

BME 42-620 Engineering Molecular Cell Biology

Lecture 03:
Basics of Evolution Theory;
Overview of Model Organisms

Basics of MATLAB

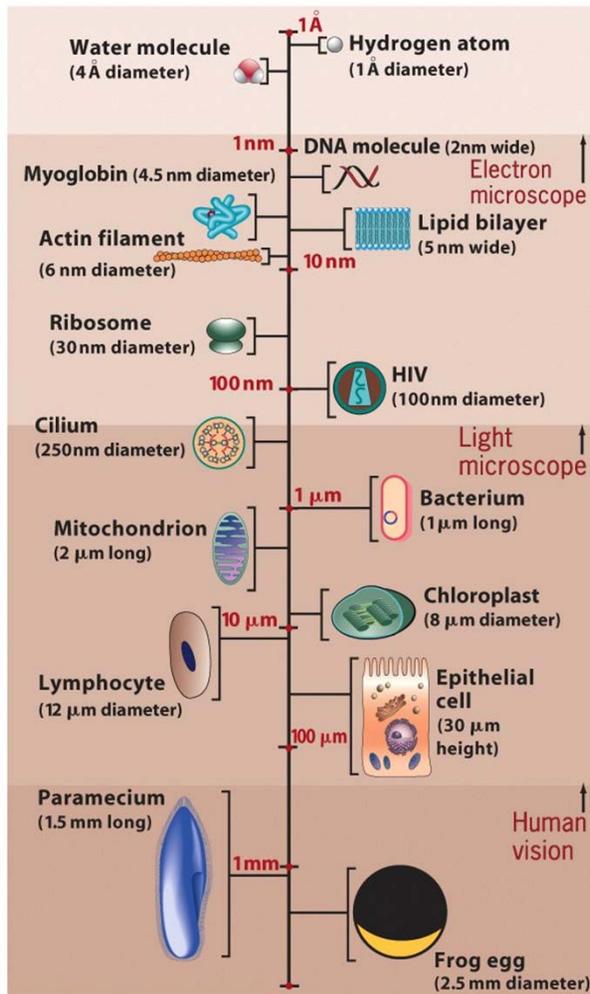
Outline

- A brief review of the previous lecture
- Basics of evolution theory
- Overview of model organisms
- Basics of MATLAB

Outline

- A brief review of the previous lecture
- Basics of evolution theory
- Overview of model organisms
- Basics of MATLAB

