Chemistry 430: Simulation in Chemistry & Biochemistry Spring 2018

Class Meetings: Monday and Wednesday, Lecture, 11:00am-Noon, 201 Lab Science
Friday, Laboratory Sessions, 11:00am-2:00pm, 457 Louderman

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Web Site: http://dasher.wustl.edu/chem430/

Objectives: Chemistry 430 explores a wide range of computational applications in molecular modeling, biochemistry and biophysics, including *ab initio* quantum mechanics, semi-empirical MO theory, molecular mechanics, molecular dynamics simulation, coarse-grained models, electrostatic methods and biomolecular structure prediction. A major component of the course are weekly laboratory sessions using major software programs in the field, including VMD, Avogadro, Spartan, Q-Chem, Psi4, Gaussian, VMD, Tinker, FFE, APBS, AutoDock, SDA7 and others. Many of the lab exercises target proteins, nucleic acids and other biological structures. Students have the option to complete a short independent project using tools from the course.

Books: The book that most closely follows the course outline is Molecular Modeling by Andrew Leach. While not required, Leach is a well-written, useful introduction. Other useful books are listed below, and readings from these will be provided.

General Molecular Modeling:

Molecular Modeling – Principles and Applications, 2nd Ed., Andrew Leach, 2001
Molecular Modeling and Simulation, 2nd Ed., Tamar Schlick, 2010
Introduction to Computational Chemistry, 3rd Ed., Frank Jensen, 2017
Essentials of Computational Chemistry, 2nd Ed., Christopher Cramer, 2004
Computational Chemistry, 2nd Ed., Errol Lewers, 2010
The Theory of Intermolecular Forces, 2nd Ed., Anthony Stone, 2013

Algorithms & Theory for Quantum Chemistry:

Modern Quantum Chemistry, Attila Szabo & Neil Ostland, 1982 (reprinted by Dover)
Quantum Chemistry, 3rd Ed., John Lowe and Kirk Petersen, 2006
Frontier Orbitals – A Practical Manual, Nguyen Trong Anh, 2007
Molecular Orbitals & Organic Chemical Reactions, Ian Fleming, 2010

Simulation & Biochemical Applications:

Computer Simulation of Liquids, 2nd Ed., M. P. Allen & D. J. Tildesley, 2017
Understanding Molecular Simulation, 2nd Ed., Daan Frenkel & Berend Smit, 2002
Computational Biochemistry & Biophysics, Becker, *et al*., 2001
A Guide to Biomolecular Simulations, Becker & Karplus, 2006

Other Info: Chemistry 430 is targeted at advanced undergraduates, but is also suitable for graduate students wanting to learn modern computational and modeling approaches to chemical, biochemical and biophysical problems. A course in physical chemistry is recommended as background, but not required. Basic familiarity with computers (text editing, writing small scripts or programs) is useful, but not required.

Module 1:	**Molecular Mechanics & Simulation Techniques**
Jan 17	Overview of Molecular Modeling
Jan 19	Lab 1: Unix Tutorial: Using Chimera, VMD, FFE & Spartan
Jan 22	Introduction to Molecular Mechanics I
Jan 24	Introduction to Molecular Mechanics II
Jan 26	Lab 2: Conformational Analysis of Alanine Dipeptide
Jan 29	Potential Energy Surfaces & Optimization Methods
Jan 31	Basics of Molecular Dynamics Simulation I
Feb 2	Lab 3: Liquid Properties *via* Molecular Dynamics Simulation
Feb 5	Basics of Molecular Dynamics Simulation II
Feb 7	Using Molecular Dynamics to Compute Properties
Feb 9	Lab 4: Global Optimization of Lennard-Jonesium & PolyAlanine
Feb 12	Introduction to Monte Carlo Methods I
Feb 14	Introduction to Monte Carlo Methods II
Feb 16	Lab 5: Relative Hydration Free Energy of Monovalent Ions
Feb 19	Methods for Free Energy Calculations
Feb 21	Proteins: Amino Acids & Secondary Structure
Feb 23	Lab 6: Normal Modes & Vibrational Spectra of Water, Benzene & Phenol
Feb 26	Proteins: Tertiary Structure, Motifs & Fold Classes
Feb 28	Proteins: Mechanism of Protein Folding
Mar 2	Lab 7: APBS Poisson-Boltzmann Calculations on Lysozyme
Mar 5	Electrostatics & Solvation in Biomolecular Systems I
Mar 7	Electrostatics & Solvation in Biomolecular Systems II
Mar 9	Lab 8: Folding Simulation of the TrpCage Miniprotein, Part I
Module 2:	***ab Initio* & Semi-Empirical Quantum Mechanics**
Mar 19	Basics of *ab Initio* Molecular Orbital Theory I
Mar 21	Basics of *ab Initio* Molecular Orbital Theory II
Mar 23	Lab 8: Folding Simulation of the TrpCage Miniprotein, Part II
Mar 26	Methods for Treating Electron Correlation
Mar 28	Semi-Empirical Molecular Orbital Methods
Mar 30	Lab 9: Computing the Rotational Barrier in Hydrazine
Apr 2	Density Functional Theory (DFT)
Apr 4	Quantum Mechanics/Molecular Mechanics (QM/MM)
Apr 6	Lab 10: Frontier Orbital Analysis of Regioselectivity

Module 3:	**Electrostatics, Coarse Graining & Biomolecular Structure Prediction**
Apr 9	Protein Structure Prediction, Engineering & Design
Apr 11	Small Molecule & Protein Docking I
Apr 13	Lab 11: Docking Indinavir to HIV Protease Using Autodock
Apr 16	Small Molecule & Protein Docking II
Apr 18	Computing Binding Rate Constants *via* Brownian Dynamics
Apr 20	Lab 12: Diffusional Association of the Barnase-Barstar Complex
Apr 23	Coarse Grained Molecular Modeling
Apr 25	Machine Learning in Computational Chemistry
Apr 27	Lab 13: Independent Project *or* Finish Previous Labs
May 9	**Lab Reports & Take-Home Final Examination Due**