2023 Fall Biology 2171 Genetics Course Outline

Instructor: Dr. Wensheng Qin
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Office Hours: CB4016, Tuesdays, 11:45 am to 12:45 pm (or by appointment or by zoom)
Lecture Location: SN 1015
Time: Tuesdays & Thursdays: 1:00-2:30 pm
Duration: 2023/05/09 – 2023/04/12
Credits: 0.50

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Textbook: ISE Genetics: From Genes to Genomes (7th Edition) by Michael Goldberg, Janice Fischer, Leroy Hood, and Leland Hartwell. Publisher: McGraw-Hill Education. Students are highly encouraged to buy this textbook, but not required. Whether you buy this 7th edition textbook or use other versions of the textbook or use another similar textbook, it is totally up to you. One copy of the textbook will be reserved in the library.

Additional Requirements: (1) Preview the textbook and think about the questions in the related chapter(s) before the applicable class. (2) Review the textbook and try to answer the questions in the chapter(s) after the class. (3) Read the entire lectured chapters 1-13 for exams. The PPT slides do not contain all the information needed for exams, you must study the textbook as well. (4) Students must understand well enough to solve all the problem questions in chapters 1-13.

Genetics Learning Objectives
Understand Mendel's genetic laws, experimental design, and how they apply to the heredity patterns which Mendel observed in pea plants.
Understand the link between genotype and phenotype.
Understand the difference between a character and a trait.
Understand the difference between dominant and recessive alleles and the difference between homozygous and heterozygous.
Understand extensions to the Mendel's laws.
Learn chromosome and inheritance and sex chromosomes.
Learn gene linkage, recombination, and gene mapping.
Learn DNA replication, gene mutation, and gene functional analysis.
Learn genome annotation and genomic analysis.
At the end of the course, students will also be able to finish the following tasks after their theoretical and experimental studies.

(1) Explain the mechanisms of simple Mendelian inheritance of traits, including X-linked traits, lethal traits, and other gene linkage.
(2) Explain what epistasis is, how a few types work, and how they generate the phenotype ratios observed.
(3) Create a Punnett square for multiple generations to predict genotypes and phenotypes of progeny.
(4) Conduct a Chi-squared analysis (Goodness of Fit, as well as Test for Independence) with a properly formatted Chi-Squared table, an appropriate null hypothesis, correct calculations, and conclusions.
(5) Set up and maintain cultures of Drosophila melanogaster (fruit flies).
(6) Anesthetise and manipulate Drosophila melanogaster to observe traits.
(7) Identify and sort Drosophila melanogaster based on sex and deviations from wild-type features.
(8) Create and evaluate a pedigree using standard nomenclature and symbols.
(9) Explain the inheritance method, probability of inheritance, and pedigree flags of the BRCA1 gene and its associated cancers.
(10) Discuss the effect of mutation, reproduction, and selection on the evolution of organisms, and how that affects speciation or conservation efforts.
(11) Effectively communicate opinions on genetics related societal topics e.g.,GMO foodstuffs, species interpretation in canids.
(12) Describe how Single Nucleotide Polymorphisms (SNPs) and Genome Wide Association Studies (GWAS) can help increase our knowledge of genes and loci involved with traits and diseases across multiple organism models, specifically in dogs and humans.
(13) Identify phenotypes and likely genotypes for simple genes in cats, corn, fast plants, and fruit flies.
(14) Describe how epigenetics and transposable elements affect traits and gene expression.
(15) Discuss how data collection, sample size, and biases may affect scientific results.

Grading Scheme: The PowerPoint slides do not cover all the information for exams, so intensive reading and understanding of the whole lectured chapters 1-13 are necessary.

