BIOL 207

Molecular Genetics and Heredity

3 Credits

Instructor: Delsa Fluney

Original Developer: Dr. Robert Cuny

Current Developer: Dr. Robert Cuny

Reviewer: Dr. Raymond Anana

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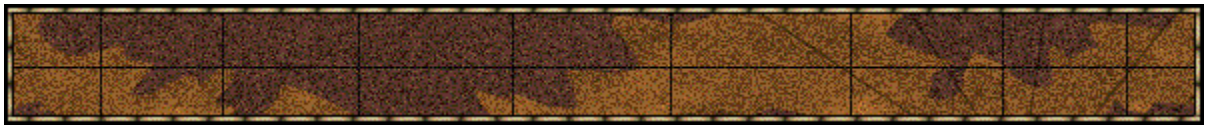

Molecular Genetics and Heredity

Calendar Description

The chromosomal and molecular basis for the transmission and function of genes. The construction of genetic and physical maps of genes and genomes. Strategies for the isolation of specific genes. Examples of regulatory mechanisms for the expression of the genetic material in both prokaryotes and eukaryotes.

Rationale

BIOL 207 deals with the passing on of traits from generation to generation in bacteria, plants, fungi, animals, and humans. Both classical Mendelian breeding experiments as well as modern gene cloning techniques are used to link the molecular events on the DNA of chromosomes to macroscopic or physiological changes.

This course is offered to students who plan to major in the biological sciences, the health professions, agriculture, or students of other programs who need to fulfill natural science requirements. BIOL 207 is a prerequisite for senior level courses in genetics, biotechnology, microbiology, cell and molecular biology, physiology, and evolution. The course may also be taken as an elective by students interested in heredity.

Prerequisites

BIOL 107

Co-Requisites

None

Course Learning Outcomes

Upon successful completion of this course, students will be able to (cognitive skills)

1. explain chromosome structure and chromatin composition, karyotype and chromosome banding pattern.
2. describe the structural and functional organization of genomic DNA, genes, regulatory, other functional and non-functional sequences.

3. discuss the chromosome theory of inheritance, the cell cycle, the phases of mitosis and meiosis I, II, and bacterial binary fission.
4. epitomize sexual reproduction and recombination, as well as conjugation of bacteria or ciliates.
5. outline the Mendelian analysis, dominance, random segregation, independent assortment, probability, pedigree analysis, and allele frequency.
6. itemize gene product interactions, such as multiple alleles, pleiotropy, polygenic inheritance, epistasis, complementation, penetrance.
7. specify sex linkage, carriers, sex determination, X-chromosome inactivation, Barr bodies; life cycles, gametophyte and sporophyte generations.
8. identify autosomal linkage, recombination frequencies and map distance, in dihybrid and two or three-point test crosses.
9. quote the chromosome mapping techniques, intragenic maps, interference, mapping function for long distances; ordered and unordered tetrads.
10. distinguish extranuclear inheritance in mitochondria and chloroplasts, and mitotic recombination.
11. recognize maternal effect mutants expressed up to gastrulation, positional information, polarity-gap-pair rule-segment polarity-homoeotic genes, homeobox.
12. quote the DNA theory of inheritance, chemical structure of the DNA double helix, DNA-binding motifs of DNA-associated enzymes.
13. specify the semi-conservative replication of DNA, the function of DNA polymerases, and other replication enzymes in the replication fork.
14. discuss the one gene-one polypeptide hypothesis, transcription, eukaryotic RNA exon splicing, translation into proteins by using the universal genetic code.
15. itemize bacterial and viral recombination by double crossover, conjugation, transformation, transduction, and transfection.
16. define mutation types at DNA and protein levels, mutagens and carcinogens, recognition of DNA lesions, point mutations, and enzyme action in DNA repair.
17. distinguish nondisjunction, polyploidy, aneuploidy, duplication, deletion, translocation, inversion, and reproductive isolation.
18. name the recombinant DNA techniques, DNA restriction, cloning vector properties, genomic, chromosomal, and complementary DNA library construction.
19. explain the isolation of genes or other DNA sequences, *in situ* DNA-DNA or RNA-DNA hybridization and electroblotting techniques.
20. outline enzymatic DNA or RNA chain termination, ion torrent, and pyro-sequencing; radioisotopic, enzymatic or fluorescent tagging of nucleic acid probes.
21. specify *Taq* DNA polymerase chain reaction, chromosome walking, shotgun genomic read assembly, chimaeric genes, and transgenic organisms, *CRISPRcas9*.
22. distinguish gene regulation in *Escherichia coli*: the *trp, ara, lac* operons, promoters, operators, leader peptide, attenuation, repressors and activators.
23. itemize gene regulation in eukaryotes: ß-globin proximal enhancer elements, immunoglobulin genes; transposons and retrotransposons, gene amplification.
24. list yeast *GAL* and *MAT* systems, ß-interferon enhanceosome, histone acetylation or methylation, barrier insulator, enhancer-blocking insulator, imprinting.

