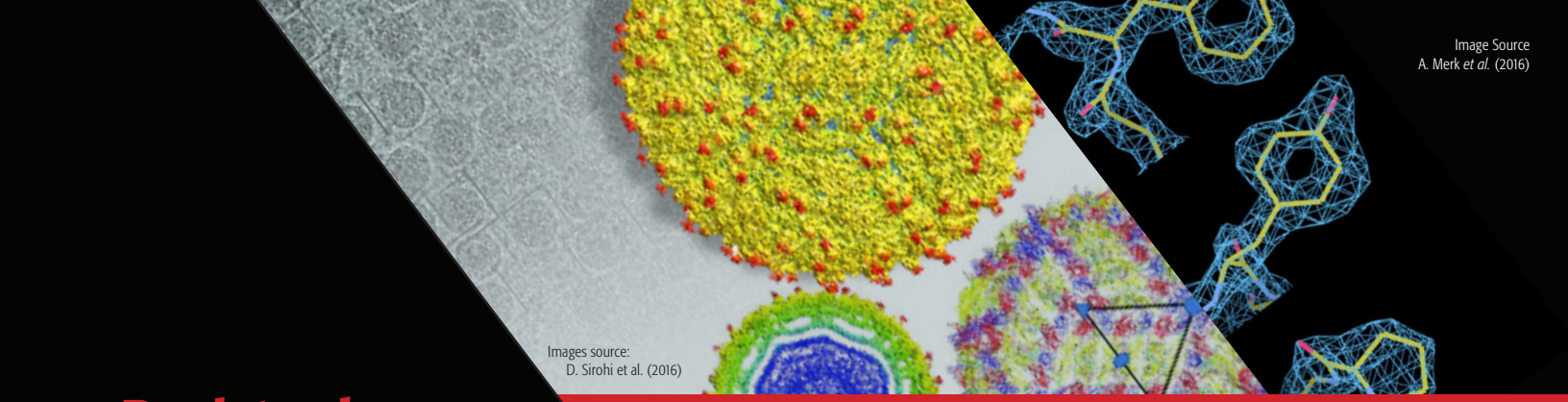

Image Source
A. Merk *et al.* (2016)

Images source:
D. Sirohi et al. (2016)

Register by JANUARY 29th!

NEW COURSE: 16:682:532:01 11:115:485:01 STRUCTURAL BIOPHYSICS

SPRING, 2025

Institute for Quantitative Biomedicine & Department of Biochemistry and Microbiology, Rutgers University

Registration:

Space is limited to 15 graduate and undergraduate students. Register by January 29th at 5:00 pm at:
sims.rutgers.edu/csp/

Course Instructors:

Prof. Arek Kulczyk and Invited Lecturers
kulczyk-lab.cryoemcorp.com

Questions:

arek.kulczyk@rutgers.com

Time & Venue:

Thursdays, 12:10-3:10 PM

IQB, Room 206, Bush Campus

IQB RUTGERS

Institute for Quantitiatve Biomedicine
Rutgers Busch Campus • 174 Frelinghuysen Road
Piscataway, NJ 08854

GPS Address for Parking
Lot A, B, or C; 679 Hoes Lane West, Piscataway, NJ

Advanced Methods for 3-D Structure Determination of Biomolecules

Agenda:

- We will discuss physical basis of cryo-EM, NMR and X-ray crystallography. Special emphasis will be put on cryo-EM.
- Other emerging methods including: SAXS, CLEM, cryo-ET and FIB –SEM will also be introduced.
- Except of learning theory, students will have the opportunity to determine a high-resolution cryo-EM structure using a high-performance computing Linux cluster.
- Students will visit state-of the-art cryo-EM and NMR facilities.

Skills & learning objectives:

- Understand the theory and practice of modern methods for 3-D structure determination of biomolecules.
- Calculate a high-resolution cryo-EM structure using high-performance computing.
- Deliver a scientific presentation in front of the class.

Grading Policy:

- 30% - the midterm exam covering theory
- 30% - the ability to calculate a cryo-EM structure
- 30% - student presentation
- 10% - participation in lectures and practicals

Structural Biophysics:
Advanced Methods for 3-D Structure Determination of Biomolecules

Offered: Spring Semester

Credits: 3

Enrollment: 15 students

Classroom: Institute for Quantitative Biomedicine, Room 120, 174 Frelinghuysen Road, Piscataway, NJ 08854

Prerequisites: Biochemistry

Course Coordinator: Arek Kulczyk

E-mail: arek.kulczyk@rutgers.edu

Office: Institute for Quantitative Biomedicine, Room 208H

Course Description: This course surveys advanced techniques for determining the three-dimensional structures of biomolecules. Topics include: (i) The physical principles underlying cryo-electron microscopy (cryo-EM), nuclear magnetic resonance (NMR), and X-ray crystallography, with special emphasis on cryo-EM. (ii) Emerging methods such as small-angle X-ray scattering (SAXS), femtosecond X-ray scattering (FXS), neutron diffraction, correlative light and electron microscopy (CLEM), cryo-electron tomography (cryo-ET), and focused ion beam–scanning electron microscopy (FIB–SEM). (iii) Comparative advantages and limitations of each technique. (iv)Case studies of biomolecular complexes whose 3D structures have been determined using these methods. In addition to learning theoretical foundations, students will visit state-of-the-art cryo-EM and NMR facilities and gain hands-on experience determining a high-resolution cryo-EM structure using a high-performance Linux computing cluster.