1. Mid-term exam: October 19, 2023 [25%]. Covering the chapters 1-5. The midterm exam may include (1) Fill in the blank questions, (2) Multiple choice questions, (3) True/False questions, (4) Essay questions, etc.
2. Final exam (Chapter 6-13) [45%]. Final exam may include (1) Fill in the blank questions, (2) Multiple choice questions, (3) True/False questions, (4) Essay questions, etc.
3. Lab components [20%]. This will be assigned and evaluated by the lab instructor Mr. Michael Moore. His office is CB 3011A, and his phone number is 807-343 8010-8909 and his email is mnmoore@lakeheadu.ca.
4. Class attendance (10%): Some classes will be randomly selected to ask the students to sign attendance.

5. Bonus marks: Some bonus points for raising your final grades may be offered when necessary (see the notes below).

Notes: If you miss any examination (midterm exam or final exam), we strictly follow the university regulations of "Missed Examinations Due to Illness or Other Extenuating Circumstances". If you are permitted to write your missed exam, an alternative test paper (Test B or even Test C, Test D, etc.) will be made. Test B, C, D will be different or even totally different in formats and questions from the test questions in Test A for the class. Please try your best to avoid missing an exam.

Extra notes:
(1) We strictly follow the course outline as rules for the course.
(2) The important contents and information for examinations will often be emphasized in class. Occasionally, I will provide some example questions in the class. The example questions will be related to our contents but may not be from the textbook.
(3) Slides in D2L and slides for lecturing may be slightly different. To encourage students to take good notes of the lectures, the lectured slides will not be sent to the students.
(4) Bonus points:
[1] Actively ask questions and answer questions in the class.
[2] Pop quizzes, only for the students who attend the class.
[3] Each bonus point can value more or less than 1% adding to the student's final grade. The bonus point value depends on class average marks. If the class average marks are too low, pop quizzes may be arranged for extra bonus points.

Course contents and schedule

	Fall 2023	Chapters	[Part I: Basic Principles: How Traits Are Transmitted]
Week 1	Sept 5-10	1	Mendel's Principles of Heredity
Week 2	Sept 11-17	2	Extensions to Mendel's Laws
Week 3	Sept 18-24	3	Chromosomes and Inheritance
Week 4	Sept 25-Oct 1, 2023	4	Sex Chromosemes
Week 5	Oct 2-8	5	Linkage, Recombination, and Gene Mapping
	Oct 9-15 Fall Reading Week without Class)		[Part II: What Genes Are and What They Do]
Week 6	Oct 16-22 (Oct 19 Thursday Midterm 25%, covering chapters 1-5)	6	DNA Structure, Replication, and Recombination
Week 7	Oct 23-29	7	Mutation
Week 8	Oct 30-Nov 5	8	Using Mutations to Study Genes

Week 9	Nov 6-12	9	Gene Expression: The Flow of Information from DNA to RNA to Protein
Week 10	Nov 13-19	10	[Part III: Analysis of Genetic Information] Digital Analysis of DNA
Week 11	Nov 20-26	11	Genome Annotation
Week 12	Nov 27-Dec 3	12	Analyzing Genomic Variation
Week 13	Dec 4 Last Glass	13	The eukaryotic chromosome

Fall 2023 Term Courses	
First Day of Classes	Tuesday, September 5, 2023
Final Day of Classes	Monday, December 4, 2023
Final Date to Register (Add)	Monday, September 18, 2023
Final Date to Withdraw (Drop)	Friday, November 3, 2023
Examination Period	Thursday Dec. 7, 2023 - Sunday Dec. 17, 2023 (11 Days)
Exam Contingency Date	Monday, December 18, 2023

Assignments: Except the questions in the textbook after each lectured chapter, the following questions are for your reference as well. Submission of the assignments are not required, but one or more questions or similar questions may be used in the exams.

[1] Short hair in rabbits is produced by a dominant gene (l+) and long hair by its recessive allele (l). Black hair results from the action of a dominant gene (b+) and brown hair from its allele (b). Determine the genotypic and the corresponding phenotypic ratios of the F2 offspring, beginning with a parental cross of a female rabbit with brown hair and a male rabbit with long hair. Assume that the P female is homozygous for short hair and the P male is homozygous for black hair.