Upon successful completion of this course, students will be able to (applied skills)

25. recognize stages of mitosis in onion root tips and whitefish blastulas, as well as meiosis I and II in rye anthers and grasshopper testes; as well to prepare acetocarmine-stained chromosome spreads of onion root tips.
26. adjust compound and dissecting light microscopes to assess phenotypes of small objects, like, onion root cells, rye anther cells, and flies.
27. work safely in a Level-2 biosecurity lab, using aseptic technique, inoculation rod, and heating mantle; to sample and streak out cultures, prepare bacterial or yeast lawns using a sterile glass spreader and alcohol lamp; dispose of biohazardous samples in the correct way.
28. test the induced histidine mutation reversion frequency after various doses of ultraviolet light exposure in yeast *Saccharomyces* on histone-negative medium, subtracting colonies of spontaneous mutations observed in unexposed control cultures.
29. calculate viable yeast cells in the original yeast cell suspension from colony counts in serial dilutions on complete medium, and to graph the results of serial dilution in complete medium and the results of increasing doses of ultraviolet light exposures.
30. identify the mutated gene in the methionine biosynthesis pathway of an auxotrophic strain of *Escherichia coli* that cannot grow on minimal medium, or minimal media supplied with some of the biochemical pathway intermediates.
31. revert a methionine auxotrophic strain (example $metB^-$) of *Escherichia coli* into a prototrophic strain by transforming it with a chloramphenicol-resistance plasmid with the wildtype allele (example pCA-$metB^+$) inserted.
32. write a scientific research report, with title, authors, lab address, abstract, introduction with hypothesis, methods and design, results presented in tables, graphs, pictures with statistics, discussion, and literature citation.
33. anesthetize and score *Drosophila* flies under the dissecting microscope for male/female sex, normal/vestigeal wing and red/white eye phenotypes.
34. construct Punnett squares to analyze *Drosophila* fly F_1 and F_2 generation reciprocal dihybrid crosses that involve an autosomal (*vestigeal* wing) and a sex-linked (*white eye*) gene.
35. formulate a null hypothesis based on Mendel's equal segregation or independent assortment for each of the two genes tested in the dihybrid crosses of *Drosophila* flies, and then make the corresponding numerical prediction.
36. apply Chi square statistical tests to the *Drosophila* fly counts, to calculate degrees of freedom, to compare the critical Chi square value, and to make a statement regarding significance and acceptance of the null hypothesis, or any alternative hypothesis.
37. distinguish linkage, including sex linkage, from independent assortment based on the recombination frequency and Chi square statistics with assigned *Drosophila* fly crosses, when using the online Classical Genetics Simulator.
38. extract ampicillin-resistant plasmid vector DNA from the *Escherichia coli* DH5 alpha strain, to restrict and ligate it with the *lux* operon and to transform ampicillin-sensitive competent *Escherichia coli DH5 alpha* cells with the recombinant ampicillin-resistant *lux* plasmid.

39. recognize bacterial colonies that carry the recombinant plasmid, based on their ampicillin-resistance but chloramphinicol-sensitivity, their green *lux* glow in the dark, and their white, not brown color on plates supplied with IPTG *lac* operon inducer and *S-gal* color substracte.
40. purify supercoiled recombinant as well as control plasmid DNA from *Escherichia coli* genomic DNA, RNA and proteins with the mini prep technique, and to restrict the plasmid DNA with the same restriction endonucleases.
41. separate the recombinant and control DNA restiction fragments by agarose gel electrophoresis, run parallel to molecular length standards, and to visualize them by UV-induced *Sybr-Green* fluorescence DNA detection.
42. extract genomic human DNA from hair follicles into sodium hydroxide solution, to amplify the non-coding *Alu* DNA element at the *PV92* Locus on chromosome 16, starting with synthetic primers in the DNA polymerase chain reaction on a thermocycler.
43. determine whether the human population sample of the class is in Hardy-Weinberg equilibrium based on the *PV92* Locus allele frequency, a selection-neutral non-functional DNA region.

