Bio 311 Learning Objectives

This document outlines the learning objectives for Biol 311 (Principles of Genetics). Biol 311 is part of the BioCore within the Department of Biological Sciences; therefore, it is meant to provide a foundation in the field of Genetics that will be important for the topics covered in many of the more advanced courses offered in the Department of Biological Sciences.

Learning Objective 1- Understand how the behaviour of chromosomes during Meiosis can explain Mendel’s Laws of Equal Segregation and Independent Assortment

- What are the key features of chromosomal behaviour in meiosis that cause alleles to be segregated equally?
- What are the key features of chromosomal behaviour in meiosis that cause alleles of different genes to assort independently?
- What are the differences between mitosis and meiosis that result in identical vs. non-identical products, respectively?
- How does chromosomal behaviour in meiosis explain dominant and recessive inheritance patterns?
- How are parental and recombinant gametes formed for genes on different chromosomes?

Learning Objective 2- Understand how inheritance patterns are affected by position on chromosomes

- How does the behaviour of sex chromosomes in meiosis explain sex-linked inheritance patterns?
- How are parental and recombinant gametes formed if two genes are on the same chromosome?
- What happens to the chromatids, and DNA molecules, when crossing-over occurs?
- How can the relative position between genes be inferred based on the frequency of recombinant gametes?
- How does the frequency of recombinant gametes correlate with the frequency of crossing-over?
- How to perform a three-point test cross.
- Understand why the maximum recombination frequency is 50%

Learning Objective 3- Understand the similarities and differences between how genetic information is passed on in eukaryotes and prokaryotes

- How is genetic information passed between bacterial cells?
- How is the F factor transferred from one bacterial cell to another.
- How are Hfr strains generated in bacteria.
- How can interrupted mating be used to map genes on a bacterial chromosome.
- Even though meiosis does not occur in prokaryotes, how can principles similar to eukaryotic gene mapping be used to map prokaryotic genes?
- How is genetic information passed from a virus to bacterial or mammalian cells?
• How can transducing viruses be used to map bacterial chromosomes.

Learning Objective 4- Gain an appreciation for how genes work together in biological processes
• How can a complementation test allow you to determine if two mutations are located in the same gene.
• How can genes be ordered in a biochemical pathway
• How is the phenotypic ratio affected by dominant or recessive epistatic relationships between to genes.
• How is the phenotypic ratio affected by suppressor mutations.
• What are penetrance and expressivity, and how can they affect phenotypic ratios?

Learning Objective 5- Chemical nature of heredity
• Define a gene according to its chemical nature.
• List the three components that make up a nucleotide.
• Describe how nucleotides are joined together via 3’,5’-phosphodiester bonds and list which groups are involved in the formation of these bonds.

Learning Objective 6- Genetic variability and DNA polymorphisms
• List and distinguish between SNPs, SSLPs and large-scale chromosomal changes.
• Differentiate between spontaneous and induced processes that cause the occurrence of DNA polymorphisms.
• Describe the process of tautomerization and how this process can result in the occurrence of SNPs.
• Describe the process of DNA slippage and how this process can result in the occurrence of SSLPs.
• Describe how the teaching of DNA barcoding can be used to differentiate between different species based on DNA polymorphisms.

Learning Objective 7- Detection of DNA polymorphisms
• Describe how a sample of DNA can be amplified in a test tube using the process of PCR.
• Design forward and reverse primers for use in a PCR reaction.
• Describe how the sequence of a segment of DNA can be determined using dideoxy sequencing and agarose gel electrophoresis.
• Describe how the Sanger sequencing technique was modified to sequence entire genomes.
• Describe how restriction enzyme digestion in combination with agarose gel electrophoresis can be used to detect DNA polymorphisms.

Learning Objective 8- DNA polymorphisms and phenotypic change
• Distinguish between the terms “polymorphism” and “mutation”.
• List and distinguish between the different types of mutations in the coding and non-coding regions of genes that result in phenotypic change.
• Describe how each type of mutation can cause a phenotypic change.
• Describe how the techniques of Southern blots, Northern blots and Western blots can be used to detect the presence of mutations and polymorphisms.
• Describe how microarrays can be used to detect the effect of mutations.
• Describe how restriction enzyme digestion in combination with agarose gel electrophoresis can be used to detect the presence of mutations and polymorphisms.

Learning Objective 9- Genetic variability and the control of gene expression in prokaryotes
• Describe the processes of repression and activation of the *lac* operon and list the conditions required to see these two different states.
• Describe the effect of mutations in the promoter, repressor, *lacZ*, and *lacY* genes on the expression of the *lac* operon.

