Bioinformatics Curriculum Guidelines: Toward a Definition of Core Competencies

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Curriculum Task Force
Education Committee
International Society for Computational Biology

“If I were a senior or first-year graduate student interested in biology, I would migrate as fast as I could into the field of computational biology…

… There are vast quantities of high-quality data accessible to anybody who has the skills to find the nuggets of truth that are hiding in that information.”

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Francis Collins, Director
National Inst. of Health
(March 2012)

“Generating the data is not the bottleneck…
…The bottleneck is analyzing the data.”

Eric Green,
Director, Natl Human Genome Research Inst
(June 2013)

INTERNATIONAL SOCIETY FOR COMPUTATIONAL BIOLOGY

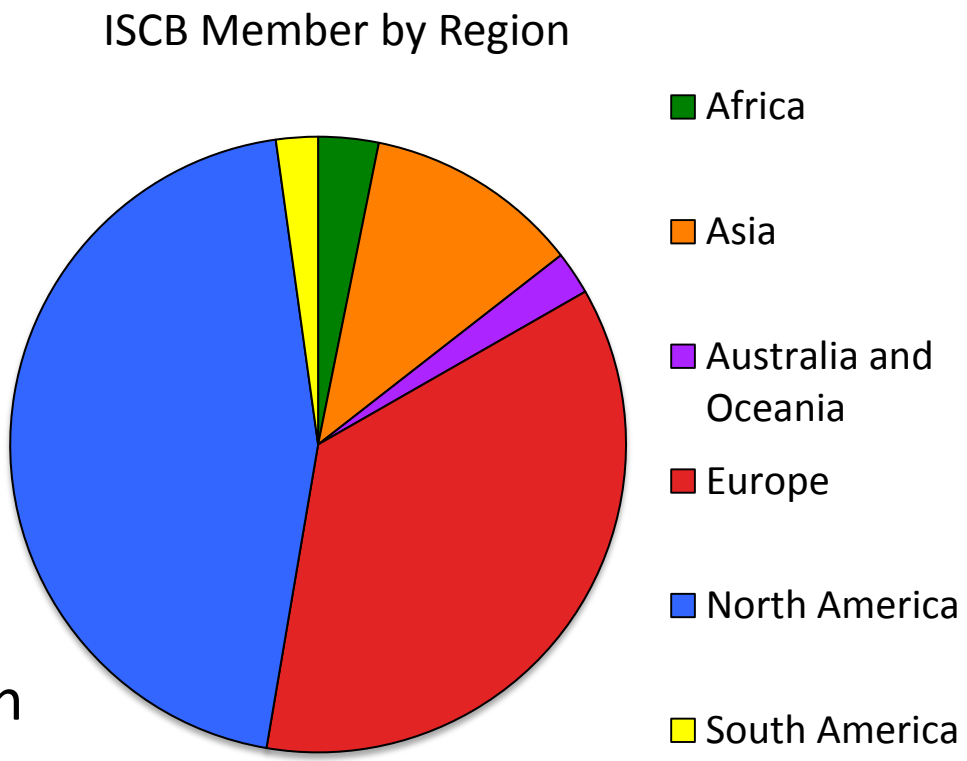
Bioinformatics & Computational Biology

Advancing the understanding of living systems…

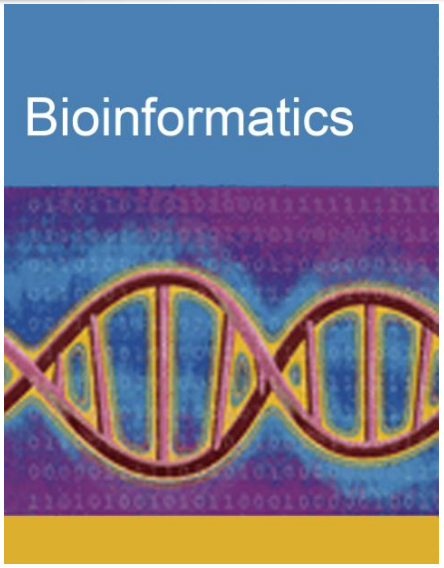
…through computation

Computational Biology Spanning the Globe

- Over 3,000 Members
- Scientific Leaders and Research Professionals, Postdoctoral Fellows, and Students
- Nurtures communities that consider important topics in computational biology