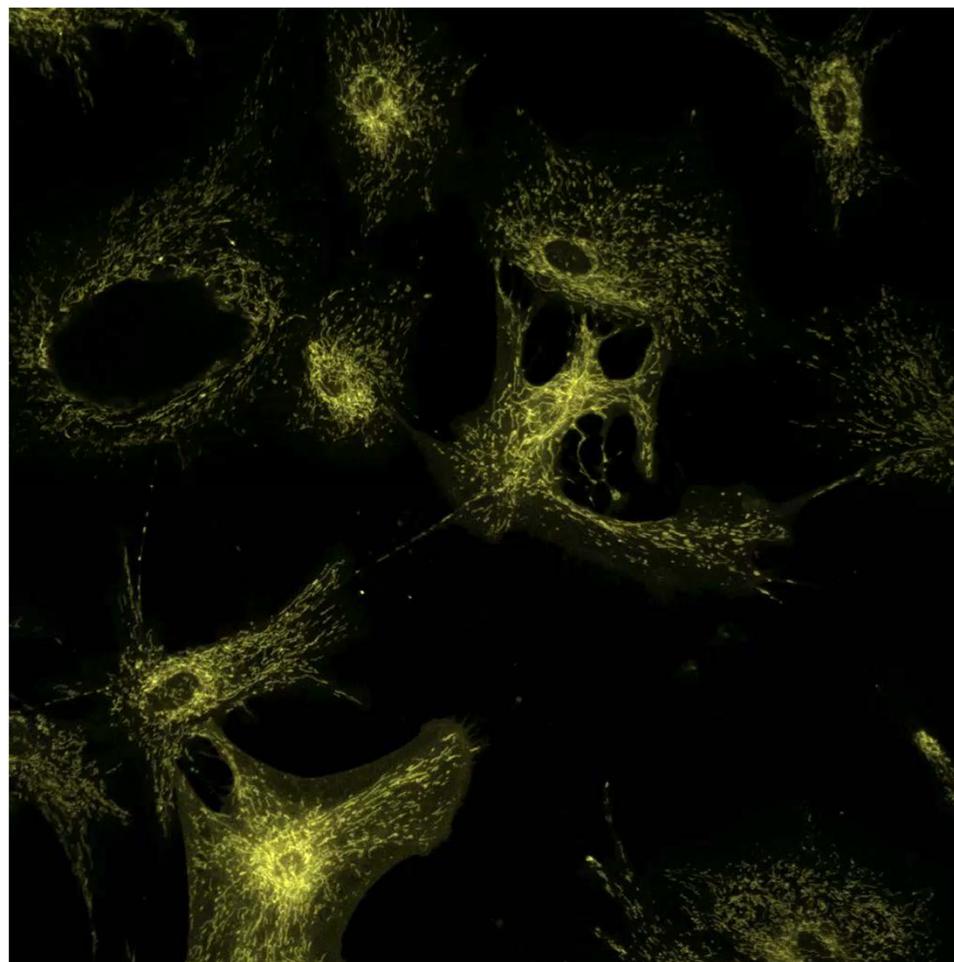
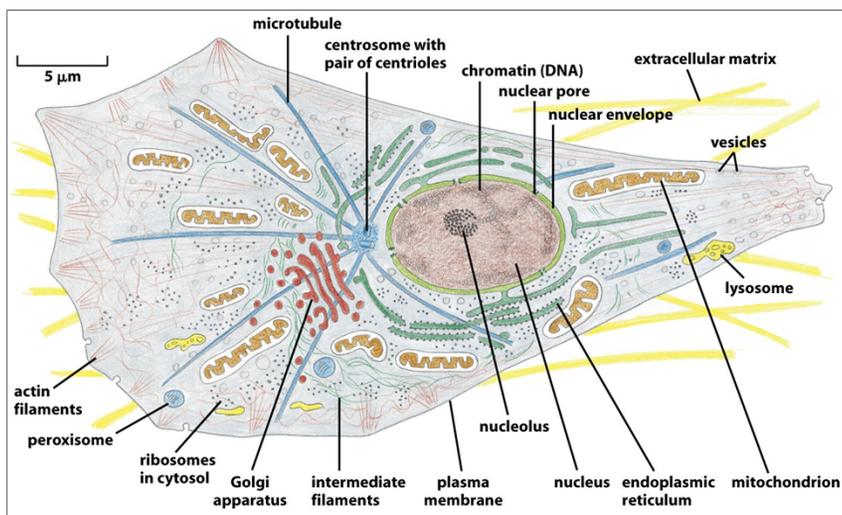
Scales of Cells and Cellular Organelles



