

Biomolecular Chemistry Syllabus

Department of Biochemistry & Molecular Biology

BIOC 3700 Fall 2024

Dalhousie University acknowledges that we are in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq People and pays respect to the Indigenous knowledges held by the Mi'kmaq People, and to the wisdom of their Elders past and present. The Mi'kmaq People signed Peace and Friendship Treaties with the Crown, and section 35 of the Constitution Act, 1982 recognizes and affirms Aboriginal and Treaty rights. We are all Treaty people.

Dalhousie University also acknowledges the histories, contributions, and legacies of African Nova Scotians, who have been here for over 400 years.

Course Instructors

Name	E-mail	Office Location
Dr. Jan K. Rainey (Lecture sections by JKR)	jan.rainey@dal.ca	Tupper 10N
Dr. Stephen L. Bearne (Lecture sections by SLB)	sbearne@dal.ca	Tupper 9J
Dr. Shawn Xiong (Lab Instructor)	shawn.xiong@dal.ca	Tupper 8J-2

Course Description

This course covers structural and functional properties of biomolecules, including the physical bases for their characterization, thermodynamic principles of protein folding and biomolecular interactions, and the kinetics and mechanisms of enzyme catalysis.

Course Prerequisites: BIOC 2300.03, 2610.03, CHEM 2401.03, and CHEM 2402.03 (all with a grade of B- or higher); MATH 1000.03 or 1215.03; or, instructor's consent. CHEM 2201.03 is highly recommended but not required.

Student Resources

Office hours with each of the BIOC 3700 instructors will be provided, with times and locations to be detailed on Brightspace. The **Biochemistry Resource Centre** will be available throughout the Fall term on Tuesdays, Wednesdays, and Thursdays from 12-2 pm in Tupper 8J-01.

Course Structure

Course Delivery

Lectures and laboratories will be in-person, with all tests and the final examination being in-person.

Lectures

8:35-9:25 (Monday/Wednesday/Friday) in Mona Campbell 1108, supplemented by online content for Dr. Rainey's material.

Laboratories

1 × 3 h (Tuesday 14:35–17:25) in Tupper 8J-01. More information regarding the lab schedule, lab manual, and lab assessment will be provided on Brightspace. Our first lab will take place on Tuesday, September 3rd.

Tutorials

In Dr. Rainey's section, Pre-lecture Problems are used to provide tutorial-type coverage of content throughout, with additional Tutorials provided in lecture (as time allows) and in video format through Brightspace. In Dr. Bearne's section, Supplemental Learning Exercises are used to provide tutorial-type coverage of key concepts and material.

Course Materials

Suggested textbooks:

Klostermeier, D., & Rudolph, M.G. (2017) *Biophysical Chemistry*, CRC Press, Taylor & Francis Group, Boca Raton, Florida.

Segel, I.H. (1976) *Biochemical Calculations*, 2nd Edition, John Wiley & Sons, Inc., New York.

Course website & online content: BrightSpace

Additional References:

Biophysical Chemistry

Atkins, P., & de Paula, J. (2006) *Physical chemistry for the life sciences*, Freeman.

Hammes, G.G. (2000) *Thermodynamics and kinetics for the biological sciences*. Wiley-Interscience, New York. (QP 517 P49 H35 2000)

Hammes, G.G. (2005) *Spectroscopy for the biological sciences*. Wiley-Interscience, New York.

Note: The previous two books comprise Hammes, G.G. (2007) *Physical chemistry for the biological sciences*. Wiley-Interscience, New York.

Roussel, M.R. (2012) *A Life Scientist's Guide to Physical Chemistry*, Cambridge University Press. **(Available as an online book, Dal Library)**

Tinoco, I., Sauer, K., Wang, J.C., & Puglisi, J. (2002) *Physical chemistry: Principles and applications in the biological sciences*, Pearson/Prentice Hall, Upper Saddle River, N.J.

Allen, J.P. (2008) *Biophysical Chemistry*, Oxford Press/Wiley-Blackwell, Hoboken, NJ. **(QT 34 A427b 2008)**

Correia, J.J., & Detrich, H.W. (Eds.) (2008) *Biophysical tools for biologists* (volumes 1 & 2), Academic Press, Burlington, MA. **(QH 581 P929m)**

Creighton, T.E. (1993) *Proteins: Structures and molecular properties*, 2nd Ed., W.H. Freeman and Co., New York.

