Bioinformatics for Immunologists

Ferhat Ay, PhD
Institute Leadership Assistant Professor of Computational Biology
La Jolla Institute for Immunology

Assistant Adjunct Professor
Department of Pediatrics, UCSD

Latest schedule as of Jan 2023

- Week 1: Barry Grant - intro
- Week 2: Ferhat - gene expression analysis
- Week 3: Tiffany Amariuta - advanced topics in human genetics
- Week 4: Bjoern Peters - epitopes
- Week 5: Hannah Carter - neoantigens
- Week 6: Sam Myers - Proteomics
- Week 7: Pieter Dorrestein – Metabolomics
- Week 8: Graham McVicker - human genetics
- Week 9: Zbigniew and Sara from LJI - imaging analysis
- Week 10: Ferhat - epigenomics in immune cells

Dr. Barry J. Grant, Lecturer, Molecular Biology

Teaching

- BGGN-213: Foundations of Bioinformatics
- BIMM-143: Introduction to Bioinformatics
- BIMM-194: Genomics, Big Data and Human Health
- BIMM-173: Clinical Applications of Genomic Technologies

Recap of Foundations of Bioinformatics (Week 1)

- Working with UNIX
- Sequence alignment
- Key online resources
- Data analysis and visualization with R and Bioconductor
- Annotation of gene lists (GO term and pathway enrichment)
- Biomolecular sequence-structure-function relationships

Dr. Ferhat Ay, LJI, Pediatrics (Adjunct)

Research

- Computational biology
- Epigenetic gene regulation
- 3D chromatin structure
- Cancer, malaria and autoimmune diseases

Analysis of gene expression data in bulk (Week 2)

- RNA-seq concepts and basics
- Processing RNA-seq data
- Differential gene expression and relevant statistics
- Gene co-expression analysis
- Visualization of RNA-seq data

Dr. Ferhat Ay, LJI, Pediatrics (Adjunct)

Research

- Computational biology
- Epigenetic gene regulation
- 3D chromatin structure
- Cancer, malaria and autoimmune diseases

Analysis of epigenomics data from immune cells (Week 10)

- Analysis of ChIP-seq for histone modifications and transcription factor binding
- Analysis of chromatin accessibility using ATAC-seq data
- Analysis of 3D genome architecture and enhancer-promoter interactions using Hi-C and HiChIP/PLAC-seq data

Dr. Graham McVicker, Salk, CMM (Adjunct)

Research

- Human genetic variation
- Pathogenic variants in immune cells and cancer cells
- Variants that impact regulatory elements
- Profiling enhancers in immune cells

Genetics of immune traits (Week 8)

- Genome-wide association studies with a focus on immune-related diseases
- Identification of expression quantitative trait loci (eQTLs)
- Identification of chromatin/histone quantitative trait loci (hQTLs)
- CRISPR screens for enhancer regions of immune genes

Dr. Tiffany Amariuta, HDSI, UCSD Medicine

Research

- Human genetic variation
- Machine learning methods applied to GWAS data
- eQTL mapping
- TWAS and fine mapping

Genetics of immune traits (Week ?)

- Fine mapping

Dr. Bjoern Peters, LJI, Medicine (Adjunct)

Research

- Computational immunology
- Epitope discovery
- Vaccine design
- Co-investigator of Immune Epitope Database (IEDB)
- Cancer, infectious diseases, autoimmune disorders

Prediction and analysis of epitopes (Week ?)

- Background: antibodies, T cell receptors, MHC molecules, epitopes
- The Immune Epitope Database (IEDB)
- Machine learning approaches for peptide:MHC binding

Dr. Hannah Carter, UCSD Medicine

Research

- Interplay between cancer mutations and immune system
- Identification of cancer genes
- Immunoediting and infiltration in tumors
- Statistical modeling

Analyzing neoantigen presentation versus occurrence in tumors (Week ?)

- Brief review of HLA-antigen binding prediction
- HLA-typing from exome data
- Tumor neoantigens
- Analysis of immunoediting in tumors
- Tumor-immune infiltrates

Dr. Samuel Myers, LJI, UCSD (TBD)

Research

- Mass spectrometry
- Proteomics
- Genomics techniques

Proteomics (Week ?)

- Proteomics

Dr. Pieter Dorrestein, UCSD Skaggs School

Research

- Mass spectrometry for metabolomics
- Metabolic exchange
- Post-translational modifications
- Microbial communities

Metabolomics (Week ?)

- Metabolomics

Drs. Mikulski and McArdle, Imaging Core, LJI

Dr. Zbigniew Mikulski
Director, Microscopy and Histology Core

Dr. Sara McArdle
Microscopy Specialist

"Imaging Scientist" award by CZI

Research

- Imaging of the immune system
- Immunostaining
- RNA imaging
- Machine learning for image processing
- Flow cytometry
- Intravital microscopy

Analysis of imaging data (Week ?)