Learning Objective 10- Genetic variability and the control of gene expression in eukaryotes
• Describe the processes of repression and activation of the GAL system in yeast.
• Describe the effect of mutations in the promoter, upstream-activating-sequence elements, and *GAL4* gene on the expression of the GAL system.

Learning Objective 11- Genetic engineering and the manipulation of DNA
• Describe the process of inserting a gene into a plasmid to form recombinant DNA.
• List and describe three processes that can be used to insert recombinant DNA molecules into cells.
• List and distinguish between the elements required on the plasmid for protein expression in a eukaryotic cell and in a prokaryotic cell.
• Describe how restriction mapping in combination with agarose gel electrophoresis can be used to verify whether a plasmid is carrying a DNA insert of interest.

Learning Objective 12- Epigenetics
• Define the term “epigenetics”.
• Describe how the methylation of genes can result in gene silencing.
• Describe how epigenetic tags added to histones can result in gene silencing.
• Describe how epigenetic changes can occur due to environmental exposure to chemicals.

Learning Objective 13- Control of gene expression and the process of development in eukaryotes
• Distinguish between spatial and temporal control of gene expression.
• Describe the effects of miRNA on gene expression and control of developmental timing.
• Describe how the study of mutant organisms has led to the identification of toolkit genes important in controlling development.
• Define the term “toolkit gene”.
Describe how toolkit genes control the proper development of an organism.

Learning Objective 14- Transposable elements
- Define the term “transposable element”.
- Distinguish between eukaryotic class 1 and class 2 transposable elements, and describe how each is replicated in the genome.

Learning Objective 15- Genetics of cancer
- Distinguish between loss-of-function mutations and gain-of-function mutations.
- Distinguish between oncogenes and tumor suppressor genes.

Learning Objective 16- Inheritance of complex traits
- Define the term “complex trait”.
- Distinguish between polygenic traits and multifactorial traits.
- Describe how genome-wide association studies (GWAS) are performed to study multifactorial inheritance.
- Describe the process of QTL mapping.

Learning Objective 17- Genetic testing and genetic therapies
- Describe the process of enzyme replacement therapy.
- Differentiate between germline gene therapy and somatic gene therapy.
- Debate the scientific and ethical concerns surrounding gene therapy.

Learning Objective 18- Gain an appreciation for how disruption of normal genetic processes can cause developmental problems and disease
- Be able to identify the mode of inheritance based on pedigree analysis.
- Be able to determine probabilities of specific genotypes based on pedigree analysis.
- Describe the different types of large-scale chromosomal rearrangements.
- Describe possible mechanisms by which large-scale chromosomal rearrangements occur.
- Become familiar with how health care workers utilize genetic understanding to aid in patient diagnosis and treatment.
- Become familiar with the ethical implications associated with new genetic technologies.

Laboratory component of BIOL 311

There are thirteen different laboratory exercises in this course, and each is briefly described below:

<table>
<thead>
<tr>
<th>Laboratory exercise</th>
<th>Learning objectives</th>
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<tbody>
<tr>
<td>1: Mitosis and meiosis in diploid cells</td>
<td>• describe and illustrate the steps involved in the processes of mitosis and meiosis;</td>
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</table>
- calculate the ploidy number and the copy number in each daughter cell after each of the different steps of mitosis when given the starting number of chromosomes and copy number in the mother cell;
- calculate the ploidy number and the copy number in each gamete after each of the different steps of meiosis when given the starting number of chromosomes and copy number in a meiocyte;
- list and describe two key differences between the processes of mitosis and meiosis; and
- use the two probability rules and the chi-square test to analyze genetic data.