Answer:#	Genotype	Phenotype
1	l+l+ b+b+	Short Black
2	l+l b+b+	Short Black
2	l+l+ b+b	Short Black
4	l+l b+b	Short Black
1	l+l+ bb	Short Brown
2	l+l bb	Short Brown
1	ll b+b+	Long Black
2	ll b+b	Long Black
1	llbb	Long Brown

[2] In rats, the gene for the pigment (P) is dominant to no pigment (p). The gene for black (B) is dominant to the gene for cream (b). If a pigment gene (P) is absent, genes B and b are inoperative. Predict the genotypes and phenotypes of the F2 of a parental cross between a homozygous black rat and an albino homozygous for cream.
Answer: 9 Black; 3 cream; 4 colorless

	Genotype	Phenotype
1	PPBB	Black
2	PPBb	Black
2	PpBB	Black
4	PpBb	Black
1	ppBB	colorless
2	ppBb	colorless
1	PPbb	cream
2	Ppbb	cream
1	ppbb	colorless

[3] You have obtained an interesting flower for your garden from your neighbor. The neighbor has given you two pure lines of the plant, one with red flowers and one with yellow flowers. You decide to cross them and find that you obtain all orange flowers. The curious molecular geneticist in you decides to test two independent hypotheses: Hypothesis 1: Incomplete Dominance; Hypothesis 2: Recessive Epistasis. The first step in your test is to self the F1 orange plants, which you complete only to find that the results do not statistically distinguish the two hypotheses. a) What ratio of yellow, orange, and red would you expect in the F2 population for each hypothesis and b) what crosses would you complete next to definitively test your two hypotheses?

Answer:

a) The expected phenotypic ratio for recessive epistasis is 9:3:4, and for incomplete dominance, 1:2:1. b) Cross the yellow F2 flowers with true breeding red flowers. If the hypothesis for incomplete dominance is correct, the yellow color will be determined by a single gene and all F2 yellow flowers will be homozygous recessive and give rise to only orange flowers in the F3 population [aa x AA = Aa]. However, if the hypothesis for recessive epistasis is correct, a cross of F2 yellow and true breeding red flowers will give rise to some red and some orange flowers [Yyrr x yyRR = either yyRr or YyRr].

[4] In Drosophila, white eyes (w) and yellow body (y) are both recessive X-linked mutations. The wild type alleles, w+ and y+, control red eyes and dark body color, respectively. If a homozygous yellow body, red-eyed female is crossed with a dark body, white-eyed male, and F1 progeny are interbred, what will the phenotypes and ratios of the F1 and F2 be?

Answer:

F1—females: all dark body, red eyes

males: all yellow body, red eyes
F2—females: yellow body, red eyes—1/2
dark body, red eyes—1/2
males: yellow body, red eyes—1/2
dark body, white eyes—1/2

[5] In crosses of white-eyed Drosophila females with red-eyed males, Bridges recovered white-eyed daughters and red-eyed sons at a rate of around one per 2,000 offspring. (Most of the offspring were white-eyed males and red-eyed females.) He hypothesized that these exceptional progeny resulted from nondisjunction of the X chromosomes in meiosis in the female. Why did he suspect that nondisjunction was occurring in the female parent? What types of progeny would result from nondisjunction in the male parent?

Answer:

XXY are white-eyed females and XO are red-eyed males, so male nondisjunction does not account for the observed exceptions. The two XX's of XXY offspring must have come from the white-eyed female parent, and the lack of the second X in the XO, but with the presence of red eyes, also indicates that the X from the white-eyed female parent is missing.

[6] The Holliday model of recombination has been modified. The current model, termed the consensus model, is now consistent with current research. What are the five properties of recombination, as they are now understood?

Answer:

1. Homologs physically break, exchange parts, and rejoin
2. Breakage and repair create reciprocal products of recombination
3. Recombination events can occur anywhere along the DNA molecule
4. The exchange is precise, there is no gain or loss of nucleotides
5. Gene conversion can give rise to an unequal yield of two different alleles

[7] When Meselson and Stahl performed the experiment that showed that replication is a semiconservative process, they utilized E. coli, and various isotopes of nitrogen (15N and 14N). Explain briefly what their results would have been if DNA replicated conservatively.