Highest Quality Scientific Publications – Official Journals



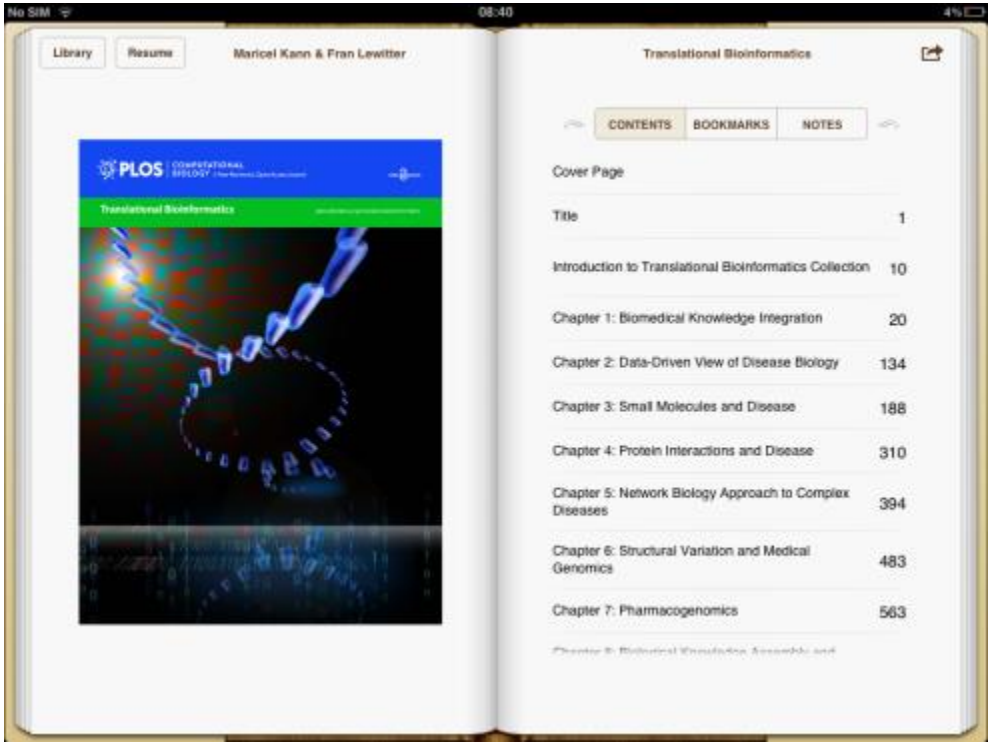
Bioinformatics

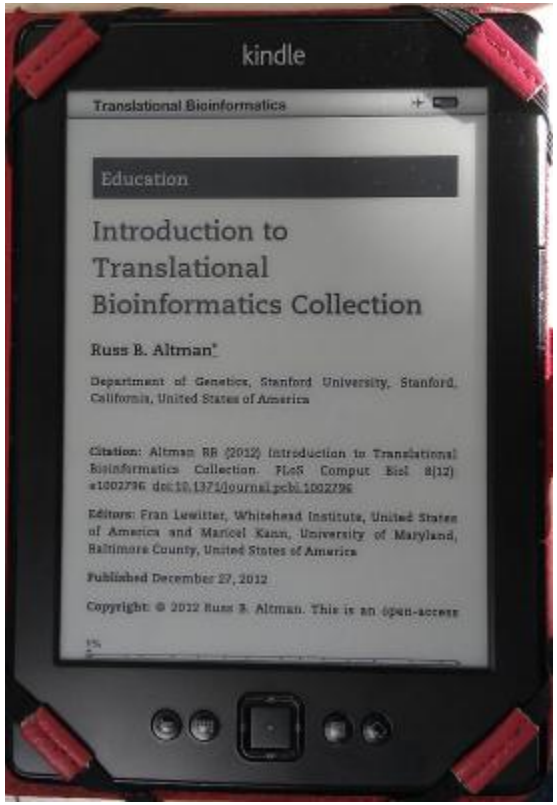
PLOS COMPUTATIONAL BIOLOGY

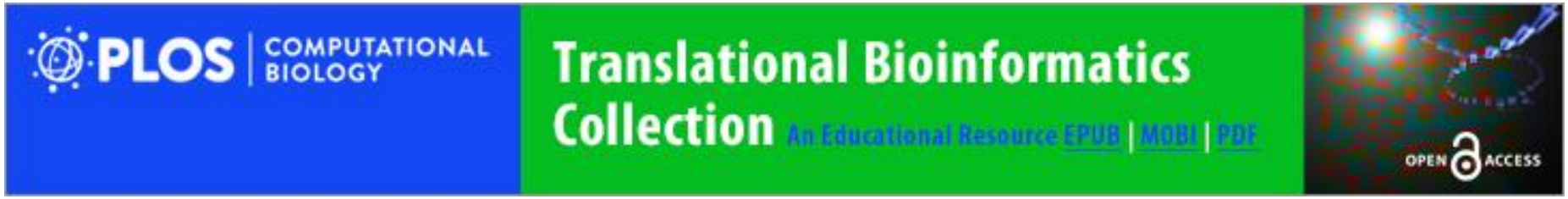
PLOS Computational Biology

ISCB INTERNATIONAL SOCIETY FOR COMPUTATIONAL BIOLOGY

Download the full Translational Bioinformatics collection here: PDF | EPUB | MOBI







ISCB Education Committee

Promotes worldwide education and training in computational biology. Serves as a resource and advisor to institutions and industry interested in developing educational programs.

* Annual ISMB Workshop on Education in Bioinformatics
* Develop curricular guidelines for Bioinformatics
* Bioinformatics in secondary schools
* Educating biologists in Bioinformatics
* Wikipedia as training material

GOBLET – Global Organization for Bioinformatics Learning, Education and Training (mygoblet.org)

Workshop on Bioinformatics Education 2013

- **Biomedical informatics training in the era of translational medicine**
  Russ Altman, Stanford University

- **Bioinformatics for the Clinical Audience**
  Donna Slonim, Tufts University

- **What should everyone know about bioinformatics?**
  Hienke Sminia, Netherlands Bioinformatics Centre

- **Bioinformatics for the Public Eye**
  Winston Hide, Harvard School of Public Health