Resource Materials

Required Textbook and Lab Manual:

Griffiths, A. J. F., Doebley J., Peichel, C., & Wassarman, D. A. (2020). *Introduction to genetic analysis* (12th ed.). New York, NY: W. H. Freeman, MacMillan Learning.

Williams, C. (2019-2020). *Biology 207, molecular genetics and heredity. Lab manual*. Edmonton, AB: Department of Biological Sciences, University of Alberta.

Cuny, R. (2020). *BIO 207. Molecular Genetics and Heredity*. *Course Notes*, printed, Lakeland College.

Cuny, R. (2020). *BIO 207. Molecular Genetics and Heredity*. Desire-2-Learn D2L online, Lakeland College.

Reference Text:

Deyholos, M., Locke, J., Harrington, M., Wolansky, M., Canham, L., Kang, M.K. (2015). *Open genetics lectures*. Edmonton, AB: Department of Biological Sciences, University of Alberta.

http://opengenetics.net/Files/OpenGenetics-Editable/OpenGeneticsLectures/OGL(Fall2015)Optimized(40MB).pdf

Conduct of Course

This is a 3 credit course with 3 hours of lecture and 3 hours of lab per week. (3-0-3).

Lectures - Three hours per week

The lectures are supported by PowerPoint data projection, white board, and occasionally by a short movie or animation. The printed course notes and electronic files placed on Desire-to-Learn must be supplemented by notes taken by the students. The library can be used to access the biological literature online databases. Students are expected to do the assigned reading in the textbook and lab manual on a weekly basis.

Labs - Three hours per week

In the laboratory students perform experiments on their own, or they work in groups. Safety procedures must be followed and **lab coats must be worn when in the Biosecurity Level 2 Lab**. The students formulate a hypothesis, use quantitative, and sometimes Chi square statistical tests to either accept or refute the null hypothesis. The student realizes that keen observation, logical analytical thinking, and accurate record keeping are essential to be successful in this field. When handling acids, bases, carcinogens, flammables, corrosives, pathogenic bacteria, or while viewing gels on the UV transilluminator, students must wear safety shields, goggles and surgical gloves. Do not start the high-speed centrifuge if the tubes are not balanced, or load a gel while the apparatus is plugged into the high-voltage power supply.

Students generally hand in completed lab worksheets for every lab activity within one week. In addition, half a lab report is required for the *his*-reversion UV mutagenesis, and a full lab report (with title, names and address, abstract, introduction with hypothesis, methods, results, discussion, and reference list) for the *met*-pathway transformation rescue. Reports should not exceed 2 pages single-spaced, excluding graphs and tables. Although the laboratory work may be performed in groups of up to 4 students, each student is responsible for an independent data analysis, and an individual interpretation of the results. Citation of peer-reviewed primary research articles follows a scientific format (usually APA).

The WHMIS Workplace Hazardous Materials Information System requires the safe handling and storage of chemicals, as specified in the (M)SDS Materials Safety Data Sheets. Live animals must be handled in accordance with the Guidelines of the Canadian Council on Animal Care CCAC, and cruelty or neglect is not tolerated. Microbes on Schedule 2 of the Human Pathogens and Toxins Act HPTA fall under the rules of the Pathogens Regulation Directorate of the Public Health Agency of Canada PHAC. Microbes and viruses are to be handled under supervision by qualified staff, must be fully contained, and must be destroyed before their disposal. All laboratory equipment is operated as specified in the Operation Manual.

Evaluation Procedures

The learning performance is evaluated in percentage points that reflect the weighted number of correct answers on exams, and the quality of the lab assignments. In the laboratory component,

students must achieve a mark of 50% or higher, which includes the lab exam, lab reports, worksheets, practical work, and group presentation.

The final grade is an aggregate of the following components:

Lecture:		
Lecture Quiz 1 (1)	5%	
Lecture Midterm Exam (1)	20%	
Lecture Final Exam (1)	35%	
(Lecture Total)		**60%**
Laboratory:		
Laboratory worksheets (7+3bonus)	14%(+4%bonus)	
Half Lab Report(UV mutagenesis)(1)	3%	
Full Lab Report (BCP plasmids)(1)	5%	
Group presentation (1), draft (1)	3%	
Lab Final Exam (1)	10%	
Laboratory practical work	5%	
(Laboratory Total)		**40%**
Total		**100%**

No supplemental assignments or exam re-writes are allowed in the University Studies Department. Lecture exams are composed of a 2:1 mixture of multiple choice questions and short answer questions. The laboratory exam is a practical exam about the laboratory experiments; stations are set up at the lab benches, and students take turns answering the questions at each station. The laboratory reports do not exceed 2 pages single-spaced, excluding tables and graphs. They follow a scientific format: Title, author's name and address, abstract, introduction with hypothesis, methods, results with tables and graphs, discussion, reference list (APA). Worksheets provide a record of the data collected and their analysis. Late submissions of assignments suffer a 5% deduction per day late on the mark, except under documented extraordinary circumstances.

