Specialized Disciplines
Quantitative Biology
Course Syllabus

Course Faculty

Instructors:	Justin Kinney (lead)
	Alex Dobin
	Peter Koo
	Adam Siepel
	David McCandlish
	Jon Preall
	Hannah Meyer
Course TAs:	Anna Posfai
	Mahdi Kooshkbaghi

Lectures:

- September 8, Wednesday, 2pm-4pm, Kinney
  Statistics I
- September 10, Friday, 2pm-4pm, Kinney
  Statistics II
- September 15, Wednesday, 2pm-4pm, Kinney
  Statistics III
- September 16, Thursday, 2pm-4pm, Kinney
  Statistics IV
- September 22, Wednesday, 2pm-4pm, Kinney
  Statistics V
- September 24, Friday, 2pm-4pm, Kinney
  Statistics VI
- October 6, Wednesday, 1pm-3pm, Dobin
  Machine Learning I
- October 8, Friday, 2pm-4pm, Dobin
  Machine Learning II
- October 13, Wednesday, 2pm-4pm, Koo
  Machine Learning III
- October 15, Friday, 2pm-4pm, Koo
  Machine Learning IV
- October 20, Wednesday, 2pm-4pm, Siepel
  Algorithms I
- October 21, Thursday, 2pm-4pm, Siepel
  Algorithms II
- October 27, Wednesday, 2pm-4pm, Siepel
  Algorithms III
- October 29, Friday, 2pm-4pm, Siepel
  Evolution I
- November 3, Wednesday, 2pm-4pm, Preall
  Genomics I
- November 5, Friday, 2pm-4pm, Preall
  Genomics II
- November 10, Wednesday, 2pm-4pm, McCandlish
  Evolution II
- November 15, Monday, 2pm-4pm, McCandlish
  Evolution III
- November 17, Wednesday, 2pm-4pm, Meyer
  Genomics III
- November 19, Friday, 2pm-4pm, Meyer
  Genomics IV
- December 1, Thursday, 2pm-4pm, Kinney
  Biophysics I
- December 3, Friday, 3:00pm-5:00pm, Kinney
  Biophysics II

Student Evaluation:
Problem sets: 80%, Lecture participation: 20%

Learning Objectives

- Acquire a working knowledge of standard statistics and Python programming
- Exposure to more advanced topics in machine learning, genomics, population genetics, neuroscience and biophysics

Learning Outcomes

- Be able to analyze and interpret large data sets
- Be able to frame biological hypotheses quantitatively

Background reading:

Núñez, M.A.B., Nuckolls, N.L., and Zanders, S.E. 2018. Genetic villains: killer meiotic drives. *Trends in Genetics* 34: 424-433.

Reference Material

There is a GitHub repository for the QB course
https://github.com/jbkinney/20_qbbootcamp
Download and install Anaconda with Python 3.8

- https://www.anaconda.com/download

Specialized Disciplines
Genetics and Genomics
Course Syllabus

Course Faculty

Lead Instructor:	Dr. Ullas Pedmale
Invited Experts:	Dr. Dave Jackson
	Dr. Zach Lippman
	Dr. Rob Martienssen
	Dr. Benjamin Roche
	Dr. Sophie Zebell
Tutor:	Dr. Benjamin Roche

Lectures:

- **Tuesday, September 7 2:30pm-4:30pm: Pedmale**
  Topic: Plants – what makes them different and similar to animals?
- **Thursday, September 9 2pm-4pm: Pedmale**
  Topic: Hormones and Light Signaling
- **Monday, September 13 2pm-4pm: Zebell**
  Topic: Plant Immunity
- **Tuesday, September 14 2:30pm-4:30pm: Pedmale**

Paper Discussion:

a. Jung JH, Barbosa AD, Hutin S, Kumita JR, Gao M, Derwort D, Silva CS, Lai X, Pierre E, Geng F, Kim SB, Baek S, Zubieta C, Jaeger KE, Wigge PA. 2020. A prion-like domain in ELF3 functions as a thermosensor in Arabidopsis. Nature 585: 256-260.
b. Tao Y, Ferrer JL, Ljung K, Pojer F, Hong F, Long JA, Li L, Moreno JE, Bowman ME, Ivans LJ, Cheng Y, Lim J, Zhao Y, Ballaré CL, Sandberg G, Noel JP, Chory J. 2008. Rapid synthesis of auxin via a new tryptophan-dependent

- **Friday, September 17 2pm-4pm: Lippman**
  Topic: Fundamentals (molecular and genetic) of flowering in development, evolution, domestication and breeding.
- **Monday, September 20 2:00pm-4:00pm: Pedmale**
  Topic: Genetics basics, Principles of genetic screens, mapping, and gene identification
  Background reading: Griffiths Ch. 1-3
  Background reading: Griffiths Ch. 4, and

a. Nüsslein-Volhard, C., and Wieschaus E. 1980. Mutations affecting segment number and polarity in Drosophila. *Nature* 287: 795-801, and,
b. Mayer, U., Torres-Ruiz, R. A., Berleth, T., Miséra, S. and Jürgens, G. 1991. Mutations affecting body organisation in the Arabidopsis embryo. *Nature* 353: 402–407.