Instructors: Arek Kulczyk & Invited speakers

Textbook and Readings: There will be no specific textbook for the course. Students will be provided with handouts or referred to resources available online or through Rutgers Libraries.

Course URL: Course materials will be posted on Canvas.

Course-specific Learning Goals: Upon completion of this course, students will be able to: (i) Understand the theory and practice of modern methods for 3-D structure determination of biomolecules. (ii) Calculate a high-resolution cryo-EM structure

using high-performance computing. (iii) Deliver a scientific presentation in front of the class.

Exams, Assignments, and Grading Policy: The exam covering a theoretical part of the course will count for 30% of the grade. The ability to calculate a cryo-EM structure will count for 30% of the grade. The student presentation will count for 30% of the grade. Class participation will also be taken into account (10%) , particularly during the structure calculation sessions and student presentations. There will be no final exam.

Draft Schedule

Week	Class	Topic	Reading
1	1	Introduction: building blocks of proteins and nucleic acids. Overview of methods for structure determination of biomolecules	Handout
2	2	Basic concepts in EM: electron waves, field emission guns, lenses, energy filters and direct detectors	Handout Online resources: http://cryo-em-course.caltech.edu/videos
	3	Fourier transforms, Contrast Transfer Function (CTF), phase and amplitude contrast, defocus	Handout Online resources: http://cryo-em-course.caltech.edu/videos
3	4	Sample preparation and workflow in cryo-EM	Handout Online resources: http://cryo-em-course.caltech.edu/videos
	5	EM data collection, image processing and structure calculations	Handout Online resources: http://cryo-em-course.caltech.edu/videos
4	6	Algorithms for cryo-EM structure calculation	Handout
	7	Tour of the cryo-EM and NMR facilities in the IQB	
5	8	Correlative Light and Electron Microscopy (CLEM), cryo-Electron Tomography (cryo-ET) and Focus Ion Beam Scanning Electron Microscopy (FIB-SEM)	Handout Online resources: http://cryo-em-course.caltech.edu/videos
	9	Basic Concepts in NMR: energy levels, the vector model, chemical shifts, spin-spin coupling, chemical exchange, spin relaxation.	Handout Online resources: http://www-keeler.ch.cam.ac.uk/lectures/ "Nuclear Magnetic Resonance" by P.J. Hore, Oxford University Press
6	10	Multidimensional NMR	Handout

	11	Force fields and algorithms for NMR structure determination	Handout
7	12	Basic concepts in X-ray crystallography: crystal growth, X-ray generators and synchrotrons, Bragg's law, diffraction	Handout
	13	Phasing methods and structure determination in X-ray crystallography	Handout
8	14	X-ray crystallography- Protein Data Bank - Guest Lecturer	Handout
	15	Emerging technologies: Neutron diffraction, Small Angle X-ray Scattering (SAXS) and Fluctuation X-ray Scattering (FXS)	Handout
9	16	Scientific storytelling and preparing a scientific presentation – Guest Lecturer	Handout
	17	Exam	
10	18	Cryo-EM structure calculation: importing movies, motion and CTF corrections	Handout
	19	Cryo-EM structure calculation: particle picking, extraction, screening and 2-D classification	Handout
11	20	Cryo-EM structure calculation: 2-D classification, creating an initial model	Handout
	21	Cryo-EM structure calculation: 3-D classification	Handout
12	22	Cryo-EM structure calculation: 3-D refinements	Handout
	23	Fitting atomic coordinates to cryo-EM map	Handout
13	24	Student presentations and discussion	
	25	Student presentations and discussion	
14	26	Student presentations and discussion	
	27	Student presentations and discussion	
15	28	Final wrap-up and farewells	

Assessment Plan

i) Understand the theory and practice of modern methods for 3-D structure determination of biomolecules.

Assessment: the exam including multiple-choice and essay questions.

(ii) Calculate a high-resolution cryo-EM structure using high-performance computing.

Assessment: we will provide computational resources and clearly define goals that will have to be achieved by students at the end of each session concerned with calculations of a cryo-EM structure. We will compare students' results with previously calculated benchmarks. For example, at the beginning of class #21, students will have to be able to demonstrate a set of 3-D structures calculated using

a script: relion 3-D classification.

(iii) Deliver a scientific presentation in front of the class.

Assessment: students will receive instruction during Class #16 on how to prepare an effective PowerPoint presentation and how to critically analyze and evaluate a primary research article. After this session, students may select a paper of their choice for presentation. Each student must consult with me and submit a PDF of their chosen article by Class #20 for approval. Presentations will take place during Classes #24–28 and must be delivered in PowerPoint format. Each presentation will be evaluated based on the following criteria: (a) Comprehension: did the student demonstrate a clear and concise understanding of the subject matter during both the presentation and Q&A session? (b) Spoken Communication Skills: did the student use correct terminology, speak clearly, stay on topic, and transition smoothly between slides? Was the presentation engaging and well-organized? (c) Written Communication Skills: was the text on the slides clear and accurate? Were visuals (e.g., images, figures) appropriately sized and labeled? Did the slide content reflect literacy in the chosen subject area?