CMB 710 A - F
Cell & Molecular Biology Modules – Fall 2019
MWF 10:20 -11:40
Course Directors: Don Fox, Stefano Di Talia

Course Overview & Requirements: Modules in the CMB 710 series (A – F) are offered sequentially during the Fall semester and together cover 26 topics. These are the core offerings of the Cell & Molecular Biology Program and allow maximum flexibility for a student-designed curriculum. Four different topics are available during each module and students select one (in Module IV and Module VI there are five topic selections). Topics reflect the expertise of the corresponding faculty and emphasize either in-depth critical discussion of the primary literature or quantitative/mathematical approaches to addressing biological questions. Each module lasts for 2 weeks, with 3 meetings per week. Students entering through CMB are required to take 6 modules in fall semester of their first year and at least 4 of these modules must be in the CMB 710 series. The other two may be from the UPGEN 778 series. A total of 12 modules are required for the CMB certificate, and 8 of these must be from CMB710.

Special Note: The Drop/Add deadline for Fall 2019, Friday, September 6th* is the LAST day to make changes to all of the individual modules. Changes after September 6th will display as a withdrawal on your transcript.

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TOPIC DESCRIPTIONS:

CMB 710A-01 / CELL & MOLEC BIO MODULE I: INTRODUCTION TO EXPERIMENTAL DESIGN AND STATISTICS
Instructor: Lew, Daniel J
Location: LSRC C144
08/26/2019 - 09/06/2019
Summary: What is a good experiment and what isn’t? What controls should be present in the experiment, and why? How can we avoid being misled? How much data do we need to persuade someone of our conclusions? This class will use problem sets and group learning to address these questions. No prior readings required.

CMB 710A-02 / CELL & MOLEC BIO MODULE I: MECHANISMS OF EARLY DEVELOPMENT
Instructor: McClay, David R
Location: GSRB-I 4002
08/26/2019 - 09/06/2019
Summary: This module will cover the maternal to zygotic transition, initial asymmetries that launch cellular diversity, onset of signaling, mechanisms of specification, and control mechanisms necessary for morphogenesis. It will emphasize the means by which genomic information is used to drive development. Each class period will be a combination of primary literature review, lecture and discussion. Animal examples will be drawn from across the animal kingdom.
Reading:
2) Developmental Biology, Gilbert, 10th edition - Chapters 1-3

CMB 710A-03 / CELL & MOLEC BIO MODULE I: MAMMARY GLAND DEVELOPMENT
Instructor: Alvarez, James
Location: Nan Duke 384
08/26/2019 - 09/06/2019
Summary: The mammary gland is a secretory organ that mammals use to produce milk to feed their young. The majority of mammary gland development occurs postnatally, and the mammary gland undergoes dramatic morphological and functional changes during pregnancy and lactation. Studies of mammary gland development have provided important insights into organizing principles of tissue development, including the organization of stem cell hierarchies, crosstalk between epithelial and stromal cells, the importance of immune cells in epithelial tissue development, and how tissues can integrate both local and systemic signals to control development. Furthermore, dysfunction of mammary gland development is intimately linked to the risk of developing breast cancer. In this class we will cover the fundamentals of mammary gland development — including the current intense interest in mammary stem cells — and discuss the implications of these topics for breast cancer.
Reading:

CMB 710A-04 / CELL & MOLEC BIO MODULE I: HANDS ON DEVELOPMENT
Instructor: Silver, Debra
**Location:** Nan Duke 437  
08/26/2019 - 09/06/2019  
**Summary:** This module, open to first and second year DSCB students, will expose students to basic principles and techniques in development and stem cell biology. Students will spend the morning in Duke labs learning hands-on methods.  
**Reading:** N/A

**CMB 710B-01 / CELL & MOLEC BIO MODULE II: CONTROLLING THE CELL CYCLE**  
**Instructor:** Lew, Daniel  
**Location:** LSRC C144  
09/09/2019 - 09/20/2019  
**Summary:** The accurate copying of a cell's contents and their distribution to produce two daughter cells is a stunning feat requiring exquisite coordination. The set of carefully orchestrated steps by which proliferating cells make copies of themselves constitutes the cell cycle. In this module, we will discuss landmark papers that established the conserved mechanisms underlying cell cycle control, as well as recent papers dissecting the control circuitry. In addition to learning about a fundamental process, we will explicitly deal with strategies for reading primary Journal articles to critically assess the validity of their conclusions. We will also discuss how to turn cartoon diagrams of regulatory pathways into equations and graphs producing quantitative predictions of pathway behavior, and address the importance of feedback pathways and bistable systems in generating sharp transitions in cell behavior.  
**Reading:**  
from "The Molecular Biology of the Cell", Alberts et al.  
Chapter 17: The Cell Cycle. (including the Mechanics of Cell Division).