ISCB INTERNATIONAL SOCIETY FOR COMPUTATIONAL BIOLOGY

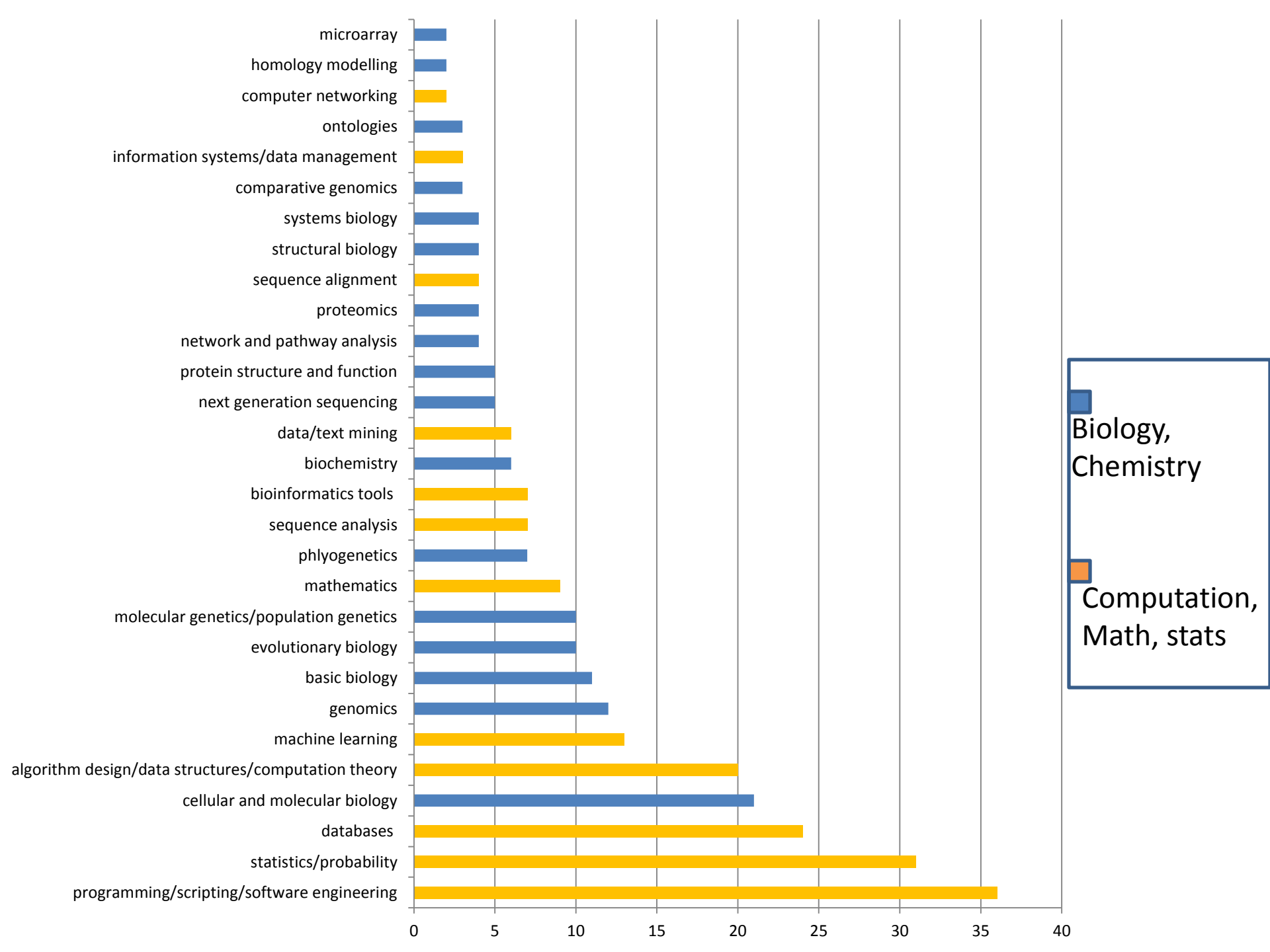
The ISCB Education Committee
Task Force on Bioinformatics Curriculum

Welch LR, Schwartz R, Lewitter F.

"A Report of the Curriculum Task Force of the ISCB Education Committee."

PLoS Comput Biol. 2012 Jun;**8(6)**:e1002570.

INTERNATIONAL SOCIETY FOR COMPUTATIONAL BIOLOGY


microarray
homology modelling
computer networking
ontologies
information systems/data management
comparative genomics
systems biology
structural biology
sequence alignment
proteomics
network and pathway analysis
protein structure and function
next generation sequencing
data/text mining
biochemistry
bioinformatics tools
sequence analysis
phlyogenetics
mathematics
molecular genetics/population genetics
evolutionary biology
basic biology
genomics
machine learning
algorithm design/data structures/computation theory
cellular and molecular biology
databases
statistics/probability
programming/scripting/software engineering
0
5
10
15
20
25
30
35
40
Biology, Chemistry
Computation, Math, stats

Survey of Core Facility Directors

- 29 core facility directors responded
- core facility directors were asked
  - what skills are needed for success in the field of bioinformatics
  - what skills are lacking in recently hired bioinformaticians
- In general, these lists were very similar (i.e. skills needed are often lacking)

Career Opportunities

- Computational Biologist (GlaxoSmithKline R&D Ltd, Computational Biology, UK)
- Programmer for the Center for Computational Genetics and Genomics (Temple University, Center for Computational Genetics and Genomics, USA-PA)
- Bioinformatics Data Analyst (Vanderbilt University School of Medicine Biomedical Informatics United States-Tennessee-Nashville)

Survey of Career Opportunities

- Listings from the *ISCB Members Job Board* (http://www.iscb.org/iscb-careers)
- Sampled 75 of 130 job listings
- Items collected:
  - Geographic location (5 continents, 17 countries)
  - Job title
  - Duties
  - Skills

Types of Bioinformatics Training

Bioinformatics users

- access bioinformatics resources to perform job duties in specific application domains
- For example, medical professionals

Types of Bioinformatics Training

Bioinformatics scientists

- use computational methods to advance the scientific understanding of living systems