- Introduction to 2D imaging of 4D objects and QuPath
- Cell classification with random forests
- Pixel classification with artificial neural networks
- Quantification of tumor-immune infiltrates
- Quantification of RNA molecules in cells with RNAscope
- Data export for FlowJo analysis and deep learning

Thank you

Course director and contact information:

Ferhat Ay

Associate Professor of Computational Biology

La Jolla Institute for Immunology

E-mail: ferhatay@lji.org, Office: 858-752-6612

Address: 9420 Athena Circle, La Jolla, CA 92037

Course administrator and contact information:

Donaldo Sosa Garcia

Research Admin Assistant to Dr. Ay

La Jolla Institute for Immunology

E-mail: donaldo@lji.org

Address: 9420 Athena Circle, La Jolla, CA 92037

Similar courses outside UCSD

Bioinformatics Resources for Immunologists

Date: Monday 4 - Friday 8 June 2018

Venue: European Bioinformatics Institute (EMBL-EBI) - Wellcome Genome Campus, Hinxton, Cambridge, CB10 1SD, United Kingdom

Application opens: Monday 04 December 2017

Application deadline: Tuesday 06 March 2018

Participation: Open application with selection

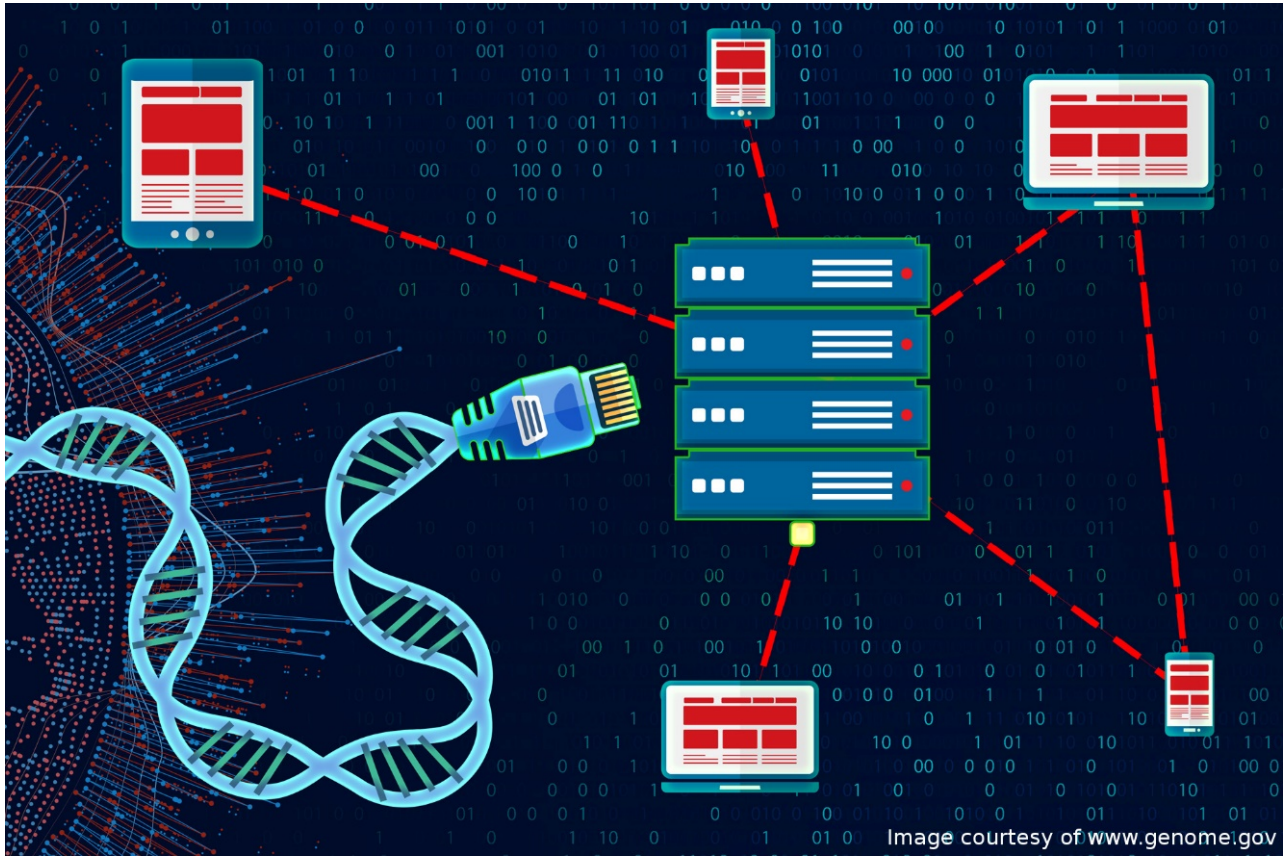
Contact: EMBL-EBI Training Team

Registration fee: £670

https://www.ebi.ac.uk/training/events/2018/bioinformatics-resources-immunologists