| 2: Transmission of autosomal and X-linked genes in *Drosophila melanogaster* | use the model organism *Drosophila melanogaster* to identify different patterns of gene inheritance in monohybrid crosses;
- distinguish between patterns of autosomal and sex-linked inheritance on the basis of the results of reciprocal monohybrid crosses; and
- using the $\chi^2$ test, determine whether experimental data obtained in F$_2$ generations of monohybrid crosses are compatible with theoretical (Mendelian) expectations |
|---|---|
| 3: Independent assortment versus linkage in dihybrid crosses in *Drosophila melanogaster* | recognize parental and recombinant allele combinations amongst the gametes as well as the progeny of dihybrid individuals;
- identify different patterns of segregation by analyzing experimental data derived from F$_2$ and testcross generations of dihybrid crosses;
- determine if the experimental data obtained from dihybrid crosses are compatible with theoretical (Mendelian) expectations, using the $\chi^2$ test;
- differentiate between the segregation patterns of independent assortment and linkage on the basis of recombination frequencies; and
- recognize the implications of the unique absence of crossing-over in *D. melanogaster* males and utilize this idiosyncrasy in genetic mapping |
| 4: Bacterial gene transfer | • use proper sterile technique to handle and work with bacterial strains in the laboratory;  
• differentiate between an Hfr strain and an \( F^- \) strain;  
• set up a conjugation experiment between an Hfr strain and an \( F^- \) strain;  
• set up a gradient of transfer experiment using sterile technique and without contaminating media with unwanted biochemicals;  
• use data from a gradient of transfer experiment to draw a standard curve to determine the location of unknown traits and draw a chromosomal map; and  
• write a results section and a discussion summarizing the results obtained, with proper comparison to literature values |
|---|---|
| 5: Mapping genes to linkage groups using \textit{Caenorhabditis elegans} | • distinguish between male and hermaphrodite \textit{C. elegans} worms;  
• distinguish between self-crosses and out-crosses in \textit{C. elegans} and explain how each is set up;  
• use proper genetic nomenclature to refer to genes and their alleles in \textit{C. elegans};  
• predict the expected progeny from self-crosses and out-crosses when given the genotypes and/or phenotypes of the parent(s); and  
• use data from dihybrid crosses and the chi-square test to map the location of a gene to a linkage group |
| 6: Selection and identification of lysine synthesis mutants in \textit{S. cerevisiae} | • culture yeast strains in the laboratory using sterile technique;  
• use proper genetic nomenclature to refer to genes and their alleles in yeast;  
• successfully use replica plating to mate yeast haploid strains and transfer diploids from one medium to another; and  
• set up a complementation test and determine whether different mutant yeast strains belong to the same complementation group  
• write a results section and a discussion summarizing the results obtained, with proper comparison to literature values |
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<tr>
<th>Chapter</th>
<th>Title</th>
<th>Objectives</th>
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| 7       | Gummi bear genetics: inferring gene interactions                      | - recognize the presence of epistasis if given data from an F<sub>2</sub> generation of a dihybrid cross;  
- distinguish between the following types of epistasis: genes in the same pathway, recessive epistasis, dominant epistasis, and suppressors; and  
- use the Chi-square test to test a hypothesis of the presence of epistasis |
| 8       | Linking genotype to phenotype: Bioinformatics analyses of genes and diseases | - use PubMed to find a peer-reviewed review article on a topic of your choice;  
- use Google Patents to find a patent that relates to a gene and/or mutation implicated in a genetically-inheritable human disease;  
- use OMIM records to identify the mode of inheritance of a genetically-inheritable disease and its causative gene(s) and mutation(s);  
- use NCBI records to obtain data on gene architecture, mRNA length, and protein length; and  
- prepare and present a scientific poster that explains using molecular biology data why specific phenotypes are seen in individuals of certain genotypes |
| 9       | An introduction to genetically-modified organisms                    | - extract DNA from a food sample;  
- perform PCR on your isolated DNA;  
- prepare samples for agarose gel electrophoresis and run the gel; and  
- analyze an electrophoretogram to determine if a food sample contains genetically-modified ingredients |
| 10      | A look at paternity disputes using DNA markers and rapid-cycling Brassica rapa | - list the attributes that make rapid-cycling *Brassica rapa* a good model organism in genetics;  
- describe the process of paternity exclusion testing and describe the importance of obligate alleles;  
- distinguish between trait-based markers and DNA-based markers and describe their usefulness in paternity exclusion testing; and  
- determine a parent-child relationship given |
the genetic profiles of the individuals involved in a paternity dispute

| 11: *Alu* transposable elements and ancestry DNA | • extract and amplify DNA from the cheek cells of a human being;  
| | • analyze DNA polymorphisms using restriction enzyme digestion and gel electrophoresis; and  
| | • describe how genetic variability can be caused by transposable elements and SNPs |
| 12: Examining the *lac* operon | • culture *E. coli* strains in the laboratory using sterile technique;  
| | • qualitatively analyze the results of a β-galactosidase activity assay under different conditions to determine the likely location of a mutation in the *lac* operon; and  
| | • describe the effect of mutations in regulatory regions and in coding regions on the expression of the *lac* operon under different conditions |
| 13: An introduction to chromosomal aberrations | • list and distinguish between deletions, duplications, inversions and translocations;  
| | • describe how each of the above-listed large-scale chromosomal changes occurs; and  
| | • describe the effect of these large-scale chromosomal changes on gamete formation |