Bergethon, P.R., & Simons, E.R. (1990) *Biophysical chemistry: molecules to membranes*, Springer-Verlag, New York **(QH 505 B397 1990)**

Cantor, C.R., & Schimmel, P.R. (1980) *The conformation of biological macromolecules* (parts 1-3), W. H. Freeman, San Francisco. **(QH 345 C36)**

Van Holde, K.E., Johnson, W.C., & Ho, P.S. (2006) *Principles of physical biochemistry*, Pearson/Prentice Hall, Upper Saddle River, N.J. **(QD 453.2 V256p 2006)**

Freifelder, D. (1982) *Physical biochemistry: applications to biochemistry and molecular biology*, W.H. Freeman, San Francisco. **(QU 4 F862 1982)**

Kinetics & Enzyme Chemistry

Fersht, A. (1999) *Structure and Mechanism in Protein Science*, W.H. Freeman and Co., New York. **(QU 55 F399s 1999)**

Cook, P.F., & Cleland, W.W. (2007) *Enzyme Kinetics and Mechanism*, Garland Science, New York. **(QU 135 C771e 2007)**

Silverman, R.B. (2000) *The Organic Chemistry of Enzyme-Catalyzed Reactions*, Academic Press, San Diego, CA.

Dugas, H. (1996) *Bioorganic Chemistry. A Chemical Approach to Enzyme Action*, Spriger-Verlag, New York. **(QU 135 D866b 1996)**

Segel, I.H. (1975) *Enzyme Kinetics: Behavior and Analysis of Rapid Equilibrium and Steady-State Enzyme Systems*, John Wiley & Sons, Inc., New York. **(QU 135 S454e 1993)**

Roberts, D.V. (1977) *Enzyme Kinetics*, Cambridge University Press, New York. **(QU135 R45 1977)**

General Textbooks

Abeles, R.H., Frey, P.A., & Jencks, W.P. (1992) *Biochemistry*, Jones and Bartlett Publishers, Boston. (QU 4 A139 1992)

Branden, C., & Tooze, J. (1991) *Introduction to protein structure*, Garland Publishing, Inc., New York. (QU 55 B816i 1991)

Petsko, G.A., & Ringe, D. (2004) *Introduction to protein structure and function*, New Science Press Ltd., London, UK. (QU 55 P498p 2004)

Nelson, D.L., & Cox, M.M. (2008) *Lehninger: Principles of Biochemistry*, 5th Ed., W.H. Freeman and Co., New York. (QU 4 L523p 2008)

Voet, D. & Voet, J.G. (2011) *Biochemistry*, 4th Edition, John Wiley & Sons.

Assessment

*Laboratory (30% of final grade**)*

A detailed breakdown of laboratory assessments and their timing will be provided in the lab.

Tests (30% of final grade)

Two 50-minute Midterm Tests each worth 15% of the final grade will be held during regular class time on **Friday, October 4th** and **Monday, November 4th**.

*Final exam (40% of final grade**)*

A three-hour final examination will be scheduled by the Registrar during Dalhousie's Fall Exam Period of December 6-17, 2024.

Other course requirements

**** Both the laboratory and the final exam must be passed in order to pass the course.**

Conversion of numerical grades to final letter grades follows the

Dalhousie Grade Scale

A+ (90-100)	B+ (77-79)	C+ (65-69)	D (50-54)
A (85-89)	B (73-76)	C (60-64)	F (0-49)
A- (80-84)	B- (70-72)	C- (55-59)	

Department of Biochemistry & Molecular Biology Policy for Students repeating a BIOC course with an integral lab component (BIOC 3300, BIOC 3400, BIOC 3700):

Students who have previously taken BIOC 3300, BIOC 3400, or BIOC 3700 and passed the laboratory component will not be allowed to retake the lab component if they redo the course. The previous lab marks will be used to assign the grade for the lab component based on the weight given to this component in the syllabus for the course in the year it is retaken.

BIOC 3700 Policy on missed examinations and mid-terms:

A student who misses a midterm test or lab in BIOC 3700 due to illness must notify the instructor or course coordinator prior to the scheduled time for that component. The student must also submit a Student Declaration of Absence Form through the course Brightspace page within three (3) calendar days following the last day of absence. Special 'make-up' tests (if offered) will normally be written within 7 calendar days after the missed test. Absence for non-medical reasons is not ordinarily acceptable unless prearranged with the instructor. A missed evaluation component for which no satisfactory arrangement has been made will be given a mark of zero. The Student Declaration of Absence form can only be submitted up to two (2) separate times per course during a term. Students who exceed this limit must inform their course instructors and will be required to register with an Advisor at Student Academic Success (SAS). If students have recurring short-term absences and do not register with SAS, it is at the instructors' discretion to disallow any further Student Declarations and deny alternate coursework arrangements.