Cheating, falsifying or fabrication of laboratory data, plagiarism, copyright, non-compliance with course procedures, safety regulations, or the code of conduct, are academic and professional offences. Depending on the severity of the offence, a student may be reminded, sent out of the classroom, reported to the department chair, may have marks deducted, assigned a failing grade in the course, or may be expelled from the college.

Grade Equivalents and Course Pass Requirements

A minimum grade of D (50%) (1.00) is required to pass this course.

Letter	F	D	D+	C-	C	C+	B-	B	B+	A-	A	A+
Percent Range	0-49	50-52	53-56	57-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-100
Points	0.00	1.00	1.30	1.70	2.00	2.30	2.70	3.00	3.30	3.70	4.00	4.00

Students must maintain a cumulative grade of C (GPA - Grade Point Average of 2.00) in order to qualify to graduate.

Attendance

Attendance is recorded by the instructors, and the lab attendance is mandatory. If more than 2 labs are missed, excused or unexcused, the student is required to withdraw (RW) or is assigned a failing grade (F) for the entire course. If you do not meet the lecture attendance requirement of 80%, the Registrar may withdraw you from the course (RW). If you are absent due to illness or due to a critical family situation, please provide the documentation. In any case, it is the responsibility of the student to acquire the missing information and to complete missed course work.

Students are only allowed to submit lab reports or worksheets for labs that they have attended. If the student's absence is excusable, the missed lab is not counted. If the absence is inexcusable, the lab assignment is assigned a mark of 0.

Course Units/Topics

Week	Type	Lectures and Labs
		CHROMOSOME THEORY OF INHERITANCE
1	Lec -	(LABOUR DAY), registration, orientation
	Lab -	
	Lec 1	Introduction, karyotype, chromatin packing levels, chromosome banding, epigenetics
	Lec 2	Eukaryotic DNA organization on chromosomes, functional sequences, repeats, telomeres
2	Lec 3	Mitosis(whitefish blastula), meiosis(lily anther, newt), proof of the chromosome theory, nondisjunction
	Lab 1	Mitosis (onion root tip, whitefish blastula); *Escherichia coli met* pathway: streak assigned auxotrophic strains on minimal media supplied with or without methionine or one of its precursors

		MENDEL'S ANALYSIS OF INDEPENDENT GENES
	Lec 4	Mendelian analysis, dominance, equal segregation, Punnett square
	Lec 5	Independent assortment, line presentation, probability of phenotypes, chi^2-test statistics
3	Lec 6	Extensions of Mendel's 1-gene analysis, lethal alleles, codominance, incomplete dominance, haploids
	Lab 2	Meiosis (rye anthers, grasshopper testis); observe growth of *Escherichia coli met* auxotrophs on the different media and identify the defective enzyme; work group sets transformation rescue design
	Lec 7	Two or more genes: Polygenic inheritance, pleiotropy, enzymes in the same biochemical pathway
	Lec 8	Two or more genes: Recessive and dominant epistasis, complementation, suppression, duplicates
4	Lec 9	Penetrance, expressivity, pedigree analysis, conditional probability
	Lab 3	Do *met* $^{A-F}$ plasmid transformation that rescues competent auxotrophic *Escherichia coli* cells when grown on minimal medium; group database search of a human genetic syndrome (for presentation)
		GENE LINKAGE AND GENE MAPPING
	Lec 10	Sex chromosomes, X-, Y-, XY-linkage, sex determination, XY, ZW. and X0 sex chromosome systems
	Lec 11	Lyon hypothesis, Barr bodies, gene dosage; autosomal linkage and recombination frequencies
5	Lec 12	Genetic map distance, dihybrid, 2-gene and 3-gene test-crosses, genetic maps, linkage groups
	Lab 4	Yeast *his*$^-$-*his*$^+$revertion UV-mutagenesis set-up, cell dilution series plated on minimal and histidine$^+$ media; UV exposure; test-streak *met* $^+$-plasmid-transformed *Escherichia coli* cells to minimal medium.
	Lec 13	**Lecture Quiz 1**; molecular markers, probes, physical chromosome maps, chromosome walking
	Lec 14	Correction of interference of close gene loci; mapping function for distant gene loci
6	Lec -	(THANKSGIVING DAY)
	Lab 5	Count viable and *his*$^+$revertant yeast cell colonies (half report); read results of *Escherichia coli met* $^-$ strain rescue (full report)
	Lec 15	Mitotic crossing-over; viral genetics, viroids, prions; Benzer's intragenic mapping in the rII locus
	Lec 16	Tetrad analysis in haploid fungi, ordered and unordered, centromere distance to gene locus
7	Lec 17	Extranuclear inheritance: chloroplast, mitochondrion, maternal effect (developmental) mutants
	Lab 6	Single gene inheritance in *Drosophila* flies: score the monohybrid crosses, autosomal (vestigeal) and sex-linked (white); chi^2-test statistics
	Lec 18	Bacterial recombination by conjugation, transduction, transformation, bacterial gene mapping