- **Tuesday, September 21 2:30pm-4:30pm: Martienssen**
  Topic: Transposons and gene silencing
- **Thursday, September 23 2pm-4pm: Jackson**
  Topic: genetics and signaling of the plant meristem.
- **Monday, September 27 2pm-4pm: Pedmale**
  Topic: Epistasis, Clinical Genetics or genetic basis of diseases.
  a. Background reading: Griffiths Ch. 6.
  b. Background reading: Griffiths pp. 749-755.
- **Tuesday, September 28 2:30pm-4:30pm: Roche**
  Topic: Genomic approaches to classical genetics
  Background reading:

a. Schneeberger, K., and Weigel, D. 2011. Fast-forward genetics enabled by new sequencing technologies. *Trends Plant Sci*. 16: 282-288, and,
b. Rowan, B.A., Weigel, D., and Koenig, D. 2011. Developmental genetics and new sequencing technologies: the rise of non-model organisms. *Dev Cell* 21: 65-76.

- **Thursday, September 30 2pm-4pm: Roche**
  Topic: Non-Mendelian Inheritance – epigenetics and strange genetics

a. Background reading: Núñez, M.A.B., Nuckolls, N.L., and Zanders, S.E. 2018. Genetic villains: killer meiotic drives. *Trends in Genetics* 34: 424-433.

- **Tuesday, October 5 2pm-4pm**: **Pedmale**
  Topic: Paper Discussion:
  a. Bomblies K, Lempe J, Epple P, Warthmann N, Lanz C, Dangl JL, Weigel D. 2007. Autoimmune response as a mechanism for a Dobzhansky-Muller-type incompatibility syndrome in plants. *PLoS Biol*. **5**: e236.
  b. Cadieu E, Neff MW, Quignon P, Walsh K, Chase K, Parker HG, Vonholdt BM, Rhue A, Boyko A, Byers A, Wong A, Mosher DS, Elkahloun AG, Spady TC, André C, Lark KG, Cargill M, Bustamante CD, Wayne RK, Ostrander EA. 2009. Coat variation in the domestic dog is governed by variants in three genes. *Science* **326**: 150-153.

Student Evaluation:

- Problem sets: 40%; Journal club discussions: 30%; Lecture participation: 30%

Learning Objectives:

- To place modern genetics and genomics into the context of classical genetics.
- Genetic basis of diseases.
- History, technique, and perspective of genetic inference along with four levels of analysis: forward genetics, natural genetic variation, gene interaction, and genomics.
- Integration of classical with modern questions of genetic analysis: How are genes mapped and "cloned"? How do gene mutations help to define biological processes? How are more complex traits genetically dissected into their component parts? What concepts and techniques are used to organize genes into pathways and networks? What defines a gene and what gene variation exists in natural populations? What are the functional consequences of gene variation, and how is it detected? How are genomes organized and coordinately regulated? How can genomic information be catalogued, organized and mined?

Learning Outcomes:

- Apply the principles of genetics
- Demonstrate an understanding of the concept of Mendelian and non-Mendelian inheritance
- Describe tools and techniques used in genetics and genomics.
- Demonstrate an understanding of the genetic basis of phenotype and complex phenotypes

Reference Material:

- Textbooks: Griffiths, A.J.F, Wessler, S.R., Carroll, S.B., and Doebley, J. *Introduction to Genetic Analysis*. W.H. Freeman, 2015.

Reviews:

- Benzer, S. 1955. Fine structure of a genetic region in bacteriophage. *PNAS* 41: 344-354.
- Cadieu, E. *et. al.,* 2009. Coat Variation in the Domestic Dog Is Governed by Variants in Three Genes. *Science* 326: 150-153.
- Miki, Y. *et al.,* 1994. A Strong Candidate for the Breast and Ovarian Cancer Susceptibility Gene BRCA1. *Science* 266:66-71.
- Bomblies, K., Lempe, J., Epple, P., Warthmann, N., Lanz, C., Dangl, J.L., and Weigel, D. 2007. Autoimmune response as a mechanism for a Dobzhansky-Muller-type incompatibility syndrome in plants. *PLoS Biol* 5: e236
- Blount, Z., Borland, C., Lenski, E. 2008. Historical contingency and the evolution of a key innovation in an experimental population of Escherichia coli. *PNAS* 105: 7899-7906
- Hou J., *et al.,* 2018. Global impacts of chromosomal imbalance on gene expression in Arabidopsis and other taxa. *PNAS* 115:E11321-11330.
- Birchler J.A*., et al.,* 2016. Kinetics genetics: Incorporating the concept of genomic balance into an understanding of quantitative traits. *Plant Science* 245:128-134.