**CMB 710B-02 / CELL & MOLEC BIO MODULE II: MICROSCOPY IN CELL BIOLOGY**  
**Instructor:** Cameron, Lisa and Carlson, Benjamin  
**Location:** MSRB-III, 1125  
09/09/2019 - 09/20/2019  
**Summary:** Microscopy has been revolutionized by fluorescence and now provides a vast array of tools with which to investigate biology. This module will cover the principles and techniques of light microscopy – how microscopes and photon-based imaging systems work and what you can do with them. We will discuss a range of techniques emphasizing the most common applications encountered in biological research - widefield imaging, optical sectioning by confocals, multi-photon excitation and TIRF microscopy. The theory and physical principles of the imaging systems will be explained in the first half of the module in a lecture based setting to a level giving understanding of how they work and guidance for optimal use. The second part of the module will be a mixture of theory and exercises in FIJI/ImageJ covering the processing, visualization and quantification of microscopy data.  
**Reading:**  
Molecular Biology of the Cell, Alberts, et al., - Chapter 9 (focus on the sections discussing light/fluorescence microscopy)

**CMB 710B-03 / CELL & MOLEC BIO MODULE II: BIOLOGY OF CILIA AND FLAGELLA**  
**Instructor:** Goetz, Sarah  
**Location:** Nan Duke 384  
09/09/2019 - 09/20/2019
Summary: Cilia and flagella are microtubule-based cellular projections that perform a variety of important functions in eukaryotes including motility, generating fluid flow, and sensory perception. Non-motile primary cilia also play a critical role in modulating key developmental signaling pathways. Through critical reading of the primary literature, this module will examine the structure, function, and evolution of these important organelles. We will focus in particular on the relationship between cilia and cellular functions linked to human diseases including genetic syndromes, neurological disorders, and cancer.

Reading:

CMB 710B-04 / CELL & MOLEC BIO MODULE II: NUCLEAR STRUCTURE/GENE REGULATION
Instructor: Yildirim, Eda
Location: Nan Duke 437
09/09/2019 - 09/20/2019
Summary: Understanding how transcriptional status of genes are established, maintained, and regulated is crucial to answer the questions of how diverse cellular functions are orchestrated during development of multicellular organisms. During recent years, it has become evident that gene expression is controlled not only on the basis of DNA sequences at the promoter and enhancer elements, but at the epigenetic level by elements of nuclear structure. These include chromatin modifications of DNA and histones, noncoding RNA-mediated epigenetic regulation, higher-order chromatin arrangements and variable aspects of nuclear architecture. In this module, we will discuss key papers that reveal these levels of gene regulation. We will be learning to approach these exciting papers critically and design experimental ways to test and explore this new area of Cell Biology.

Reading:
Molecular Biology of the Cell, Alberts et al.
Chapter 4 - Overall Chromatin Structure (limit to pp. 202-245, in 5th edition)
Chapter 7 - Overview of Gene Control (limit to pp. 411-432, in 5th edition)
Chapter 12 - Overview of Nuclear Structure (limit to pp. 704-712, in 5th edition)

CMB 710C-01 / CELL & MOLEC BIO MODULE III: REGENERATION
Instructor: Diao, Yarui
Location: Nan Duke 437
09/23/2019 - 10/04/2019
Summary: Regeneration means the regrowth of a damaged or missing organ part from the remaining tissue. Humans can regenerate some organs, including the skin, liver, bone, and skeletal muscle. However, many other human tissues, such as heart and brain, only have very limited regeneration capacity. Questions of how and why tissue regeneration occurs or not in health and pathology have captured the attention of countless biologists, biomedical engineers, and clinicians. In this module, we will focus on skeletal muscle as the model system, to cover key concepts and mechanisms of tissue regeneration. We will also discuss the different regenerative strategies and mechanisms that are used
by a variety of model organisms, including salamanders, planarians, and zebrafish, to understand regeneration.

