GENOMES & GENOMICS

PSS/BCH 8653
Fall 2014

Time and place: 12:30 – 1:45 PM TR, Pace Seed Technology Building, Room 119

Instructor: Daniel Peterson, A131 HPC Building, Phone: 325-2747, e-mail: peterson@igbb.msstate.edu
Texts: There is no formal textbook for the class.
Grading: Traditional

There will be **two exams** (125 points each) and a **final exam** (150 points). Seventy-five points of the final will be based on the material covered since the 2nd "in-term" exam and 75 points will be based on material from the first two-thirds of the course.

An additional 100 points will be based on a **Reading/Writing Assignment** (see below for details).

In other words, grades will be based upon a total of 500 points distributed as follows:

Exam 1	125 points
Exam 2	125 points
Reading/Writing Assignment	100 points
Final Exam	150 points
	500 points

1) Material for the **first exam** will end Thursday, September 20 and the exam will be held **Tuesday, September 25**.
2) Material for the **second exam** will end Thursday, November 1 and the exam will be held **Tuesday, November 6**.
3) The **Writing Assignment** will be due on **Tuesday, October 16**.
4) The **final exam** will be held on **Tuesday, December 11 (12-3 PM)**.

Students are held responsible for the material in the same detail in which it was presented in class or as indicated by the instructor.

CLASS CALENDAR (subject to change)

AUGUST
19 - Lecture 1
21 - Lecture 2
26 - Lecture 3
28 - Lecture 4

SEPTEMBER
02 - Lecture 5
04 - Lecture 6
09 - Lecture 7
11 - Lecture 8
16 - Lecture 9
18 - Exam 1
23 - Lecture 10*
25 - Lecture 11*
30 - Lecture 12

OCTOBER
02 - Lecture 13
07 - Lecture 14
09 - Lecture 15
14 - Lecture 16
16 - Lecture 17, **Essay due**
21 - Lecture 18
23 - NO CLASS, Fall Break
28 - Lecture 19
30 - Exam 2

NOVEMBER
04 - Lecture 20
06 - Lecture 21
11 - Lecture 22, **Essay revision 1 due**
13 - Lecture 23
18 - Lecture 24
20 - Lecture 25
25 - Lecture 26
27 - NO CLASS, Thanksgiving Break

DECEMBER
02 - Lecture 27
09 - FINAL EXAM, 12-3 PM

* Peterson in China

TOPICS (subject to change)

Unit 1. Fundamental Biological Concepts

- A. *Genome* and *Genomics*
  - 1. Definitions
  - 2. Things w/ genomes and w/o genomes
- B. Editorial: "Failure of Scientific Education" and "The Balance of Nature"
- C. Fundamental biological concepts
  - 1. Central Dogma of Genetics
  - 2. Genetic Code
  - 3. Nucleic Acids
    - a. Nucleotides
    - b. Denaturation
    - c. Renaturation
  - 4. Replication
  - 5. Types of RNA/Transcription
  - 6. Translation
  - 7. Genes, alleles, and loci
  - 8. cDNAs, ESTs, transcripts
  - 9. Recombination
  - 10. RNA World

Unit 2. Molecular Biology and Molecular Mapping

- A. Restriction enzymes
- B. Molecular cloning
  - 1. Constituents of a clone
  - 2. Plasmid features
    - a. Antibiotic resistance genes
    - b. Alpha-complementation
    - c. Partitioning and replication
- C. DNA clone libraries
  - 1. Major types
    - a. cDNA
    - b. Genomic
    - c. Expression
  - 2. Ordered libraries
    - a. Robot clone picking
    - b. Clone archival
- E. Gel electrophoresis
  - 1. Standard agarose
  - 2. Pulsed-field gel electrophoresis (PFGE)
- F. Blotting techniques
- G. Polymerase Chain Reaction (PCR)
- H. Fluorescence *in situ* hybridization (FISH)
- I. Molecular markers
  - 1. Features
  - 2. Types
    - a. RFLPs
    - b. SSRs
    - d. SNPs
    - e. PCR-based
  - 3. Molecular mapping

Unit 3. DNA Sequencing

- A. Chemical sequencing (Maxam-Gilbert)
  - 1. Introduction
  - 2. Chemistry
- B. Chain termination sequencing (Sanger)
  - 1. Original Sanger sequencing
  - 2. Dye terminators
  - 3. Cycle sequencing
  - 4. Capillary electrophoresis
  - 5. Modern Sanger sequencing
- C. Next generation sequencing
  - 1. Basic concepts
    - a. Synthesis sequencing
    - b. Polonies
    - c. Single molecule vs. polony seq.
    - d. DNA libraries
  - 2. 454
    - a. Pyrosequencing
    - b. Chemistry
    - c. Paired-end sequencing
  - 3. Illumina
    - a. Reversible chain termination
    - b. Chemistry
    - c. Paired-end sequencing
    - d. Indexed libraries
    - e. HiSeq & MiSeq
  - 4. Pacific Biosciences
    - a. SMRT technology
    - b. Hairpin ends
    - c. Strobing
  - 5. Others
    - a. SOLiD (ABI)
    - b. Ion Torrent
    - c. Helicos
  - 6. Nanopore sequencing
    - a. Theory
    - b. Strand
    - c. Exonuclease
    - d. Solid state