Course Policies related to Academic Integrity

All students are expected to be familiar with and follow Dalhousie's general regulations on Academic Integrity. Cheating on tests and examinations will be addressed through Dalhousie's formal Discipline process. Detailed policies on Academic Integrity (i.e., what constitutes plagiarism, appropriate/inappropriate use of generative AI, and on individual vs. group work expectations) are outlined in the BIOC 3700 laboratory manual.

Learning Objectives

1. Discriminate between and calculate the roles of entropy, enthalpy, and molecular interactions in protein stability, folding and ligand binding.
2. Given the architecture of an enzyme active site, write a mechanism and show how general acid/base, covalent, or electrophilic catalysis may occur.
3. Given the kinetic mechanism (with or without inhibition), derive an initial velocity equation using either the steady-state assumption or the rapid equilibrium approach.
4. Draw the structure of a peptide with defined stereochemistry at a given pH.

- Given the substrates, products, and cofactors for a particular class of enzyme-catalyzed reaction, write a mechanism for the reaction.
- Analyze implications of molecular spectroscopy (absorption, emission, CD, NMR) results on polypeptide structure and environment in direct context of the physical basis of the technique in question.
- Given an enzyme mechanism, design a reversible or irreversible inhibitor.
- Apply peptide bond properties and hydrogen-bonding to predict primary and secondary structuring preferences.
- Present and analyze experimental data in a prescribed format for a formal scientific report.
- Demonstrate proficiency in biochemical laboratory techniques, including liquid handling, pH measurements, visible range spectroscopy, enzyme assays and determination of kinetic parameters, thin layer chromatography, protein isolation and quantification, and SDS-PAGE.

Course Content

Week (Class)	Date (Day)	Lecture topic/Assessment component
Protein Chemistry, Stability & Thermodynamics (JKR)		
Online review lectures (1&2) – Acid-base equilibria & amino acids.		
1 (1)	Sept. 4 (W)	Amino acids→peptide bonds; key concepts in thermodynamics 1. Amino acid stereochemistry; peptide bond formation; 1 st law of thermodynamics.
1 (2)	Sept. 6 (F)	Key concepts in thermodynamics 2. 1 st law continued & definition of enthalpy.
2 (3)	Sept. 9 (M)	Key concepts in thermodynamics 3. 2 nd law & definition of entropy.
2 (4)	Sept. 11 (W)	Key concepts in thermodynamics 4. Spontaneity & equilibria.
2 (5)	Sept. 13 (F)	Peptide bonds, polypeptide conformation & polypeptide properties. Peptide bond properties & their relation to protein conformation; backbone conformational restriction ($\phi/\psi/\omega$).
3 (6)	Sept. 16 (M)	Intra/intermolecular interactions 1. Hydrophobicity & hydrophilicity; Interactions that hold together molecules and complexes & ramifications for protein stability.
3 (7)	Sept. 18 (W)	Intra/intermolecular interactions 2. Interactions that hold together molecules and complexes & ramifications for protein stability; tutorial questions.
Protein Structure (JKR)		
3 (8)	Sept. 20 (F)	Secondary structure 1. Helices.
4 (9)	Sept. 23 (M)	Secondary structure 2 & fibrous proteins 1. β -structures & other structures; introduction to fibrous proteins.
4 (10)	Sept. 25 (W)	Fibrous proteins 2, protein folding & globular protein structure. Protein fibres; Folding; 3 ^o and 4 ^o structuring.