Reading:

CMB 710C-02 / CELL & MOLEC BIO MODULE III: CELL MIGRATION/INVASION IN DEVELOPMENT & CANCER
Instructor: Sherwood, David R
Location: Nan Duke 384
09/23/2019 - 10/04/2019
Summary: Cell migration/invasion through extracellular matrix and tissues play crucial roles in the development, maintenance and regeneration of multicellular organisms. Inappropriate and defective cell migration also underlies numerous diseases, including inflammatory diseases (i.e. asthma, rheumatoid arthritis, multiple sclerosis, psoriasis and Crohn’s disease), developmental disorders, and tumor spread. Understanding cell migration is also important for regenerative therapies, including stem-cell grafting, where defective migration/invasion is a major limitation. Cell migration takes on a variety of forms, and this course covers how cells migrate and invade as individuals, in groups as well as the plasticity of migration modes in development and cancer.

Reading:

CMB 710C-03 / CELL & MOLEC BIO MODULE V: THE EYE AS A DIGITAL CAMERA
Instructor: Arshavsky, Vadim Y
Location: GSRB-I 4002
09/23/2019 – 10/04/2019
Summary: We are well familiar with the metaphor comparing the eye with a photographic camera. Indeed, both rely on refraction and lenses to form images. What is perhaps less appreciated is that the eye functions as a digital camera. Information about the surrounding world reaches the back of the eye in the form of photons of variable wavelength, which are absorbed by rod and cone photoreceptor cells of the retina. The light-evoked electrical signals produced by photoreceptors are next processed by a network of retinal neurons, so that information about each point in visual space becomes digitized and reaches the brain through multiple channels, each reporting a different feature of the visual world (brightness, contrast, color, motion, etc.).

In this module, we will follow each step of this analog-to-digital transition by discussing critical experimental papers in three areas: phototransduction (the transformation of a light signal into an electrical signal); the functioning of the first synapse in the retina; and the split of visual information into multiple channels each carried by a highly-specialized type of the retinal ganglion cells. Our goal would be to integrate the findings of molecular, cellular and electrophysiological studies into a single big picture of how the retina works.

Reading:

**CMB 710C-04 / CELL & MOLEC BIO MODULE III: ADVANCED MICROSCOPY APPLICATIONS**

**Instructor:** Cameron, Lisa  
**Location:** MSRB-III, 1125  
**09/23/2019 - 10/04/2019**  
**Summary:** Over the last ten years, advancements in hardware and development of various probes have fueled higher resolution imaging techniques dubbed “super-resolution” along with other related methods. This module will build on the information from the “Microscopy in Cell Biology” module to cover specifics of ways to resolve beyond the diffraction limit and collect images in 3D with greater speed than typical optical sectioning. The format will be mostly lecture style with some opportunity for demonstration or tour – this will be discussed in class. We will discuss how these techniques may benefit your research and the practical limitations and factors to achieve optimal imaging.  

**Reading:**  
Toomre and Bewersdorf 2010 Annual Reviews in Cell and Developmental Biology 26:285-314 “A New Wave of Cellular Imaging”.
Lambert, TJ and JC Waters 2017 Journal of Cell Biology Jan 2; 216(1):53-63 “Navigating challenges in the application of superresolution microscopy”

**CMB 710D-01 / CELL & MOLEC BIO MODULE IV: TIDYBIOLOGY: AN INTRODUCTION TO BIOLOGICAL DATA SCIENCE IN R**

**Instructor:** Hirschey, Matthew  
**Location:** MSRB-III, 1125  
**10/09/2019 - 10/21/2019**  
**Summary:** This workshop-style module provides an introduction to the emerging field of Data Science in R, including data analysis and visualization, with a particular focus on its utility for biological insight. Students will be provided with biological datasets, and introduced to R packages and code used to examine data. In the first half of each class, students will be lectured on methods and shown demonstrations; in the second half of each class, studies will use tools to analyze real data; laptop computers are required. Methods for filtering, sorting, and transforming data will be discussed along with visualization tools and options. Particular attention will be paid to code interpretation and data provenance methods by learning to generate reproducible data output files. For a final project, students will be given a new dataset to analyze using the tools learned during the course, and will share findings with the class in a short oral presentation. Although specific datasets will be used for analysis in class, this workshop will provide broadly applicable tools to reproducibly analyze and visualize data across the biological sciences.

**CMB 710D-02 / CELL & MOLEC BIO MODULE V: MECHANISMS OF SKELETAL DEVELOPMENT & DISEASE**

**Instructor:** Karner, Courtney  
**Location:** LSRC C144  
**10/09/2019 – 10/21/2019**
Summary: This module will cover the embryonic and postnatal development of the skeleton. It will focus on the major signaling pathways and transcriptional regulation controlling the specification, commitment and differentiation of mesenchymal cells into chondrocytes and osteoblasts. Attention will also be given to these events in human skeletal diseases. Examples will be drawn from multiple species. This will primarily be a literature review course with some lecture and discussion.