Types of Bioinformatics Training

Bioinformatics engineers

- create novel computational methods needed for scientific discovery

Toward a Definition of Core Competencies

- proficiencies for each type of bioinformatics training
- guidance for bioinformatics educational programs
- synthesize the results of our surveys
- modeled after the ABET criteria for CS programs
- terminology and concepts of Bloom's Taxonomy

	Bioinformatics User	Bioinformatics Scientist	Bioinformatics Engineer
An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution.		X	X
An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs in scientific environments.			X

	Bioinformatics User	Bioinformatics Scientist	Bioinformatics Engineer
An ability to use current techniques, skills, and tools necessary for computational biology practice.	X	X	X
An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices.			X

	Bioinformatics User	Bioinformatics Scientist	Bioinformatics Engineer
An ability to apply design and development principles in the construction of software systems of varying complexity.			X
Have a detailed understanding of the scientific discovery process, and of the role of bioinformatics in the scientific discovery process.	X	X	X

Welch L, Lewitter F, Schwartz R, Brooksbank C, Radivojac P, et al. (2014) Bioinformatics Curriculum Guidelines: Toward a Definition of Core Competencies. *PLoS Comput Biol* **10(3)**: e1003496. doi:10.1371/journal.pcbi.1003496

WE INVITE YOUR PARTICIPATION

The ISCB Education Committee
Task Force on Bioinformatics Curriculum

Fran Lewitter - *lewitter@wi.mit.edu*
Russell Schwartz - *russells@andrew.cmu.edu*
Lonnie Welch - *welch@ohio.edu*

OHIO Bioinformatics Journal Club

Tuesdays, 4:35pm, ARC 321, fall 2013

Bioinformatics at Ohio University

http://www.ohio.edu/bioinformatics/

- Bioinformatics Certificates
  - Undergraduate
  - Graduate
- Bioinformatics Tracks
  - BS, Computer Science
  - MS, Computer Science
  - PhD, EECS

Bioinformatics Certificate (UG)

http://www.ohio.edu/bioinformatics/

I. Core Biology
- Genetics
- Cell Biology
- Laboratory practicum

II. Mathematics/statistics

III. Core Computer Science
- Introduction to Discrete Structures (CS 300)
- Data Structures (CS 361) or Quantitative Fndtns of Bioinformatics (MATH 387)

IV. Bioinformatics Courses
- Problem Solving using Bioinformatics Tools (CS 4160/BME 5160)
- BME 5170: Data Mining, with Applications in the Life Sciences (Programming for Bioinformatics)

Bioinformatics Certificate (G)

http://www.ohio.edu/bioinformatics/

I. Core Biology

-Biochemistry

-Additional Biology Class

II. Core Computer Science

- BME 5170: Data Mining, with Applications in the Life Sciences (Programming for Bioinformatics)

- CS 5180: Statistical Foundations of Bioinformatics

III. Bioinformatics Specialty Courses

- CS 5160: Problem Solving with Bioinformatics Tools

- CS 6150: Computational Genomics

IV. Genetics/Molecular Biology

V. Laboratory Practicum

Learning Outcome

An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution.

- Formulate scientific questions
- Determine computing requirements needed to answer the questions via data analysis

Learning Outcome

An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs.

- Map computing requirements to software designs
- Select appropriate programming languages and tools to realize designs
- Transform designs into software implementations
- Design and execute software test plans

Problem Solving using Bioinformatics Tools
CS 4160/5160

Teach students how to advance the scientific understanding of living systems through the use of computational tools.

Students will

- understand popular bioinformatics software tools and the kinds of problems for which they are used
- be able to pose and answer research questions about proteins, genes and genomes
- be able to use important computer databases, tools, websites, and algorithms
- be able to perform detailed bioinformatics analyses of a variety of scientific data sets

Data Mining: with life science applications (CS 4170/ BME 5170)

Prepare students to mine large data sets by constructing software using

- the Perl programming language
- MySQL database management system
- R package
- Unix environment

These skills are applied to gain new scientific knowledge by

- developing bioinformatics software
- analyzing biological and medical data sets

"Tomorrow's bioeconomy relies on the expansion of emerging technologies such as synthetic biology, proteomics, and bioinformatics (computational tools for expanding the use of biological and related data), as well as new technologies as yet unimagined."

-National Bioeconomy Blueprint

(White House Report, April 2012)