		DNA THEORY, REPLICATION AND TRANSCRIPTION
	Lec 19	Proof of the DNA theory of heredity, DNA is the genetic material, DNA structure
8	Lec 20	Origins of replication; the replication fork and bubble, DNA polymerases, replisome, telomeres
	Lab 7	Two gene inheritance in *Drosophila* flies: Classic Genetic Simulator assignments; human genetic syndromes literature search **group presentations**
	Lec 21	One gene–one polypeptide hypothesis, transcription, genetic code, translation on ribosomes
	Lec 22	**Lecture Midterm Exam**
9	Lec 23	RNA structure, cotranscriptional RNA processing, alternative splicing of RNA
	Lab 8	Plasmid pCA^{R}-*lux* restriction fragment ligation into pBSKII vector DNA and transformation of *Escherichia coli DH5-alpha* strian with pBSKII-*lux* plasmids
		MUTATIONS AND DNA REPAIR
	Lec 24	Mutation classification and detection systems, the Amos test
	Lec 25	Gene mutations, single nucleotide polymorphism, spontaneous and induced, mutagens, oncogenes
10	Lec 26	DNA lesion repair mechanisms, direct repair, excision repair, post-replication, transcriptional, SOS
	Lab 9	supecoiled plasmid DNA extraction from brown and white colonies by the miniprep technique; DNA restriction of pBSKII-*lux*, pCam^{R}-*lux*, and pBSKII with Kpn 1 and Bam H1 resriction enzymes
	Lec 27	Chromosome number mutations, auto- or allo-polyploidy, aneuploidy, trisomy, monosomy, nullosomy
	Lec -	(REMEMBRANCE DAY)
11	Lec 28	Deletions terminal-interstitial, insertions, translocations adjacent-alternate, inversions peri-paracentric
	Lab 10	Horizontal agarose gel electrophoresis of pBSKII-lux restriction fragments; discussion about plasmid restriction and transformation efficiency; PCR of *PV92* Locus of human hair follicle genomic DNA
		GENE REGULATION
	Lec 29	Gene regulation in bacteria, *lac*, *trp*, *ara* operons, promoters, negative repressors. positive activators
	Lec 30	Gene regulation in eukaryotes, promoters, enhancers, transposons, enhanceosome, condensin
12	Lec 31	Developmental genetics, *Drosophila* polarity, gap, pair-rule, segment-polarity genes, homeobox
	Lab 11	Horizontal agarose gel electrophoresis of polymerase chain reaction PCR-amplified human *PV92* DNA fragments; discussion about Hardy-Weinberg criteria in population genetics

		RECOMBINANT DNA AND MOLECULAR CLONING
	Lec 32	Recombinant DNA insert, cloning, shuttle, expression vectors, cDNA, restriction endonucleases
	Lec 33	DNA libraries, probes and screening, blots, agarose and polyacrylamide gel electrophoresis
13	Lec 34	Chromosome walking, RFLP restriction fragment length polymorphism, gene targeting
	Lab 12	**Final Lab Exam**
	Lec 35	DNA sequencing, dideoxy-, pyro-, nanopore methods, genomes, PCR polymerase chain reaction
	Lec 36	*In vitro* mutagenesis, gene therapy, RNAi interference, CRISPR-cas9, adeno- or baculo-virus vectors
14	Lec 37	Transgenic or chimeric organisms, knock-out mice, Ti plasmid T-DNA, metallothionein promoter
14/15		**Final Lecture Exam Period**

2602 - 59 Avenue, Lloydminster, Alberta, Canada T9V 3N7. Ph: 780 871 5700
5707 College Drive, Vermilion, Alberta, Canada T9X 1K5. Ph: 780 853 8400
Toll-free in Canada: 1 800 661 6490 E-mail: admissions@lakelandcollege.ca