<i>Structural Biology (JKR)</i>		
Online lecture (3) – NMR chemical shifts – moving from small molecules to proteins.		
4 (11)	Sept. 27 (F)	Structural biology 1. Fundamentals of NMR spectroscopy.
5 (-)	Sept. 30 (M)	University Closed – National Day for Truth and Reconciliation
5 (12)	Oct. 2 (W)	Structural biology 2. NMR spectroscopy – continued.
5 (13)	Oct. 4 (F)	Midterm test #1 (15% of final grade). Content: Lectures 1-11.
6 (14)	Oct. 7 (M)	Structural biology 3. NMR spectroscopy – continued; X-ray crystallography.
6 (15)	Oct. 9 (W)	Structural biology 4. X-ray crystallography – continued; cryo-EM.
<i>Optical Spectroscopy of Proteins (JKR)</i>		
6 (16)	Oct. 11 (F)	Optical spectroscopy 1. Vibronic states & absorption spectroscopy; circular dichroism spectroscopy.
7 (-)	Oct. 14 (M)	University Closed – Thanksgiving Day
7 (17)	Oct. 16 (W)	Optical spectroscopy 2. CD spectroscopy – continued; emission spectroscopy.
7 (18)	Oct. 18 (F)	Optical spectroscopy 3. Emission spectroscopy – continued; tutorial questions.
<i>Enzyme Kinetics (SLB)</i>		
8 (19)	Oct. 21 (M)	Fundamental kinetics 1. Rate equations.
8 (20)	Oct. 23 (W)	Fundamental kinetics 2. Progress curves and graphs of initial rates.
8 (21)	Oct. 25 (F)	Enzyme kinetics 1. Rapid equilibrium and steady-state kinetics.
9 (22)	Oct. 28 (M)	Enzyme kinetics 2. Enzyme assays and analysis of kinetic data.
9 (23)	Oct. 30 (W)	Enzyme kinetics 3. Inhibition models and determination of inhibition constants (K_i).
<i>Enzyme Catalysis & Mechanism (SLB)</i>		
9 (24)	Nov. 1 (F)	Reactivity of amino acids revisited. Side chain chemistry, covalent modification.
10 (25)	Nov. 4 (M)	Midterm test #2 (15% of final grade) Content: Lectures 12 & 14-23.
10 (26)	Nov. 6 (W)	General acid-base catalysis 1. Why are nonenzymatic reactions slow? Transition state stabilization.
10 (27)	Nov. 8 (F)	General acid-base catalysis 2. Mechanisms of isomerases.

–	Nov. 11 (M)	University Closed – Remembrance Day
–	Nov. 13 (W)	No Class – Fall Study Break
–	Nov. 14 (F)	No Class – Fall Study Break
11 (28)	Nov. 18 (M)	Promoting hydrolysis reactions 1. Covalent catalysis.
11 (29)	Nov. 20 (W)	Promoting hydrolysis reactions 2. Electrophilic catalysis.
11 (30)	Nov. 22 (F)	Design of enzyme inhibitors. Transition state analogues, suicide inhibitors, activity profiling.
12 (31)	Nov. 25 (M)	Stabilization of carbanions 1. Pyridoxal phosphate as a coenzyme.
12 (32)	Nov. 27 (W)	Stabilization of carbanions 2. Thiamine pyrophosphate as a coenzyme.
12 (33)	Nov. 29 (F)	Redox reactions 1. NAD ⁺ as a coenzyme.
13 (34)	Dec. 2 (M)	Redox reactions 2. FAD as a prosthetic group with coenzyme function.
13 (35)	Dec. 3 (Tu/[M])	Bond-forming reactions 1. Phosphoryl transfers and positional isotope exchange.
13 (36)	Dec. 4 (W/[M])	Bond-forming reactions 2. Biotin as a prosthetic group.
Final Examination (40% of final grade): To be scheduled by the Registrar during the Exam Period of December 6-17		

University Policies and Statements

Recognition of Mi'kmaq Territory

Dalhousie University would like to acknowledge that the University is on Traditional Mi'kmaq Territory. The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit or e-mail the Indigenous Student Centre at 1321 Edward St or elders@dal.ca. Additional information regarding the Indigenous Student Centre can be found at:

https://www.dal.ca/campus_life/communities/indigenous.html

Internationalization

At Dalhousie, 'thinking and acting globally' enhances the quality and impact of education, supporting learning that is "interdisciplinary, cross-cultural, global in reach, and orientated toward solving problems that extend across national borders." Additional internationalization information can be found at:

<https://www.dal.ca/about-dal/internationalization.html>

Academic Integrity

At Dalhousie University, we are guided in all our work by the values of academic integrity: honesty, trust, fairness, responsibility, and respect. As a student, you are required to demonstrate these values in all the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. Additional academic integrity information can be found at:

https://www.dal.ca/dept/university_secretariat/academic-integrity.html

Accessibility

The Student Accessibility Centre is Dalhousie's centre of expertise for matters related to student accessibility and accommodation. If there are aspects of the design, instruction, and/or experiences within this course (online or in-person) that result in barriers to your inclusion, please contact the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro. For courses offered by the Faculty of Agriculture, please contact the Student Success Centre in Truro (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>).

Conduct in the Classroom – Culture of Respect

Substantial and constructive dialogue on challenging issues is an important part of academic inquiry and exchange. It requires willingness to listen and tolerance of opposing points of view. Consideration of individual differences and alternative viewpoints is required of all class members, towards each other, towards instructors, and towards guest speakers. While expressions of differing perspectives are welcome and encouraged, the words and language used should remain within acceptable bounds of civility and respect.