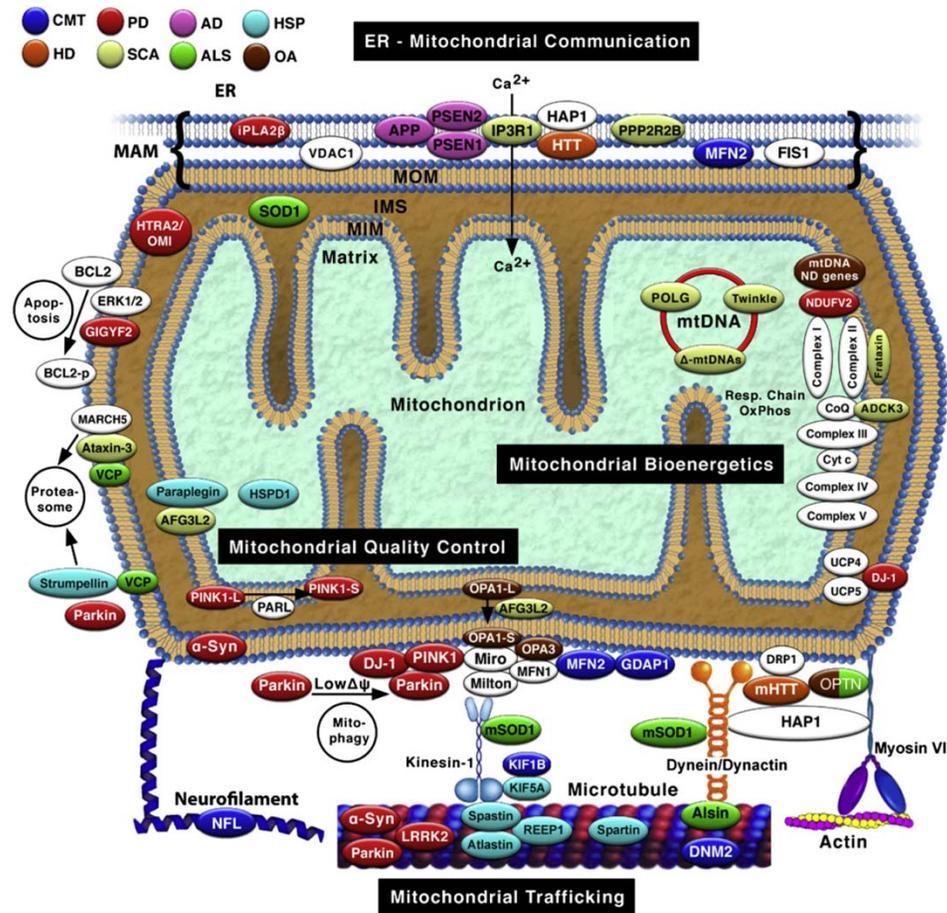
- Live imaging: light microscopy
- Below 100nm, electron microscopy
- Below 1 nm: crystallography, NMR, spectroscopy

Energy Generation/Distribution: Mitochondria

- Generation and distribution of ATP.
- Regulation of many other metabolic processes, including aging.



A More Detailed View of Mitochondria



Schon & Przedborski,
Neuron, 70:1033, 2011

System Level Analysis of Cells

- Discussion: how to study a cell at a system level?
 - To understand the functions of individual units
 - To understand the interactions between different units
 - To understand such interactions in space and time
 - To use simplified model systems
 - ...
- Some examples of related projects:
 - Virtual cell program: <http://vcp.med.harvard.edu/>
 - Cell modeling: <http://www.ccam.uchc.edu/index.html>