Supplemental reading:

- Indicated along with the lecture topic

Problem Set Papers:

- Indicated along with the lecture topic

Discussion Papers

- Indicated along with the lecture topic

Specialized Disciplines
Cancer
Course Syllabus

Module: Cancer

Course Faculty

Organizers: Mikala Egeblad
Christopher Vakoc

Invited Experts: Semir Beyaz
Jeremy Borninger
Camila dos Santos
Tobias Janowitz
Michael Lukey
David Tuveson
Linda Van Aelst

Lectures:

Friday, October 1: Egeblad
2:00pm – 4:00pm: The Hallmarks of Cancer

Monday, October 4: Tuveson
3:00pm – 5:00pm: Cancer Models

Wednesday, October 6: Vakoc
10:00am – 12:00pm: The Cancer Genome

Thursday, October 7: Vakoc
9:00am – 11:00am: Paper Discussion:

Thursday, October 7: dos Santos
12:00 pm – 2:00 pm: Cancer Epigenetics

Thursday, October 14: Vakoc
10:00am – 12:00pm: Targeted Cancer

Thursday, October 14: Egeblad
2:00pm – 4:00pm: Tumor microenvironment

Monday, October 18: Beyaz
2:00pm – 4:00pm: Tumor Immunology

Tuesday, October 19: Borniger & Janowitz
10:00am – 12:00pm: Host response to cancer

Tuesday, October 19: Beyaz
2:00pm – 4:00pm: Paper Discussion

Wednesday, October 20: Egeblad & Van Aelst
10:00am – 12:00pm: Metastasis

Thursday, October 21: Janowitz & Lukey
10:00am – 12:00pm: Cancer Metabolism

Friday, October 22: Lukey
10:00am – 12:00pm: Paper Discussion

Friday, October 22: Egeblad & Vakoc
2:00 pm – 4:00 pm: Problem Set Discussion and Course Round Up

Student Evaluation:

- 40% participation in daily discussions during lectures
- 40% based on paper discussions
- 20% based on problem set

Learning Objectives

Gain proficiency in the following:

- Hallmarks of cancer
- Tumor progression
- Cancer genome
- Cancer microenvironment
- Tumor immunology
- Metastasis

- Approaches to treating cancer, including targeted therapy

Learning Outcomes

- Elaborate on an understanding of cancer as a pathological process
- Discuss how cancer progresses
- Contemplate how to expand on current methods to treat cancer
- Design tractable methods to investigate fundamental aspects of cancer biology
- Discuss translational approaches to defeating cancer

Reference Material

Textbooks:

- Weinberg, RA 2014. The Biology of Cancer

Reviews:

- Hanahan, D., and Weinberg, R.A. 2011. Hallmarks of cancer: the next generation. *Cell* **144**: 646-674.
- Harper, J.W., and Elledge, S.J. 2007. The DNA damage response: ten years after. *Mol Cell* **28**: 739-745.
- Lowe, S.W., Cepero, E., Evan, G. 2004. Intrinsic tumor suppression. *Nature* **432**: 307-315.
- Kaelin, W.G., 2005. The concept of synthetic lethality in the context of anticancer therapy. *Nat Rev Cancer* **5**: 689-698.
- Meacham, C.E. and Morrison, S.J. 2013. Tumor heterogeneity and cancer cell plasticity. *Nature* **501:** 328–337.
- Holohan, C., Van Schaeybroeck, S, Longley, D.B, and Johnston, P.G. 2013. Cancer drug resistance: an evolving paradigm. *Nat Rev Cancer* **13**: 714-726.

Supplemental reading

- Alberts, B et al. 2008. Molecular Biology of the Cell
- Mukherjee S. 2011. The Emperor of All Maladies: A Biography of Cancer

