor of Philosophy and Master's degrees in Biochemistry and in Biophysics that are designed to train students to independently conceive and carry out original research. BBMB also offers two graduate certificate programs in Biochemistry that provide a mechanism for formal recognition of focused graduate study in a specialized area that is less comprehensive than that required for a master's degree. BBMB participates in the Interdepartmental majors of Bioinformatics and Computational Biology; Genetics and Genomics; Immunobiology; Molecular, Cellular, and Developmental Biology; Neuroscience; Plant Biology; and Toxicology. All graduate degree students in BBMB are required to teach as part of their training.

### Graduate Degree Programs

#### Concurrent Bachelor's (B.S.)/ Master's (M.S.) Degree

The department offers a concurrent enrollment degree program in either Biochemistry or Biophysics that allows ISU undergraduate students to obtain both the B.S. and M.S. degrees in about five years. The program is open to undergraduate students in the College of Liberal Arts and Sciences and in the College of Agriculture and Life Sciences. The concurrent degrees can be useful to students entering various career tracks. For those considering careers as research specialists, entry positions with higher-level responsibilities, and a higher-level salary, are made possible with the M.S. degree. For those considering careers as research directors, which require advanced study, the M.S. degree provides an advantage for admission into Ph.D. programs at the most competitive and prestigious graduate schools. Similarly, the M.S. degree can be a competitive advantage for admission in to medical, dental, law, veterinary medicine, or other professional schools.

Application to the program is made near the end of the junior undergraduate (third) year. Concurrent B.S./M.S. degree students begin research for the M.S. thesis during the summer semester after their junior year and are eligible for research assistantships, which are renewable based on academic standing and satisfactory research performance. The M.S. thesis requires intensive experience in original, independent laboratory research under the close supervision of a faculty mentor. To apply, see the concurrent B.S./M.S. application instructions found on the department's Graduate Study web page.

#### Master's (M.S.) Degree

The M.S. degree programs in Biochemistry and in Biophysics are useful for students who prefer to undertake research training without the longer-term commitment required for the Ph.D. degree. It is also useful for students interested more in the technical aspects of research rather than in careers as research directors. The program requires about 3 years on average to complete and the successful defense of an independent research dissertation is required. About half the time required to earn the degree is spent on advanced coursework and professional seminars, and the other half is devoted to research undertaken in the laboratory under the close supervision of a faculty mentor. Financial support is available.

To apply, applicants first submit the free BBMB online application found on the department website, which is used as a screening tool.

NOTE: Students interested in a research career are encouraged to consider the Ph.D. track. Students may enter the Biochemistry or Biophysics M.S. degree program as a direct admit to a faculty research group at any time during the year.

#### Doctor of Philosophy (Ph.D.) Degree

The Ph.D. programs in Biochemistry and in Biophysics are designed to train students in the ability to independently conceive and carry out original research in the general area of the chemistry or physics of the processes of life. The programs require about 5-6 years on average

to complete and the successful defense of an independent research dissertation. The majority of the time required to earn the degree is spent doing research on the dissertation project in the laboratory under the close supervision of a faculty mentor. Considerable time also is devoted to advanced coursework and professional seminars. Financial support is available. To apply, applicants first submit the free BBMB online application found on the department website, which is used as a screening tool. Students may enter the Biochemistry or Biophysics Ph.D. degree programs either as a rotation student in the fall semester or as a direct admit to a faculty research group at any time during the year.

### **Minor in Biochemistry**

Graduate students in other M.S. and/or Ph.D. programs at ISU can earn a graduate minor in Biochemistry by completing 12 credits of the following courses with a grade point average of 3.0 or above: at least 6 credits from BBMB 504, 505, 506 and 507 and at least 6 credits of other BBMB 500- and 600-level courses. A student wishing to declare a minor in Biochemistry should arrange for a member of the graduate faculty in Biochemistry to serve on the POS Committee and submit the required form found on the Graduate College Forms page.

### **Graduate Certificate Programs**

The graduate certificate program is designed for students who wish to continue or expand their knowledge in Biochemistry at the graduate level without the time commitment or lab experience required for a formal Master's or Ph.D. program. A certificate program can be an attractive option for individuals who have a bachelor's degree and are interested in broadening their expertise, or who are working in the sciences or industry and want to continue their education at the graduate level. BBMB offers two graduate certificate programs in Biochemistry: a concurrent B.S. / Graduate Certificate and a Graduate Certificate. The standards of admission and the course standards to which a certificate student are held are equivalent to those expected of a master's student. Each graduate certificate requires at least 12 graduate credits, all of which are available either on campus or on line. A graduate supervisor will be appointed to oversee the certification for each student.

If a person who completes a graduate certificate program decides to continue for a graduate degree in Biochemistry or Biophysics, program approval is required. Credits earned for the graduate certificate may be used to meet course requirements for the graduate degree program.