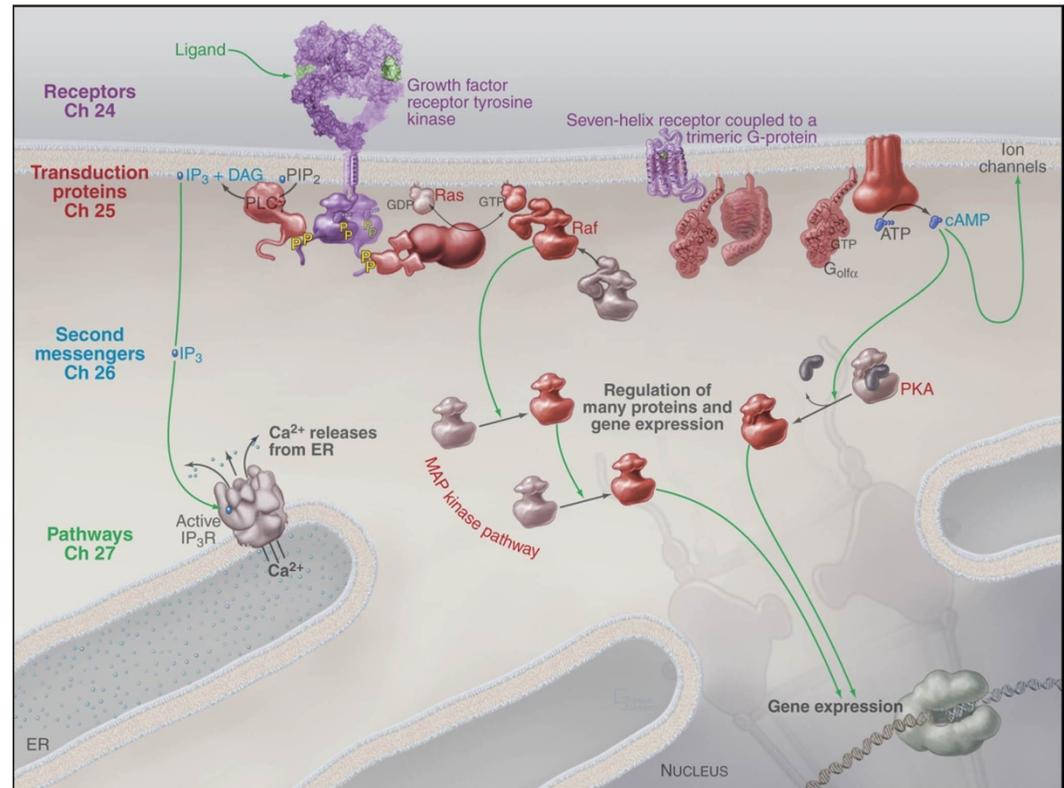
Reading Assignment 1

Outline

- A brief review of the previous lecture
- **Basics of evolution theory**
- Overview of model organisms
- Basics of MATLAB

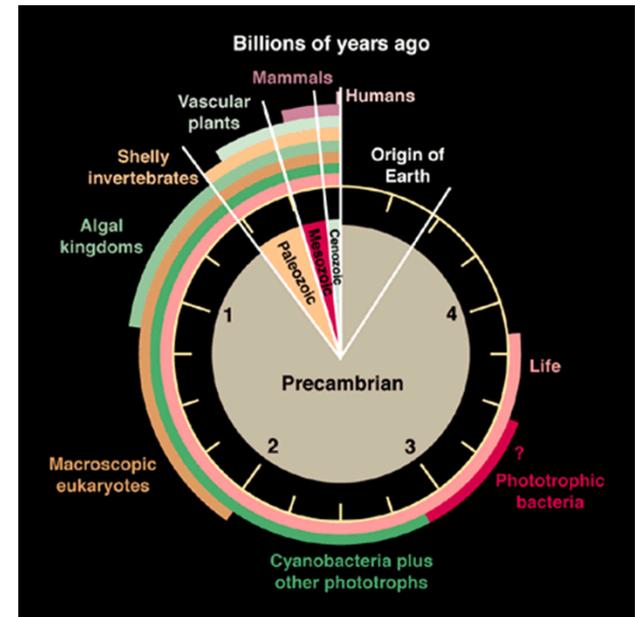
Remarkable Diversity and Specificity at Cellular and Organismal Levels

- Example: receptors
 - > 800 G protein coupled receptors in human
 - > 1000 G protein coupled receptors in mice just for sensing of smell
- Remarkable diversity and specificity at the organismal level as well.
- Where does this come from?

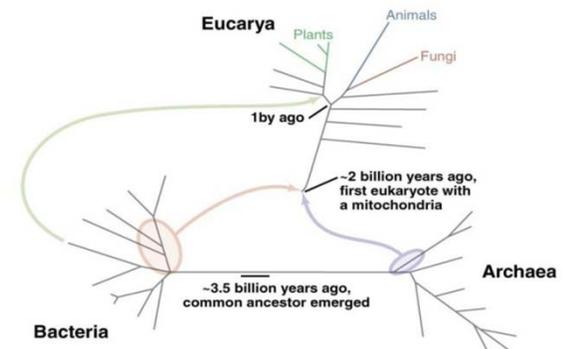


Cells Come from a Common Ancestor

- Earth forms ~4.5 billion years ago.
- The common ancestor, a primitive microscopic cell, lived over 3.5 billion years ago.
- Prokaryotes start ~2.7 billion years ago.
- The first eukaryote with a mitochondrion lived ~2 billion years ago.



