

Physical & Quantitative Biology, BME/CHE/PHY 558

Fall 2026 – Mon, Wed, Fri, 11:00 – 11:55 AM, in Laufer Center Room 101.

Recitations: Mon, 12:00 pm – 13:00 pm in Laufer Center Room 101.

Course goals: The central question is: What is Life? The central idea is free energy, a quantitative way to understand thermodynamic forces driving equilibria and transition rates in chemistry, physics and biology. We describe the components underpinning free energy: entropy and internal energy. We explore microscopic interactions - including hydrogen bonding, van der Waals interactions, electrostatics and hydrophobic forces - that explain physical and chemical mechanisms in cell biology and are the workhorse tools in computational drug discovery. We show how these basic ideas are applied: binding affinities form the basis for synthetic biology and drug discovery; coupled binding explains how biological machines convert energy and transduce signals or control gene activity; and polymer free energies form the basis for the folding of protein and RNA molecules; with implications for molecular and cellular evolution.

Textbook: Molecular Driving Forces, 3rd Ed. by Dill & Bromberg. MIT Press, 2026

Textbook: Protein Actions by Bahar, Jernigan & Dill. Garland Science, 2017

Extra textbook: Physical Models of Living Systems by Nelson. W. H. Freeman & Co., 2015

#1: 8/24) Introduction. Basic Biology. Probability, statistics. (MDF 1) [GB]

#2: 8/26) Combinatorics. Distributions. (MDF 1) [GB].

#3: 8/28) Extremum principles. Multivariate Optimization. (MDF 2,4) [GB].

#4: 8/31) Thermodynamic laws. Energy vs. Entropy formulation. (MDF 3,5) [GB]. **R:ML.**

#5: 9/2) Max Ent & Boltzmann principle. Driving forces. (MDF 6) [GB].

#6 9/4) Path integrals. Ideal gas. (MDF 7) [GB].

9/7) **NO CLASS**, Labor Day.

#7: 9/9) Carnot cycle. Helmholtz Free Energies. (MDF 8,9) [GB]. **R:ML.**

#8: 9/11) Maxwell relations. Susceptibilities. Boltzmann Law. (MDF 9,10) [GB].

#9: 9/14) Partition function. Quantum Mechanics. (MDF 10,11) [GB] **R:ML.**

#10: 9/16) Chemical equilibria. (MDF 13) [GB]

#11: 9/18) Phase equilibria. (MDF 14) [GB].

#12: 9/21) Solutions. Mixtures. (MDF 15). [GB]. **R:ML.**

#13: 9/23) Solvation effects. Fick's Laws. (MDF 16,17). [GB].

#14: 9/25) Diffusion. Reaction-Diffusion. Random walks. Time's arrow. (MDF 17,18) [GB].

#15: 9/28) Chemical kinetics. Mass-action. Transition states. (MDF 19) [GB]. **R:ML.**

#16: 9/30) Electrostatics: Charges and Fields. (MDF 20). [GB].

#17: 10/2) Electrostatic potentials. Dipoles. (MDF 21). [GB].

#18: 10/5) Electrochemical equilibria. Batteries. (MDF 22) [GB]. **R:ML.**

#19: 10/7) Salts shield charges. Poisson-Boltzmann. Intermolecular forces. (MDF 23,24) [GB].

#20: 10/9). Real gas. Phase transitions. (MDF 25,26) [GB].

10/12) **NO CLASS**, Fall Break – Columbus Day.

10/14) **MIDTERM EXAM 1.**

#21: 10/16) Adsorption & binding. Michaelis-Menten. Catalysis. (MDF 27) [LC].

#22: 10/19) Binding Polynomials. Cooperativity. (MDF 28) [LC]. **R:ML.**

#23: 10/21) Bio-machine principles. (MDF 29) [LC].

#24: 10/23) Water: Pure and as a solvent. (MDF 30, 31) [LV - tbc].

#25: 10/26) Polymers 1: Conformations. Random flights. (MDF 33, 34) [HS]. **R:ML.**

#26: 10/28) Polymers 2: Solutions, Flory-Huggins. (MDF 32,33) [HS].

#27: 10/30) Protein structures. (PA1) [ES].

#28: 11/2) Protein function & mechanisms. (PA2) [ES]. **R:ML.**

#29: 11/4) Protein folding & stability. (PA3)[CS].

#30: 11/6) Cooperativity in proteins. (PA5)[CS].

#31: 11/9) Protein evolution and sequence space. (PA7) [JRest]. **R:ML.**

#32 11/11) Protein folding on energy landscapes. Aggregation. (PA6) [ES].

#33: 11/13) Gene expression as a driven system. [DG].

#34: 11/16) Gene regulation and gene networks. [DG]. **R:ML.**

#35: 11/18) Synthetic biology. Cellular evolution. [GB].

11/20) Research Project Presentations*.

11/23) **MIDTERM EXAM 2.**

11/25) **NO CLASS**, Thanksgiving break.

11/27) **NO CLASS**, Thanksgiving break.

MDF = Molecular Driving Forces, chapter numbers. PA = Protein Actions, chapter numbers.
TA: Mateo Londoño (ML), mateo.londoo@stonybrook.edu.

Lecturers

[GB] Gábor Balázsi (Instructor & Course Coordinator, gabor.balazsi@stonybrook.edu)

[CS] Carlos Simmerling

[DG] David S. Glass

[ES] Eugene Serebryany

[HS] Helmut Strey

[JRest] Joshua Rest

[LC] Lina Carlini

[LV] Lakshmanji Verma

All lectures & recitations will be recorded, and links posted after each lecture on Brightspace.

Final grade = average of the two midterms, adj. based on homework & research presentations.

