BIOL 7110 / BIOL 4105 / CHEM 4804 / CHEM 8901
Spring, 2011

Course Syllabus

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Office hours: Monday 4–5, or by appointment

Course objectives:

- Give students practical experience in building and evaluating molecular models
- Give students a thorough understanding of the basic principles behind molecular mechanics force fields and algorithms
- Give students practical experience in molecular graphics, energy minimization and molecular dynamics
- Deepen students' understanding of principles of macromolecular structure and dynamics, and of macromolecular structure – function relationships

The course consists of lectures, laboratory exercises, discussion sections, and written examinations. The last part may include a term project and/or papers from the literature. Students registered for graduate credit will do a few more assignments than those registered for undergraduate credit.

Texts:

There is no required text. You may find one or more of the following to be helpful:

Molecular Modelling for Begineers (Also available for the kindle)
Alan Hinchcliffe (John Wiley, 2003)

An introductory text, covering both molecular mechanical models and quantum mechanics models, with an excellent appendix covering basic math. *Recommended*.

Molecular Modelling: Principles and Applications, Second Edition
Andrew R. Leach (Prentice–Hall, 2001)

Leach's book emphasizes the thermodynamic and statistical mechanical basis of simulations and covers both molecular mechanical methods and quantum mechanical methods. *Recommended for those with advanced backgrounds in physical chemistry and statistical mechanics*.

Molecular Modeling and Simulation: An Interdisciplinary Guide, Second Edition
Tamar Schlick (Springer, 2010)

A large part of Schlick's book is devoted to molecular structure, and to the motivations for modeling studies. It has an excellent coverage of molecular mechanics methods, with emphasis on algorithms. *Recommended for mathematicians and computer scientists*.

Class	Date	Sections & Topics	Assignment (due next class)
1	Jan 11	NO CLASS	
2	Jan13	Course introduction and overview; units	
3	Jan 18	Macromolecular structure Thermodynamics I: The first law; thermochemistry	HW 1: Units; Macromolecular structure; Thermo 1
4	Jan 20	Classical electrostatics (Roger Wartell)	
5	Jan 25	Thermodynamics II: The second law; entropy	HW 2: Thermo 2
6	Jan 27	Thermodynamics III: Free energy; equilibrium; ΔG in nonequilibrium conditions; the Boltzmann relationship	HW 3: Thermo 3
7	Feb 1	Thermodynamics IV: Ensembles; thermodynamics and life; thermo and molecular modeling	HW 4: Thermo 4; VMD Installation (due Feb 8)
8	Feb 3	**Exam I**	
9	Feb 8	Coordinate systems; conformational space; degrees of freedom; introduction to VMD	HW 5: Conversion between coordinate systems VMD tutorial
10	Feb 10	Introduction to molecular mechanics; historical perspective; crystallography, NMR, cryo-EM, and modeling	Install Oscar
11	Feb 15	MD I: Newton's equations; harmonic oscillator; leapfrog; equipartition; Energy functions I: Lennard-Jones potential	Oscar 1: Two atoms of Lennard-Jonesium: LJ2 (worked in class)
12	Feb 17	Energy functions II: Semi-harmonic restraint Optimization I: Grid search; steepest descent	Oscar 2: The ideal gas in a box: LJ10

13	Feb 22	Optimization I: SD & CG on LJ10; the multiple minimum problem; conformational searches; simulated annealing; Monte Carlo	Oscar 3: Minimization of LJ10
14	Feb 24	Optimization II: Simulated annealing of LJ10 with MD & MC; Energy functions III: Bonds; angles; torsions; improper torsions; van der Waals; electrostatics	Oscar 4: Optimization of LJ10
15	Mar 1	NO CLASS	
16	Mar 3	Energy functions IV: Goals, limits & compromises; Oscar structure file; Parameterization	Oscar 5: Ethane bonds, angles and torsions Oscar 6: Potentials of mean force
17	Mar 8	Energy functions V: Impropers; parameter, topology and PSF files; partial charges; water models	(finish Oscar 5 & Oscar 6)
18	Mar 10	Simulations I: Nonbonded cutoffs; pair list; RMSD; potentials of mean force (from Oscar tutorial 6); Discussion of NAMD	NAMD tutorial 1 (Introduction to NAMD)
19	Mar 15	Analysis I: Comparison and evaluation of models; SASA; solvation free energy; contact maps Simulations II: Heating, equilibration & production	NAMD tutorial 2 (Steered MD)
20	Mar 17	Energy functions VI: scaled 1-4 interactions; Simulations III: Rigid bonds; restart files; spherical boundary conditions; repeating boundary conditions; NAMD: Practical considerations	
Mar 21-25		***Spring Break*** ***NAMD Workshop at Georgia Tech***	
21	Mar 29	Review of NAMD workshop; review for exam Discussion of possible projects	
22	Mar 31	**Exam II**	
23	Apr 5	Go over exam; selection and discussion of projects	
24	Apr 7	Projects: progress reports & discussion Coarse grain models I: Principles	

25	Apr 12	Projects: progress reports & discussion Coarse grain models II: Application to viral packaging	
26	Apr 14	Conformational transitions; biasing; free energy methods	
27	Apr 19	*Race for the Double Helix*	
28	Apr 21	Adaptive steered MD (Guest lecturer: Gungor Ozer)	
29	Apr 26	NO CLASS: Work on projects	
30	Apr 28	Project presentations	