D. J. Des Marais, *Science*, 289:1703, 2000

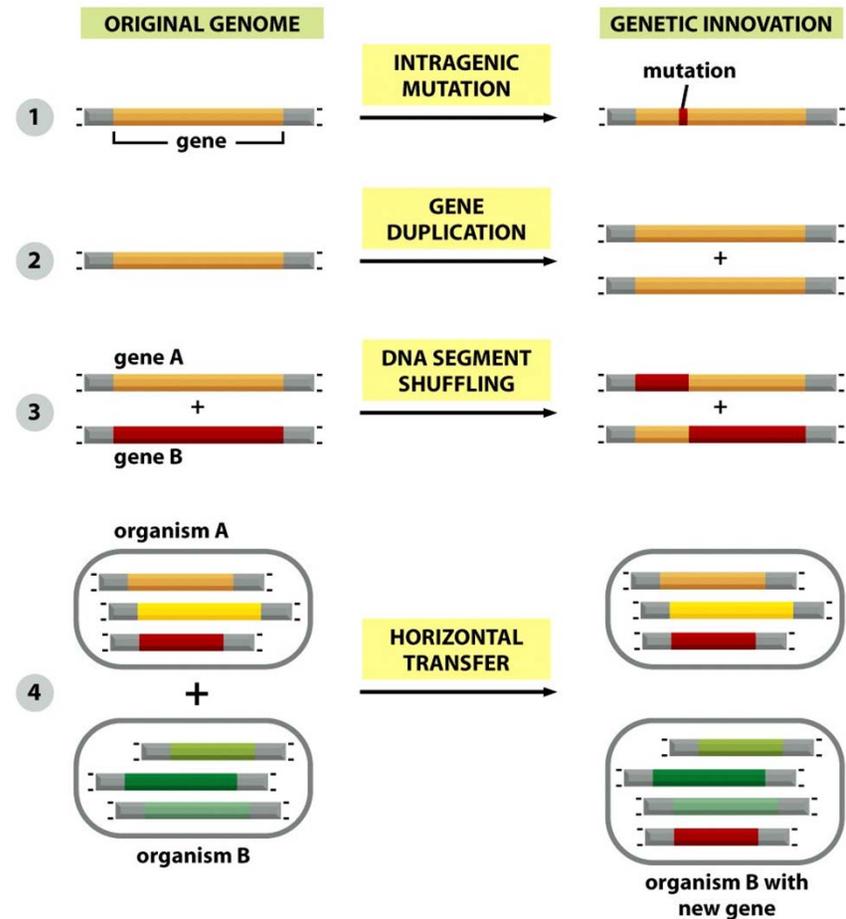


Genetic Basis of Evolution

- Evolution is the great unifying principle in biology.

- Generation of new genes

- Mutation
- Duplication
- Segment shuffling
- Transfer



Elements of Natural Selection Theory (I)

- Proliferation: organisms produce more offspring than can survive.
- Genetics: Organisms pass genetic traits from generation to generation.
- Variation: there is variation in every population.
- Competition: organisms compete for limited resources.
- Natural selection: those organisms with the most beneficial traits are more likely to survive and produce.

Elements of Natural Selection Theory (II)

- Genetic changes of natural selection survivors are preserved.
- Regarding detailed evolution mechanisms, multiple models have been proposed but no conclusive consensus reached so far.
- Significant progress has been made towards understanding the molecular genetic basis of evolution.
- References
 - S. B. Carroll, *Endless forms most beautiful*, W.W. Norton, 2006
 - S. B. Carroll et al, *From DNA to diversity*, Wiley-Blackwell, 2004

Darwin: "Origin of Species"

"It is interesting to contemplate a tangled bank, clothed with many plants of many kinds, with birds singing on the bushes, with various insects flitting about, and with worms crawling through the damp earth, and to reflect that these elaborately constructed forms, so different from each other, and dependent upon each other in so complex a manner, have all been produced by laws acting around us. These laws, taken in the largest sense, being Growth with reproduction; Inheritance which is almost implied by reproduction; Variability from the indirect and direct action of the conditions of life, and from use and disuse; a Ratio of Increase so high as to lead to a Struggle for Life, and as a consequence to Natural Selection, entailing Divergence of Character and the Extinction of less improved forms. Thus, from the war of nature, from famine and death, the most exalted object which we are capable of conceiving, namely, the production of the higher animals, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one; and that, whilst this planet has gone circling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved."