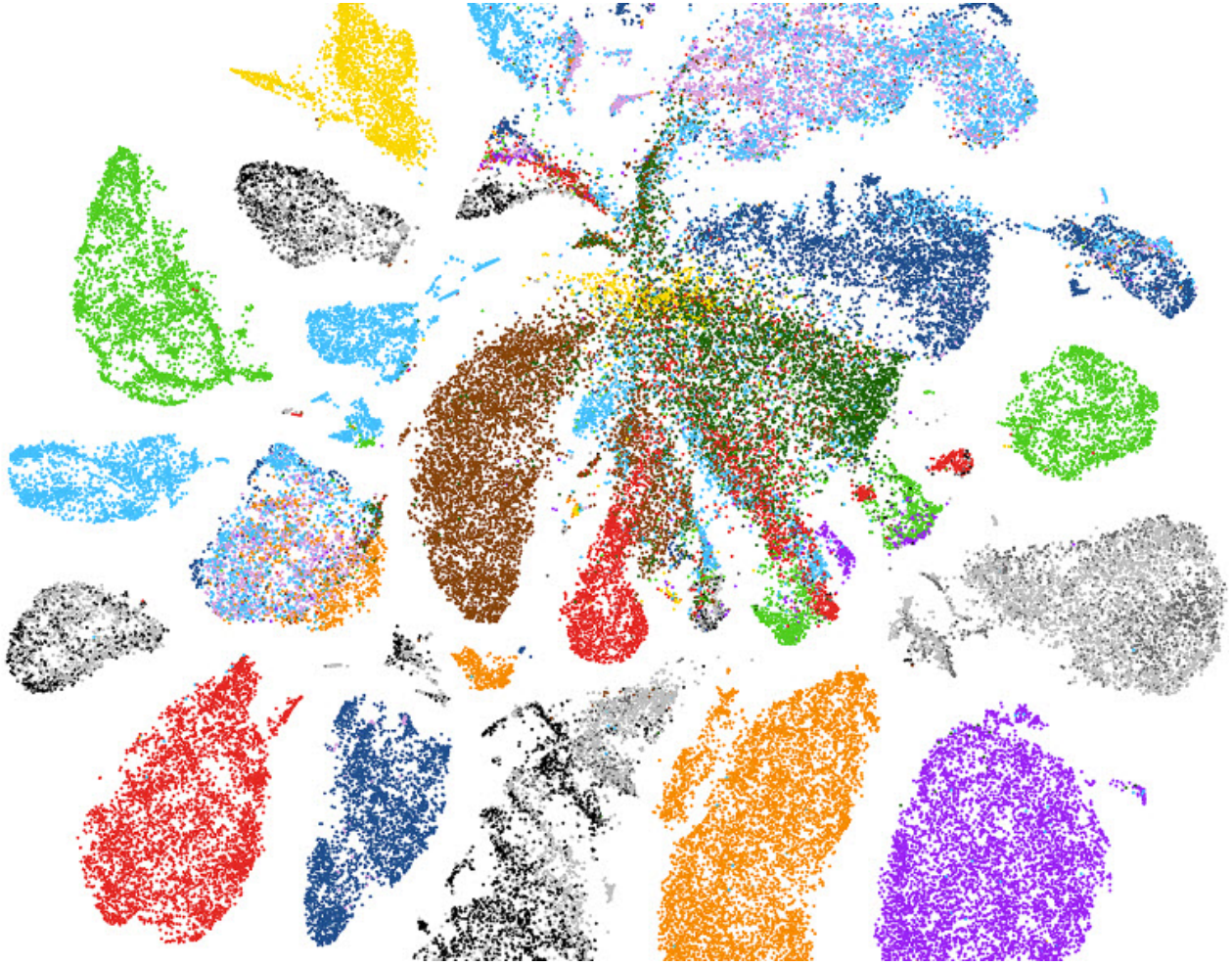
Bioinformatics

- Bioinformatics is conceptualizing biology in terms of macromolecules and then applying "informatics" techniques derived from disciplines such as applied mathematics, computer science, and statistics to understand and organize the information associated with these molecules, on a large-scale.



Bioinformatics in Immunology

- Among many other discoveries, bioinformatics approaches coupled with sequencing of RNA and DNA molecules have enabled the discovery of new immune cell types and previously uncharacterized functions for known immune cells in the context of different diseases.