Discussion Papers

- Restifo NP, Smyth MJ, Snyder A. 2016. Acquired resistance to immunotherapy and future challenges. Nat Rev Cancer. 16:121-6.
- Ringel AE, Drijvers JM, Baker GJ, Catozzi A, García-Cañaveras JC, Gassaway BM, Miller BC, Juneja VR, Nguyen TH, Joshi S, Yao CH, Yoon H, Sage PT, LaFleur MW, Trombley JD, Jacobson CA, Maliga Z, Gygi SP, Sorger PK, Rabinowitz JD, Sharpe AH, Haigis MC. 2020. Obesity Shapes Metabolism in the Tumor Microenvironment to Suppress Anti-Tumor Immunity. Cell 183: 1848-1866.
- Lam KC, Araya RE, Huang A, Chen Q, Di Modica M, Rodrigues RR, Lopès A, Johnson SB, Schwarz B, Bohrnsen E, Cogdill AP, Bosio CM, Wargo JA, Lee MP, Goldszmid RS. 2021. Microbiota triggers STING-type I IFN-dependent monocyte reprogramming of the tumor microenvironment. Cell. 184(21):5338-5356.
- Caroline R. Bartman, Yihui Shen, Won Dong Lee, Tara TeSlaa, Connor S.R. Jankowski, Lin Wang, Lifeng Yang, Asael Roichman, Vrushank Bhatt, Taijin Lan, Zhixian Hu, Xi Xing, Wenyun Lu, Jessie Yanxiang Guo, Joshua D. Rabinowitz. Slow TCA flux implies low ATP production in tumors. bioRxiv 2021.10.04.463108;doi: https://doi.org/10.1101/2021.10.04.463108

Specialized Disciplines
Systems Neuroscience
Course Syllabus

Course Faculty

Instructors: Dr. Stephen Shea (lead)
Dr. Florin Albeanu

Tutor: Dr. Pryianka Gupta

Lectures:

Wednesday, September 29, 2021 (10:00am-12:00pm): Shea

- Transduction, Conduction, and Excitability

Thursday, September 30, 2021 (10:00am-12:00pm): Shea

- Synapses, Plasticity, and Integration

Monday, November 1, 2021 (2:00pm-4:00pm): Shea

- Sensory Systems and Receptive Fields I: Olfaction, Audition, and Taste

Tuesday, November 2, 2021(2:00pm-4:00pm): Shea

- Sensory Systems and Receptive Fields II: Somatosensation and Vision

Thursday, November 4, 2021(2:00pm-4:00pm): Albeanu

- Neural Coding I: Single Neuron Coding, Rate, and Temporal Coding

Monday, November 8, 2021(2:00pm-4:00pm): Albeanu

- Neural Coding II: Reverse Correlation and Spike Triggered Averaging

Tuesday, November 9, 2021(2:00pm-4:00pm): Shea

- Neural Coding III: Population Coding and Decoding

Thursday, November 11, 2021(2:00pm-4:00pm): Shea/Albeanu

- Analysis of Behavior

Monday, November 29, 2021(2:00pm-4:00pm): Albeanu

- Causality in Neuroscience

Tuesday, November 30, 2021(2:00pm-4:00pm): Shea

- Title of Lecture Feedback and Neuromodulation

Thursday, December 2, 2021 (2:00pm-4:00pm): All

- Paper Presentations/Debates

Thursday, December 3, 2021(10:00am-12:00am): All

- Paper Presentations/Debates

Student Evaluation: There will be three main components to the class: lectures, a problem set and paper presentations. Evaluation will be based on participation during the lectures and performance during paper presentations and the problem set.

Paper Presentations: 50%
Lecture participation: 25%
Problem set: 25%

Learning Objectives

Achieve fluency with the following topics:

- Neuronal excitability and sensory transduction
- Synaptic communication and modification
- Receptive field structure and single neuron and population coding
- Analysis of natural and trained behaviors

Learning Outcomes

- Understand the logic and tools of modern neuroscience
- Master experimental design in systems neuroscience
- Think critically about systems neuroscience literature
- Understand the basics of information representation in the brain
- Appreciate the importance of causal manipulations of brain activity to neuroscience as an experimental field

Reference Material

Textbooks:

- "Principles of Neurobiology" by Liqun Luo

Supplemental reading

- Nature (2013) 497(7450): 482
- Nature (1989) 341(6237): 52
- Nature (1990) 346(6280): 174

Discussion Papers

- Singh Alvarado J, Goffinet J, Michael V, Liberti W 3rd, Hatfield J, Gardner T, Pearson J, Mooney R. 2021. Neural dynamics underlying birdsong practice and performance. Nature. 2021 599: 635-639.
- Kim HR, Malik AN, Mikhael JG, Bech P, Tsutsui-Kimura I, Sun F, Zhang Y, Li Y, Watabe-Uchida M, Gershman SJ, Uchida N. 2020. A Unified Framework for Dopamine Signals across Timescales. Cell 183:1600-1616.
- Evans DA, Stempel AV, Vale R, Ruehle S, Lefler Y, Branco T. 2018. A synaptic threshold mechanism for computing escape decisions. Nature 558: 590-594.
- Lee KH, Tran A, Turan Z, Meister M. 2020. The sifting of visual information in the superior colliculus. Elife. 9:e50678.