Unit 4. Prokaryotic Genomes

- A. Introduction
- B. Prokaryotes
  - 1. Characteristics
  - 2. Monera
  - 3. Archaea
- C. The Prokaryotic Cell
- D. The Prokaryotic Genome
  - 1. Bacterial chromosome
  - 2. Archaeal chromosome
- E. Prokaryotic Genes

Unit 5. Viral Genomes

- A. Definition of Virus

B. Structure - Virion shapes
C. Transfection
D. Viroids
E. Virus reproductive cycle
1. Lytic reproductive cycle
2. Lysogenic reproductive cycle
3. Enveloped virus reproduction cycle
F. Plant viruses
G. Types of Viral genomes
1. DNA viruses
2. RNA viruses
3. Retroviruses - Generic retrovirus genome
H. Transduction
I. Viruses 'R' Us – Us 'R' Viruses

Unit 6. Organellar Genomes

A. Introduction to chloroplasts & mitochondria
B. Endosymbiont theory
C. Secondary endosymbiosis
D. Chloroplasts
E. Mitochondria
F. Reproduction of mitochondria and chloroplasts
G. Maternal inheritance of mitochondria

Unit 7. Eukaryotic Genomes

A. Eukaryotes – Definition
B. Ring of Life
C. Characteristics of eukaryotes
D. Eukaryotic genomes
1. Ploidy, Polyploidy, and Aneuploidy
2. C-value and the C-value paradox
3. Gene duplication
4. Repetitive DNA
E. Eukaryotic genes
1. Exons
2. Introns
3. Spliceosome and alternative RNA splicing
4. Regulation of eukaryotic genes
5. Induction
6. Eukaryotic vs. prokaryotic gene regulation
7. Other gene control mechanisms
8. Promoter model
F. Gene expression
1. Enhancers
2. Silencers
3. Insulators and Insulators in imprinting
G. Gene islands and interspersion
H. Gene evolution and speciation
I. Differential gene expression

Unit 8. Regulatory RNAs

A. Post-transcriptional gene regulation
1. miRNAs
2. siRNAs
3. RNAi
a. Evolution & function
b. RNA components
c. Protein components
d. Mechanism
e. Variations in eukaryotes
f. In prokaryotes
4. Use of miRNAs/RNAi
a. Biomarker development
b. Gene knockdown
c. Functional genomics
d. Health & disease treatment
e. Biotechnology
B. Other small RNAs

Unit 9. Mobile Elements

A. Introduction
1. Discovery
2. Origins
3. Autonomy
B. Classification
1. Retrotransposons
a. LTR retrotransposons
b. LINEs
c. SINEs
2. DNA transposons
a. TIR elements
b. Helitrons
c. Mavericks
C. Non-autonomous elements
1. MITEs
2. LARDs
3. SNACs
4. TRIMs
D. Mobile elements in evolution

Unit 10. Nucleus and Chromatin

A. Nuclei
1. Size and shape
2. Nucleus structure
a. Envelope
b. Pores
c. Lamina
d. Matrix
B. Chromatin
1. Matrix attachment regions (MARs)
2. Scaffold attachment regions (SARs)
3. Eukaryotic nucleosomes
4. 10 nm chromatin fiber
5. 30 nm chromatin fiber
6. Eukaryotic chromosome condensation
7. Nucleosomes & transcription
C. Euchromatin and heterochromatin
1. Definitions
2. CpG islands
3. Types of heterochromatin
4. Position-effect variegation (PEV)

5. Nucleolus

Unit 11. Chromosomes & Cell Cycle

A. Chromosomes
1. Homologous chromosomes
2. Idiogram and karyotype
3. Sister chromatids
4. Nucleolus Organizer Regions (NORs)

B. Cell cycle of eukaryotes
C. Euploidy & aneuploidy
D. Chromosome aberrations

Unit 12. Meiosis, Recombination, and Sex

A. Meiosis and sex
1. Fertilization
2. Meiosis and ploidy
3. Meiocytes
4. Mixis and apomixes
5. Amixis

B. Evolution of meiosis
C. Results of meiosis
D. Stages and substages of meiosis
E. Sex, meiosis, & diversity

Unit 13. Physical Mapping

A. BACs
1. BACs vs. YACs
2. BAC vectors
3. "Ordered" BAC libraries
4. Genome coverage

B. Macroarrays
C. Probes
1. ESTs
2. Molecular markers
3. Sequence tagged sites (STSs)
4. Sequence tagged connectors & BAC end sequences
5. Overgos