Immunology at UCSD and LJI

- 70+ faculty members
  - 50+ at UCSD
  - 20+ at LJI

- Program in Immunology

Why “Bioinformatics for Immunologists”?

- A dedicated course to teach bioinformatics with a specific focus on its applications to important problems in immunology
- A strong lineup of faculty and instructors who are **renowned experts** in their respective fields
- Practical and **hands-on training likely to impact students’ overall success** in their research
- Bioinformatics expertise and scientist with cross-disciplinary training is in **high demand in academia and industry**
- Up-to-date information about finding and utilizing the latest tools, sources and databases related to immunology research

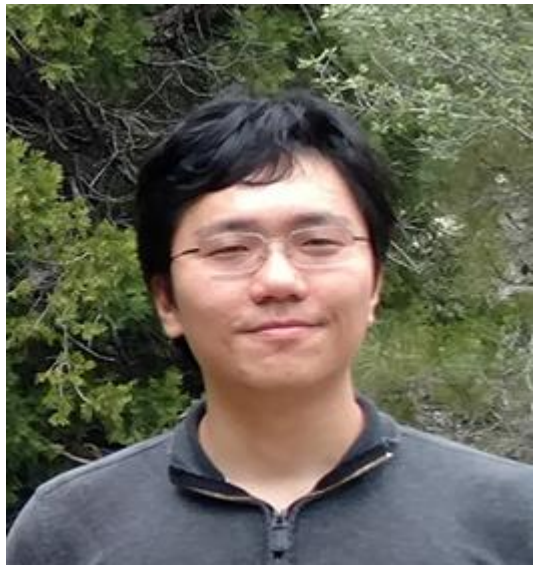
Learning goals

- Understand main computational concepts underlying commonly used bioinformatics tools
- Be familiar with online databases and resources (e.g., GWAS catalog, IEDB, DICE, ImmGen, ENCODE, IHEC) and efficient ways to query them
- Be able to utilize existing tools to perform data analysis for several different sequencing and imaging techniques (RNA-seq, ChIP-seq, ATAC-seq, RNA imaging)
- Learn and actively utilize best practices for reproducible research and collaboration related to bioinformatics (project organization, version control, online lab notebooks)

Envisioned to become a core course for The Program in Immunology

	Fall Quarter	Winter Quarter	Spring Quarter
Year 1	BGGN 299 (4) Rotation (6-8 week) BGGN 200 (2) Grad School Fund BIOM 200A (6) Molecules to Organisms: Concepts	BGGN 299 (4) Rotation BIOM 200B (2) Molecules to Organisms: Concepts BGGN 225A/BIOM 253A (4) – Grad Immunology	BGGN 299 (4) Rotation BGGN 225B/BIOM 253B (4) Graduate Immunology
Year 2	BGGN 213 (4), Foundations of Bioinformatics BIOM 219 (1) Ethics in Scientific Research BGGN 299 - Thesis Research in Biology	Bioinformatics for immunologists *(new)* (4) BGGN 299 Thesis Research in Biology	BGGN 216 (4)– Graduate Biostatistics BGGN 299 (4) Thesis Research in Biology
Year 3	BGGN 299 (12)	BGGN 299 (12)	BGGN 299 (12)
Year 4	BGGN 299 (12)	BGGN 299 (12)	BGGN 299 (12)

Dr. Xiaoyi Cao, Scientist, Zhong Lab, Bioengineering



Research

- Single cell analysis
- Functional genomics
- Epigenomics
- Data visualization and browser design

Analysis of single-cell gene expression data (Week 3)

- Unsupervised clustering by cell or by gene
- Analysis of alternative splicing from single-cell data
- Trajectory inference

Dr. Olivier Harismendy, Moores Cancer Center

Research

- Genetics and epigenetics of cancer
- Cancer mutational profiling
- DNA damage
- Cloud computing for cancer genomics

TCR repertoire assays and analysis (Week 6)

- Technologies for targeted sequencing
- Application of targeted sequencing to analysis of T-cell repertoire
- Computational analysis of deep repertoire sequencing
- The prognostic and predictive value of T-cell diversity in oncology

Dr. Yana Safonova, Scientist, Pevzner Lab, CSE

Research

- Computational immunology, immunoinformatics
- Repertoire sequencing and analysis
- Teaching: CSE 180 (Biology Meets Computing) and CSE 291 (Genomic Data Science)

Applications of immune repertoire analysis to personalized medicine and drug design (Week 7)

- Overview of repertoire sequencing (Rep-Seq) technologies
- Bioinformatics problems related to analysis of Rep-Seq data
- Repertoire construction, reconstruction of clonal lineages, inference of immune genes
- Biomedical applications of Rep-Seq data