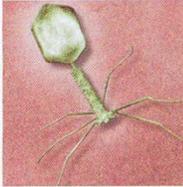
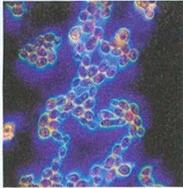
Outline

- A brief review of the previous lecture
- Basics of evolution theory
- **Overview of model organisms**
- Basics of MATLAB

Model Organisms

- Commonly used animal models

- fruit fly
- *C. elegans*
- mice/rat

<p>(a)</p> 	<p>Viruses</p> <p>Proteins involved in DNA, RNA, protein synthesis Gene regulation Cancer and control of cell proliferation Transport of proteins and organelles inside cells Infection and immunity Possible gene therapy approaches</p>	<p>(b)</p> 	<p>Bacteria</p> <p>Proteins involved in DNA, RNA, protein synthesis, metabolism Gene regulation Targets for new antibiotics Cell cycle Signaling</p>
<p>(c)</p> 	<p>Yeast (<i>Saccharomyces cerevisiae</i>)</p> <p>Control of cell cycle and cell division Protein secretion and membrane biogenesis Function of the cytoskeleton Cell differentiation Aging Gene regulation and chromosome structure</p>	<p>(d)</p> 	<p>Roundworm (<i>Caenorhabditis elegans</i>)</p> <p>Development of the body plan Cell lineage Formation and function of the nervous system Control of programmed cell death Cell proliferation and cancer genes Aging Behavior Gene regulation and chromosome structure</p>
<p>(e)</p> 	<p>Fruit fly (<i>Drosophila melanogaster</i>)</p> <p>Development of the body plan Generation of differentiated cell lineages Formation of the nervous system, heart, and musculature Programmed cell death Genetic control of behavior Cancer genes and control of cell proliferation Control of cell polarization Effects of drugs, alcohol, pesticides</p>	<p>(f)</p> 	<p>Zebrafish</p> <p>Development of vertebrate body tissues Formation and function of brain and nervous system Birth defects Cancer</p>
<p>(g)</p> 	<p>Mice, including cultured cells</p> <p>Development of body tissues Function of mammalian immune system Formation and function of brain and nervous system Models of cancers and other human diseases Gene regulation and inheritance Infectious disease</p>	<p>(h)</p> 	<p>Plant (<i>Arabidopsis thaliana</i>)</p> <p>Development and patterning of tissues Genetics of cell biology Agricultural applications Physiology Gene regulation Immunity Infectious disease</p>

Lodish et al, *Mol. Cell. Biol.*, 6e, W. H. Freeman, 2008

Model Organisms

Organism	Genome Size (Mb)	Genes	Homologous Recombination	Meiotic Recombination	Biochemistry
E. coli	4.6	4,288	Yes	No	Excellent
S. cerevisiae	12.1	6,144	Yes	Yes	Good
S. pombe	14	4,900	Yes	Yes	Good
C. elegans	97	18,266	Difficult	Yes	Poor
Drosophila	180	13,338	Difficult	Yes	Fair
Arabidopsis	100	25,706	No	Yes	Poor
Mouse	2500	22,011	Yes	Yes	Good
Human*	2900	22,808	Yes*	Yes	Good

*cultured cells

Why Use Model Organisms

- Made possible by evolution
 - Remarkable similarities between genes/proteins in different organisms
 - Often possible to insert genes/proteins from one organism into the genome of the other to rescue functions.
- Model organisms provide a way to tackle diversity.
- Model organisms are chosen for the ease of studying them.
- Often there is substantial shared resources for cost effectiveness in studying model organisms.