Reading:
10/09/2019 - 10/21/2019

Summary: How the brain is wired during development and how these connections are modified by experience are fundamental questions of neural cell biology. In this module we will cover examples of how axons navigate to properly innervate their targets. We will also cover how the synapse is formed and how the strength of the synaptic connection is modified by experience. Finally, we will investigate how impairments to these processes are the basis to many neurological disorders.

Reading:
Molecular Biology of the Cell, Alberts et al.
Chapter 11 - Ion Channels and the Electrical Properties of Membranes.
Chapter 21 - Neural Development

CMB 710E-01 / CELL & MOLEC BIO MODULE VI: GENOME INSTABILITY

Instructor: Fox, Donald T
Location: LSRC C144
10/23/2019 - 11/04/2019

Summary: Protection of the genome is key to maintaining normal cellular function. Numerous safeguards exist to detect genome alterations and potential cell division errors, thus maintaining a stable genome. Failure in such regulation leads to genome instability. A variety of human diseases are derived from genome instability, including diseases of aneuploidy such as trisomies. Genome instability is also present in cancer, and a current debate in the literature is whether genome instability is a major cause, rather than a consequence, of cancer.

In this module, we will take a look at recent literature on causes and consequences of genome instability in various model systems and in human disease. In the six papers we will discuss, the wide range of concepts discussed will include cell cycle checkpoints, aneuploidy, and cancer genomics. Methods used in the papers will similarly cover a wide range of genetic, molecular, and cell biological assays. Most importantly, this class is geared towards developing critical literature analysis skills.

Reading:
2) Optional reading (if further background is needed): Alberts et al, Chapter 17 (The cell cycle).

CMB 710E-02 / CELL & MOLEC BIO MODULE IV: INTERSECTION OF SIGNALING & THERAPEUTICS

Instructor: Wood, Kris C
Location: MSRB-III, 1125
10/23/2019 - 11/04/2019

Summary: It is now possible to comprehensively map the numerous genomic alterations present in individual human tumors. As a result of this stunning technological advance, we can now begin to design therapeutic strategies that function by “targeting” these alterations. However, identifying the optimal therapeutic targets for a given tumor is challenging, and this challenge is further exacerbated by the problem of drug resistance, which commonly emerges as tumors evolve under pharmacological selection pressures. In this module, we will construct a framework for understanding the related topics of pharmacogenomics and drug resistance in cancer, discussing landmark papers that established the guiding principles in each field.

Reading:

**CMB 710E-03 / CELL & MOLEC BIO MODULE V: PROTEIN-PROTEIN INTERACTION**

**Instructor:** Erickson, Harold P  
**Location:** Nan Duke 384  
10/23/2019 – 11/04/2019  

**Summary:** Proteins are the machines of the cells. A few enzymes operate alone, but most proteins interact with others to form more complex machines. In this unit we will learn the basic principles of protein-protein interaction and bonding and address the following questions.

How big is a protein molecule; how do you determine if it is a monomer or tetramer; how do you determine its shape? What is the structure of a protein-protein bond? How many amino acids are in contact? How does the dissociation constant relate to the strength of the bond? How fast do two proteins form a bond, and once formed how long does the complex last before it dissociates? If you want to eliminate or reduce a protein-protein bond by mutagenesis, how many amino acids do you need to change? How do you decide which ones?

**Reading:**  
Molecular Biology of the Cell”, Alberts et al.  
Chapter 3 - Proteins.  
Chapter 2 (to review basic biochemistry. Most important is to know the amino acids, which ones are hydrophobic, hydrophilic, charged)

**CMB 710E-04 / CELL & MOLEC BIO MODULE V: QUANTITATIVE CELL & DEVELOPMENTAL BIOLOGY**

**Instructor:** Di Talia, Stefano  
**Location:** Nan Duke 437  
10/23/2019 - 11/04/2019  

**Summary:** It is a common belief that biology is the least quantitative and theoretical of the natural sciences. However, many fundamental discoveries in biology (e.g. membrane excitability, spikes, proofreading) have come from the use of modeling and theoretical ideas. The goal of this module is to show how theoretical and mathematical ideas can contribute to develop deeper insights on biological problems. Focusing on primary literature, we will discuss how recent advancements in imaging technologies are improving our understanding of cell and developmental biology. Ideally by the end of this module, students will be able to distinguish good informative mathematical models from less informative models.