C. Traditional physical mapping
1. Steps in physical mapping
2. Minimum tiling paths
3. Insert sizes

D. Bar-code physical mapping
1. Steps
2. Minimum tiling paths
3. Advantages and limitations

E. Optical mapping
F. Cytomolecular mapping

Unit 14. Genome Sequencing

A. Sequencing strategies
1. Whole genome shotgun sequencing (WGSS)
2. Clone-by-Clone Sequencing
3. Gene enrichment
a. EST sequencing
b. Methylation Filtration (MF)
c. Hypomethylated partial restriction
d. Methyl-spanning linking libraries
e. Cot Filtration (CF)
f. Gene enrichment combinations
4. Bar-code synthesis sequencing
a. Utility
b. A case study

B. Assembly
C. Utilizing whole genome sequences

Unit 15. Gene Expression

A. ORFs (open reading frames)
B. Differential gene expression techniques
1. Northern blotting
2. EST sequencing
3. Microarrays
4. Gene microarrays
5. Bisulfite sequencing
6. RNA-Seq

C. Microarray methods
1. Quantifying gene expression
2. Changes in expression over time
3. Large-scale expression analysis
4. Unigene sets
5. Limitations

Unit 16. Genomic Diversity

A. A genome sequence?
B. SNPs and indels
D. SNPs as molecular markers
E. Reference genomes
F. Detecting SNPs and indels
G. DNA resequencing techniques
1. PCR and resequencing
2. Oligonucleotide chips
3. Array-based resequencing
4. Detecting base mismatches
5. DHPLC
6. Flow cytometry
7. Synthesis sequencing

H. Synteny
I. Molecular phylogenetics

Unit 17. Evolution of Genomics

A. *Omes* and *Omics*
1. Proteomics
2. Transcriptomics

B. Genomics subdisciplines
1. Functional genomics
2. Comparative genomics
3. Structural genomics

C. Gene -> Protein -> Phenotype
1. Gene knockout
2. Yeast two-hybrid system
3. Directed mutagenesis & gene synthesis
4. Gene knockdown/RNAi

Writing Assignment (worth 100 points)
All students should be able to get the full credit (100 points) or nearly full credit on this assignment. Essays should be turned in by September 16. Dr. Peterson will read the essays, give each an "initial score," and suggest revisions. Students can improve their score by making the suggested revisions and returning a revised copy of their essay to Dr. Peterson for re-grading. If Dr. Peterson finds that the essay needs no further revisions, the student will receive full credit. If not, the essay will be returned with additional suggested revisions. After two rounds of review it is hoped that, through the revision process, all students will have essays that merit full credit.

Each student is required to write an overview of his/her dissertation or thesis research project. The overview is limited to a 1 to 2 page *Project Description* and a *References Cited* page(s) (i.e., a page providing an alphabetized listing of publications cited in the *Project Description*). The *Project Description* should provide key background information, outline the main goals of the project, and provide an overview of the methods to be utilized. In addition, **it should clearly discuss the value of the project (directly or indirectly) to humankind**. Students can summarize preliminary research results if desired. The *Project Description* should be prepared so that it can be readily understood by someone with a moderate knowledge of biology (*e.g.*, someone with a B.S. degree in biological sciences). References should be cited in the text and listed on the *References Cited* page using the format described below. Ask Dr. Peterson if you have questions about citation format and appropriateness.

Citing References
References should be cited in the text using the Harvard (name−date) system. Where there are three or more authors, only the first author's name should appear, followed by *et al*. Where several references are cited at the same point in the text, these should be arranged in chronological order. In the *References Cited* list, citations should be arranged in alphabetical order. References should include: names and initials of all authors; year of publication; full title of the article; source using abbreviations for journals as shown in *Index Medicus*; volume number; and first and last page numbers. Abstracts should be identified as such. For citations from books, the chapter title should be followed by the names and initials of all editors, the title of the book, edition, place of publication, publisher and first and last page numbers.

Examples:
Harrison G (1989) When we was fab. *J. Fab* **16**:E231.
Lennon JW (1968) An estimate of holes in Blackburn, Lancashire. *J. Holes* **22**: 45-48.
Lennon JW, Harrison G, Starkey R, McCartney JP (1969) A day in the life of a hole filler. In: *Confessions of a Day Tripper*. Edited by: Martin G. Apple Publishing, Liverpool, England, pp. 53-69.
Lennon JW, McCartney JP (1968) *A Census of Holes in the British Isles*. George Martin Publishing, London.
McCartney JP, Starkey R, Harrison G, Lennon JW (1970) Fixing a hole. *Sgt. Pepper's J. Constr. Sci.* **29**: 12-34.

Only accepted papers/books/chapters should be referenced; all unpublished material should be referred to in the text as 'in preparation', 'personal communication,' or 'unpublished observations,' and should not be included in the reference list.

You can cite Internet articles, webpages, etc., if necessary. However, remember that popular magazine articles, blogs, and websites do not undergo the same sort of peer review as scientific journal articles. When citing an Internet source, please consult the following guide provided by the American Psychological Association: http://www.apastyle.org/manual/index.aspx.

Wikipedia – In my humble opinion, Wikipedia is one of the greatest things ever invented. However, **DO NOT CITE WIKIPEDIA!** It is not a scientifically refereed source of information.