### **Concurrent B.S./Graduate Certificate**

This B.S. /Graduate Certificate program is intended for exceptional undergraduate students majoring in Biochemistry. In this program, the student completes all of the requirements for the B.S. degree and the graduate certificate in a four-year period by combining the requirements of the two programs. The student enters the Graduate College after

he/she achieves junior status and develops a plan of coursework (graduate and undergraduate) subject to the approval of the Director of Certificate (DOC). Required graduate courses are BBMB 504, 505, 506, 507, 561 and 561L. The student must satisfy the requirements of the B.S. in Biochemistry (121 credits) and the Graduate Certificate in Biochemistry (12 credits). Six credits of graduate coursework can satisfy some requirements of the B.S. degree. To apply for the B.S./Graduate Certificate, submit the application form found on the Graduate College Forms web page.

### **Graduate Certificate in Biochemistry**

The graduate certificate in Biochemistry is designed for students who have a B.S. degree in Biochemistry or a related field and wish to advance their knowledge by taking additional coursework at the graduate level.

The graduate certificate courses may be taken either on-line or on campus. Candidates for a graduate certificate in Biochemistry are admitted in the Graduate College. A total of 12 credits is required that include BBMB 504, 505, 506 and 507, plus four additional credits of BBMB coursework at the 500-level. The 12 credits earned in the graduate certificate program may be applied to meet the course requirements of a M.S. or Ph.D. program in Biochemistry at Iowa State University (ISU) if the student is accepted into one of these programs. To apply for the graduate certificate in Biochemistry, submit the ISU online application.

### **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 110: Biochemistry Learning Community Orientation**

Cr. 1. F.

*Prereq: Co-enrollment with BBMB 101 highly recommended.*

Overview of the program of study, academic planning, resources on campus for the successful transition to Iowa State, team#building, leadership, and community#focused activities. For members of the Biochemistry & Biophysics Learning Community. Offered on a satisfactory-fail basis only.

**BBMB 111: Biochemistry Learning Community**

Cr. 1. S.

*Prereq: Enrollment in BBMB102 is highly recommended.*

Overview of career-building and research resources within BBMB and across ISU, including internships, lab skills, independent research, and leadership opportunities. For members of the Biochemistry & Biophysics Learning Community. Offered on a satisfactory-fail basis only.

**BBMB 120: The Biochemistry of Beer**

(Cross-listed with FS HN). (2-0) Cr. 2. F.

An introduction to the major classes of biomolecules, basic biochemical concepts, enzymology, metabolism and genetic engineering as they apply to the production and flavor of beer. All aspects of the biochemistry of beer will be covered, including the malting of barley, starch conversion, yeast fermentation and the chemical changes that occur during the aging of beer. Intended for non-majors. Natural science majors are limited to elective credit only.

**BBMB 121: Medicines, Drugs and You**

Cr. 2. S.

*Prereq: One year of high school chemistry or CHEM 50 and biology.*

An introduction to how medicines treat disease, what drug molecules look like, how they function, how they can be toxic, modern therapeutics ranging from over-the-counter pain relievers, antibiotics and anti-depressants, to anti-cancer chemotherapies, a discussion of illegal drugs from toxicity to mechanism of action and potential therapeutic benefits. Intended for students of all 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. 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. Course offered online. Not acceptable for credit toward a major in biochemistry, biophysics, or agricultural biochemistry.

**BBMB 316: Principles of Biochemistry**

(3-0) Cr. 3. F.S.

*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. Course offered online. 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. Course offered online. 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. Course available online. 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: Prokaryotic 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 prokaryotes 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.S.

*Prereq: MICRO 302, MICRO 302L, CHEM 332, BIOL 313L*

Fundamental techniques and theory for studying the cellular mechanisms, genetic processes and diversity of microbial life. Experimental techniques will include isolation and physiological characterization of bacteria that inhabit different environments as well as an emphasis on genetic and molecular techniques to understand antibiotic resistance processes and mechanisms. Also included are techniques for phylogenetic characterization, measuring gene expression, and genetic manipulation 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 510: Molecular Biology and Biochemistry of RNA**

(2-0) Cr. 2. F.

*Prereq: BIOL 313, BBMB 405, BBMB 502, BBMB 506 and 507 or Gen 409, or equivalent*

Biochemical processes that define structure and function of nucleic acids. Emphasis on the molecular processes that take place during synthesis, processing, and function of different RNA species; review of recent advances in RNA research.

**BBMB 530: Prokaryotic 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 prokaryotes emphasizing important and distinguishing metabolic, phylogenetic, morphological, and ecological features of members of those groups.

**BBMB 532: Enzyme Kinetics and Mechanisms**

Cr. 2. Alt. S., offered odd-numbered years.

*Prereq: BBMB 504*

Advanced concepts of enzyme kinetics and catalysis. Experimental methods for determining kinetic and chemical reaction mechanisms. Enzyme structure/function relationships and the role of dynamics in catalysis.

**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 transformants. 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 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 Bioinformatics)**

(Cross-listed with BCB, COM S, CPR E, GDCB). (3-0) Cr. 3. F.

*Prereq: BCB 567, BBMB 316, GEN 409, STAT 430*

Molecular structures including genes and gene products: protein, DNA and RNA structure. Structure determination methods, structural refinement, structure representation, comparison of structures, visualization, and modeling. Molecular and cellular structure from imaging. Analysis and prediction of protein secondary, tertiary, and higher order structure, disorder, protein-protein and protein-nucleic acid interactions, protein localization and function, bridging between molecular and cellular structures. Molecular evolution.

**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 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 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 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.

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*