**Reading:**  

**CMB 710F-01 / CELL & MOLEC BIO MODULE VI: BIOINFORMATICS & GENOMICS FOR THE BIOLOGIST**

**Instructor:** MacAlpine, David M  
**Location:** LSRC C144  
11/06/2019 - 11/18/2019  

**Summary:** Computational biology and genomics are a mainstay of modern biology. For example, sequence alignments, identification of gene orthologs and paralogs by blast searches, and motif identification are now routine practices in the laboratory. In addition, the explosion of whole genome
sequencing in the last decade has led to a variety of genomic approaches (many based on microarray technology and next-generation sequencing) to phenotype the cell at the level of gene expression and identify networks of co-regulated genes. These computational tools and genomic approaches are likely to be integral components of many research projects.

In this module, we will explore the tools and approaches to analyze next-generation sequencing data. We will make extensive use of Unix, bash scripting, and the R environment for statistical computing. The student will not only learn to critically evaluate these complex genomic experiments but will also gain first-hand experience at analyzing primary data.

Reading:
Unix Tutorial
http://www.ee.surrey.ac.uk/Teaching/Unix/
R Tutorial
http://www.cyclismo.org/tutorial/R/

CMB 710F-02 / CELL & MOLEC BIO MODULE III: GERM CELLS / SEX DETERMINATION
Instructor: Capel, Blanche
Location: Nan Duke 384
11/06/2019 - 11/18/2019
Summary: This module will cover the formation, pluripotent characteristics, and male vs. female development of primordial germ cells in multiple species including Drosophila, C. elegans, fish and mammals. It will also cover sex determination and cell fate commitment in somatic cells of the gonad, including genetic and temperature/hormone-dependent mechanisms. We will likely also consider how sex chromosomes evolve and how species transition between sex determining mechanisms.
Reading:
Developmental Biology, Gilbert:
Chapter 15 - Sex Determination
Chapter 17 - The Saga of the Germ Line

CMB 710F-03 / CELL & MOLEC BIO MODULE I: GLYCOBIOLOGY
Instructor: Boyce, Michael
Location: Nan Duke 437
11/06/2019 - 11/18/2019
Summary: Glycosylation is found in all kingdoms of life and underlies every aspect of cell biology. In addition, glycobiology has major implications for an enormous range of fields, from human health to renewable energy to materials science. Recently, new technologies and experimental approaches have triggered explosive progress in the modern glycosciences. This module will sample some very recent papers – all published in 2018 – on a range of glycobiology topics, with an emphasis on protein glycosylation in mammalian health and disease. Our goals will be to get an overview perspective on current research in glycobiology, and to hone our critical reading skills.
Reading:
Chapter 1 of Varki et al., Essentials of Glycobiology, available at:
CMB 710F-04 / CELL & MOLEC BIO MODULE VI: HUMANS AS MODEL ORGANISMS

Instructor: Bennett, G Vann
Location: GSRB-1 4002
11/06/2019 - 11/18/2019

Summary: Translational research is frequently viewed as the application of established principles of basic science to promote human health. This section will develop the theme that deciphering the molecular basis for human disease can be far from straightforward, and both require and contribute to elucidation of new fundamental biology. We will focus this year on nervous system-related diseases, beginning with Creutzfeldt-Jacob and related neurodegenerative disorders where molecular breakthroughs have led to the prion concept. We will then consider Alzheimer's disease, where genetic mutations and risk factors are known, but the pathophysiology is still unresolved. We will end with discussion of autism, which since 1980 has transitioned from a rare disorder to one affecting 1% of the population. Autism is heritable and autism susceptibility genes are known. However, autism still lacks a unifying concept and is an attractive target for future research.

Reading:
1) Pruisner's Nobel Lecture

CMB 710F-05 / CELL & MOLEC BIO MODULE VI: MITOCHONDRIA IN HEALTH AND DISEASES

Instructor: Cartoni, Romain
Location: MSRB-III, 1125
11/06/2019 - 11/18/2019

Summary: Mitochondria are responsible for key cellular functions such as energy production, reactive oxygen species regulation and calcium buffering. Moreover, it is an extremely dynamic organelle that is able to divide, fuse and move along microtubule track. The importance of mitochondrial functions and dynamics is evidenced by the numerous diseases such as cancer, diabetes and neurodegenerative diseases that have been linked to mitochondrial dysfunction. Therefore it is more important than ever to better understand the physiology of this multifaceted organelle. Through a series a classic, provocative and recent papers, this course will provide an overview of mitochondrial biology and its role in pathophysiological conditions with a special emphasis on mitochondrial dynamics and neurodegeneration.

Reading:
2) Cold Spring Harb Perspect Biol 2013 Schwarz