Example: *Drosophila melanogaster*

- Genetic model system
- Often used to study development
- Many human disease models
- Generation time: ~10-15 days
- Resources:
<http://flybase.bio.indiana.edu/>
- ~75% of known human disease genes have matches in the fruit fly genome

The life cycle of *Drosophila melanogaster*

The diagram illustrates the life cycle of *Drosophila melanogaster* in a circular arrangement. At the top, a female fly and a male fly are shown. The cycle proceeds clockwise through the following stages: embryo, 1st instar larva, 2nd instar larva, 3rd instar larva, prepupa, and pupa. The pupa stage is shown as a segmented, brownish structure. The diagram is credited to FlyMove.

GSA The Genetics Society of America Conferences

5th Annual **Drosophila Research Conference**
April 7-11, 2010 • Marriott Wardman Park, Washington, DC

Home | Abstracts | Registration | Program Information | Awards | Exhibits | Hotel/Travel

REGISTER Open September 22 Early and Save | **SUBMIT** Open September 22 abstract now | **RESERVE** your hotel room

Important Dates & Deadlines

2009

- September 22 Abstract Submission Site Opens
- September 22 Conference Registration Site Open
- November 30 Deadline for Workshop Proposals
- December 3 Deadline for Receipt of Early Abstracts
- December 4 Deadline for Abstract Submissions
- December 4 Deadline for Abstract Submissions
- December 10 Deadline for Abstract Submissions
- December 11 Late Abstract Submission Site Closes

2010

- January 30 Deadline for Travel Award Submissions
- February 18 Deadline for Late Abstract Submissions
- February 18 Conference Registration
- March 16 Deadline for Hotel Reservations
- March 30 Deadline for Advance Registration

*Late abstracts will only be accepted on a space available basis.

The Latest Buzz...

2010 Meeting Organizers:

- Debbie Andrew (dandrew@hawaii.edu)
- Mark Fortini (mark_fortini@berkeley.edu)
- Clement Hou (hou@berkeley.edu)
- Lester Pick (pick@umd.edu)

Example: *Caenorhabditis elegans*

- Research started in 1974 by Sydney Brenner.
- Often used to study development, nervous system, aging.
- Generation time: ~4 days
- One of the simplest organisms with a nervous system. Connectivity of its 302 neurons have been fully mapped.
- Resources:
<http://www.wormbase.org/>



GSA The Genetics Society of America Conferences

18th International *C. elegans* Meeting June 22-26, 2011 • University of California Los Angeles, California

Abstracts Housing/Travel Program Information Highlights Registration Exhibits/Advertising

View Poster Award Winners **Schedule of Events** **Abstract Search & Program Planner**

Download Program Guide (PDF) • Download Full Abstracts (PDF) • Download Program Addendum with Late Abstracts (PDF) • Pre-registrant List (PDF)

The Organizing Committee invites you to attend the 18th International *C. elegans* Meeting, sponsored by the Genetics Society of America. The meeting will be held June 22-26, 2011 at the University of California, Los Angeles campus. The meeting will begin on Wednesday evening, June 22 at 7:00 pm and will end on Sunday, June 26 at 12:00 noon.

On Friday, June 24 at 5:00 pm there will be a Keynote Address by Joseph Culotti, Samuel Lunenfeld Research Institute, Toronto, Canada

Additional invited speakers include:
Andrew Dillin, Salk Institute
Candace Boylston, Johns Hopkins University School of Medicine
Fabio Paro, New York University
Yoshi Inou, University of Tokyo
Barbara Meyer, UC Berkeley
Jean-Louis Boccazeau, ICGEM
Paul Sternberg, Caltech
Valerie Reinke, Yale
Sophie Jarman, SCSAC
Maria Dobrinski, Columbia