Diversity and Inclusion – Culture of Respect

Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. We stand for equality. Dalhousie is strengthened in our diversity. We are a respectful and inclusive community. We are committed to being a place where everyone feels welcome and supported, which is why our Strategic Direction prioritizes fostering a culture of diversity and inclusiveness (Strategic Priority 5.2). Additional diversity and inclusion information can be found at: <http://www.dal.ca/cultureofrespect.html>

Student Code of Conduct

Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner - perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. The full Code of Student Conduct can be found at:

https://www.dal.ca/dept/university_secretariat/policies/student-life/code-of-student-conduct.html

Fair Dealing Policy

The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. Additional information regarding the Fair Dealing Policy can be found at: https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy-.html

Originality Checking Software

The course instructor may use Dalhousie's approved originality checking software and Google to check the originality of any work submitted for credit, in accordance with the Student Submission of Assignments and Use of Originality Checking Software Policy. Students are free, without penalty of grade, to choose an alternative method of attesting to the authenticity of their work and must inform the instructor no later than the last day to add/drop classes of their intent to choose an alternate method. Additional information regarding Originality Checking Software can be found at: <https://www.dal.ca/about/leadership-governance/academic-integrity/faculty-resources/ouriginal-plagiarism-detection.html>

Student Use of Course Materials

Course materials are designed for use as part of this course at Dalhousie University and are the property of the instructor unless otherwise stated. Third party copyrighted materials (such as books, journal articles, music, videos, etc.) have either been licensed for use in this course or fall under an exception or limitation in Canadian Copyright law. Copying this course material for distribution (e.g. uploading to a commercial third-party website) may lead to a violation of Copyright law.

Faculty of Science

Student Resources and Support

University Policies and Programs

Important Dates in the Academic Year (including add/drop dates):

http://www.dal.ca/academics/important_dates.html

Classroom Recording Protocol:

https://www.dal.ca/dept/university_secretariat/policies/academic/classroom-recording-protocol.html

Dalhousie Grading Practices Policies:

https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html

Grade Appeal Process: https://www.dal.ca/campus_life/academic-support/grades-and-student-records/appealing-a-grade.html

Sexualized Violence Policy: https://www.dal.ca/dept/university_secretariat/policies/health-and-safety/sexualized-violence-policy.html

Scent-Free Program: <https://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>

Learning and Support Resources

General Academic Support – Advising (Halifax): https://www.dal.ca/campus_life/academic-support/advising.html

General Academic Support – Advising (Truro): <https://www.dal.ca/about-dal/agricultural-campus/ssc/academic-support/advising.html>

Student Health & Wellness Centre: https://www.dal.ca/campus_life/health-and-wellness.html

On Track (helps you transition into university, and supports you through your first year at Dalhousie and beyond): https://www.dal.ca/campus_life/academic-support/On-track.html

Indigenous Student Centre: https://www.dal.ca/campus_life/communities/indigenous.html

Indigenous Connection: <https://www.dal.ca/about-dal/indigenous-connection.html>

Elders-in-Residence (The Elders in Residence program provides students with access to First Nations elders for guidance, counsel, and support. Visit the office in the Indigenous Student Centre or contact the program at elders@dal.ca or 902-494-6803:

<https://cdn.dal.ca/content/dam/dalhousie/pdf/academics/UG/indigenous-studies/Elder-Protocol-July2018.pdf>

Black Student Advising Centre: https://www.dal.ca/campus_life/communities/black-student-advising.html

International Centre: https://www.dal.ca/campus_life/international-centre.html

LGBTQ2SIA+ Collaborative: <https://www.dal.ca/dept/vpei/edia/education/community-specific-spaces/LGBTQ2SIA-collaborative.html>

Dalhousie Libraries: <http://libraries.dal.ca/>

Copyright Office: <https://libraries.dal.ca/services/copyright-office.html>

Dalhousie Student Advocacy Services: <https://www.dsu.ca/dsas?rq=student%20advocacy>

Dalhousie Ombudsperson: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html

Human Rights and Equity Services: <https://www.dal.ca/dept/hres.html>

Writing Centre: https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html

Study Skills/Tutoring: http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html

Faculty of Science Advising Support: <https://www.dal.ca/faculty/science/current-students/undergrad-students/degree-planning.html>

Safety

Biosafety: <http://www.dal.ca/dept/safety/programs-services/biosafety.html>

Chemical Safety: <https://www.dal.ca/dept/safety/programs-services/chemical-safety.html>

Radiation Safety: <http://www.dal.ca/dept/safety/programs-services/radiation-safety.html>

Laser Safety: <https://www.dal.ca/dept/safety/programs-services/radiation-safety/laser-safety.html>