How to Be a Successful Student in This Course

There are multiple resources, university offices, and help desks that are available to assist you with everything from advising, tutoring, accessibility and much more.

Review some Academic Success Strategies and visit the [Student Resources page](#) for links to resources on campus.

Wellness & Support Statement

Stony Brook values student well-being, including mental health, and recognizes that a variety of factors can impact emotional wellness and academic success including stress, anxiety, depression, substance use, sexual violence, family or relationship concerns, and political conflict.

[Resources are available](#) if you experience challenges or wellness concerns that affect your ability to be successful in class, and you are encouraged to reach out for help when you need it.

In the event of a short-term absence from class, students are encouraged to communicate immediately and work directly with instructors. However, if a student is struggling with an extended absence due a hospitalization, family illness or death, they are encouraged to reach out to the Student Support Team.

Technical Requirements and Assistance

[D2L Brightspace](#) is Stony Brook University's digital learning environment. It is used for the facilitation of communications between faculty and students, submission of assignments, and secure posting of grades and feedback in your courses. To access Brightspace, go to mycourses.stonybrook.edu and use your SBU NetID and password. If you are unsure of your NetID, visit [Finding Your NetID and Password](#) for more information.

Sometimes submitting coursework via a tablet and/or mobile device can be challenging.

Computers equipped with the appropriate software are available for use at the various [SINC site computer labs](#). Both physical and virtual labs are available. You can also borrow a computer through [SBU's Laptop Loan Program](#).

Visit the [Technical Requirements page](#) for additional information regarding hardware and software options.

Please use the following information if you need technical assistance at any time during the course or to report a problem with Brightspace:

Brightspace Support via SUNY Helpdesk

- Phone: 1-844-673-6786
- Submit a [ticket or chat online](#)

Stony Brook University: Academic Technology Services

- Phone: 631-632-9800
- Email: AcademicTechnologies@stonybrook.edu

Privacy Policies

This course utilizes various educational technologies to enhance the learning experience. You can access links to the [privacy policies](#) of the tools and platforms used at Stony Brook University on the Syllabus Addendum webpage.

Student Accessibility Support Center Statement

If you have a physical, psychological, medical, or learning disability that may impact your course work, please contact the Student Accessibility Support Center, Stony Brook Union Suite 107, (631) 632-6748, or at sasc@stonybrook.edu. They will determine with you what accommodations are necessary and appropriate. All information and documentation is confidential.

Students who require assistance during emergency evacuation are encouraged to discuss their needs with their professors and the Student Accessibility Support Center. For procedures and information, visit [Environmental Health and Safety](#).

Academic Integrity Statement

Each student must pursue their academic goals honestly and be personally accountable for all submitted work. Representing another person's work as your own is always wrong. Faculty is required to report any suspected instances of academic dishonesty to the Academic Judiciary. Faculty in the Health Sciences Center (School of Health Professions, Nursing, Social Welfare, Dental Medicine) and School of Medicine are required to follow their school-specific procedures. For more comprehensive information on academic integrity, including categories of academic dishonesty please refer to the [academic judiciary website](#).

Critical Incident Management

Stony Brook University expects students to respect the rights, privileges, and property of other people. Faculty are required to report to the Office of Student Conduct and Community Standards any disruptive behavior that interrupts their ability to teach, compromises the safety of the learning environment, or inhibits students' ability to learn. Faculty in the HSC Schools and the School of Medicine are required to follow their school-specific procedures. Further information about most academic matters can be found in the Undergraduate Bulletin, the Undergraduate Class Schedule, and the Faculty-Employee Handbook.

Accessibility

Stony Brook University is committed to ensuring a supportive, inclusive, and equitable learning environment for all members of our community, which includes upholding the principles of [Title II of the Americans with Disabilities Act \(ADA\)](#). As a student in this course, it is important to recognize your role in ensuring that all classmates, including those who use assistive technologies, can fully engage with and comprehend the course content. Therefore, any digital materials you create and share, such as assignments, presentations, or shared documents, must be designed to be digitally accessible using the most up to date version of the [WCAG 2.1 Level AA guidelines](#). Accessible practices include, but are not limited to, providing alternative text for images, using clear heading structures, and ensuring captions for any video or audio you incorporate. Guidance and assistance in making your digital content accessible can be found on the [Accessibility Resources for Students](#) page. For additional support, please visit [Deque University](#).

Course Materials and Copyright Statement

Course material accessed from Brightspace, Zoom, Echo 360, VoiceThread, etc. is for the exclusive use of students who are currently enrolled in the course. Content from these systems cannot be reused or distributed without written permission of the instructor and/or the copyright holder. Duplication of materials protected by copyright, without permission of the copyright holder is a violation of the Federal copyright law, as well as a violation of Stony Brook's Academic Integrity.

*Research Project Presentations will take place during the usual class time (starting from 11:00 am) as indicated. To do:

- (1) Form freely teams of ~4 members and email me your name list 1 week before Presentation Day. Those who are not part of a team by the due date will be assigned randomly into teams.
- (2) Find a peer-reviewed, published research paper that somehow relates to the class material.
- (3) Prepare a max. 10 minutes-long slide show (e.g. max. ~7 PowerPoint slides) presentation addressing: The Background, the Question, the Method, the Answer, how does it relate to the Course (i.e., which lecture(s)).
- (4) Make sure that your presentation is understandable to the whole class, e.g., students with different scientific backgrounds.
- (5) Every team must send me their final presentation slides (PPT and/or PDF format) 2 days before the event, no later than 11:59 pm.
- (6) At 11:00 am on Presentation Day: Be ready to present as a team and answer questions by others.