Plenary session chairs include:
Cynthia Kenyon, University of California, San Francisco
Jonathan Hodgkin, Oxford University
Susan Stronach, University of California, Santa Clara
Paul Sternberg, Caltech
Leon Avery, University of Texas Southwestern Medical Center
Sue Aert, Nagasaki University
Victor Ambros, UMMS Worcester
Barbara Meyer, University of California, Berkeley

► View Preliminary Schedule

Meeting Organizers:

BOOKMARK mobile schedule of events
View the *C. elegans* schedule of events on your mobile device
m.celegans.org

Follow the meeting using hashtag: #worm11
Contact Meeting Management
Add Meeting to your Calendar

GLOWorm Notes
View, Analyze, Annotate
Multi-D Movies of
Embryogenesis
Online

Limitation of Model Systems

- Our ultimate goal is to control human disease.
- None of the models can fully reproduce human physiology.
- Cultured human cell lines are also limited in many way.

Outline

- A brief review of the previous lecture
- Overview of model organisms
- Basics of evolution theory
- **Basics of MATLAB**

MATLAB Overview

- MATLAB stands for "matrix laboratory", a product of MathWorks Inc. (Natick, Massachusetts).
- It is both a language and a development and application environment.
- History of MATLAB
 - First developed in 1970's by Cleve Moler, coauthor of LINPACK & EISPACK
 - First written in FORTRAN; Later rewritten in C
 - Commercial development initiated by Jack Little
 - MathWorks was founded in 1984.
 - In 2000, rewritten based on LAPACK.

Sources:

<http://www.mathworks.com/company/aboutus/founders/clevemoler.html>

<http://www.mathworks.com/company/aboutus/founders/jacklittle.html>

http://www.mathworks.com/company/newsletters/news_notes/clevescorner/dec04.html

Advantages of MATLAB (I)

- MATLAB provides reliable and efficient numerical computation with friendly user interfaces.
 - Maple, Mathematica strong in symbolic computation
- Examples of numerical computation issues
 - Precision; numerical stability
 - Underflow and overflow
 - Code quality (debugging, exception handling)
 - Code efficiency (optimization)
- Visit www.netlib.org for more information about different numerical packages.

Advantages of MATLAB (II)

- Fast prototyping: MATLAB is an interpreted language
- Extensive toolboxes
- Versatile graphics
- Cross-platform: Windows, Unix, Linux, Mac OS
- Support parallel computing
- Support object oriented programming
- Large groups of users

MATLAB file exchange (use with caution)

<http://www.mathworks.com/matlabcentral/>

MATLAB Toolboxes (I)

- A large collection of basic math functions are provided in the MATLAB base package.
 - Function extensions are packaged as toolboxes.
 - Math and optimization
 - Optimization toolbox
 - PDE toolbox
 - Genetic algorithm and direct search algorithm
 - Statistics & data analysis
 - Statistics toolbox
 - Curve fitting toolbox
 - Spline toolbox
 - Neural network toolbox
-

MATLAB Toolboxes (II)

- Signal & image processing
 - Signal processing toolbox
 - Image processing toolbox
 - Wavelet toolbox
- Third party toolboxes
 - Pattern recognition toolbox: www.prtools.org
 - Wavelet toolbox: <http://www-stat.stanford.edu/~wavelab/>

Limitations of MATLAB

- Operation details are hidden.
- Limited efficiency: MATLAB is an interpreted language.
 - Compiler also available
 - Can use MEX (MATLAB executable) to call DLL implemented in C
- Lack of properties to support large scale software development
 - E.g. Implicit & dynamic data type
- MATLAB is the required implementation language for this class.

MATLAB Practice

- How to write a MATLAB function
 - Video
- Reminder: MATLAB computation results can be saved in .mat files and loaded back.
- Reminder: MAT files are exchangeable on different platforms.

Getting Help with MATLAB

- First, read related references and practice.
- For a specific function, it is often helpful to look in MATLAB online help.
- For a general question, it is often helpful to check related toolbox manuals.
- If none of these works, direct your questions to the instructor.

Required Reading

- MBoC 5/e chapter 1

Questions?