Answer:

Following centrifugation, the first generation of replication would yield two bands—15N and 14N (no hybrid). The second generation would again result in the same pattern with no hybrid pattern ever revealed.

[8] How is DNA altered by hydrolysis, radiation, UV light, and oxidation respectively?

Answer:

DNA hydrolysis of A or G bases results in depurination and the DNA strand has a continuous sugar backbone but an unspecified base where the depurination occurred. X-irradiation breaks

the sugar backbone while UV light induces thymidine dimerization. Oxygen free radicals oxidize bases into analogs that do not hydrogen bond properly in the DNA double strand. During replication, mismatch pairing ends up creating a base change resulting in mutation.

[9] Chemical X has just been screened using the Ames test. A total of 5,000 bacteria were tested against 0.001 M, 1 M, 0.1M, and 1M concentrations for which 4, 1, 0, and 200 colonies grew respectively. Control plate of minimal media supplemented with histidine had 5,000 colonies while minimal media alone had only two. Interpret these data.

Answer:

The control plate supplemented with histidine has 5,000 colonies which indicates the total number of bacteria present in the sample. The control plate with no histidine has 2 colonies indicating that the natural rate of his- reversion is 2/5,000. Only the high concentration of 1M chemical X caused a his- reversion at a rate significantly higher than control indicating the chemical X is a mutagen only at high levels.

[10] The local pet store received several shipments of albino ferrets. You choose two males and two females as pets one breeding pair from the same litter, one from two different litters. When your ferrets' litters are born, one litter has normally pigmented offspring. State which offspring are albino and which are pigmented and explain why?

Answer:

The breeding pair from the same litter would have albino offspring (they would carry a mutation in the same gene) while the breeding pair with the unrelated male and female could have pigmented offspring if each had a mutation in different genes involved in pigmentation. The two unrelated albino ferret's mutations complemented each other's genetic deficiency leading to pigmented offspring.

(11) The trait of medium-sized leaves in iris is determined by the genetic condition *PP'*. Plants with large leaves are *PP*, whereas plants with small leaves are *P'P'*. A cross is made between two plants each with medium-sized leaves. If they produce 80 seedlings, what would be the expected phenotypes, and in what numbers would they be expected? What is the term for this allelic relationship?

Answer:
20 (large leaves), 40 (medium leaves), 20 (small leaves); incomplete dominance

(12) The trait for medium-sized leaves in iris is determined by the genetic condition *PP'*. Plants with large leaves are *PP*, whereas plants with small leaves are *P'P'*. The trait for red flowers is controlled by the genes *RR*, pink by *RR'*, and white by *R'R'*. A cross is made between two plants each with medium-sized leaves and pink flowers. If they produce 320 seedlings, what would be the expected phenotypes, and in what numbers would they be expected? Assume no linkage.

Answer:

20 large, red
40 medium, red
20 small, red
40 large, pink
80 medium, pink
40 small, pink
20 large, white
40 medium, white
20 small, white

(13) A color-blind woman with Turner syndrome (XO) has a father who is color-blind. Given that the gene for the color-blind condition is recessive and X-linked, provide a likely explanation for the origin of the color-blind and cytogenetic conditions in the woman.

Answer:
The woman inherited an Xrg chromosome from the father. Nondisjunction in the mother (either at meiosis I or II) produced an egg with no X chromosome, which, when fertilized by the Xrg-bearing sperm, produced the Turner syndrome condition.

(14) Dosage compensation leads to a variety of interesting coat color patterns in certain mammals. For instance, a female cat that is heterozygous for two coat color alleles, say black and orange, will usually have the "calico" or mosaic phenotype. Describe the chromosomal basis for the mosaicism (calico) in the female. Explain why chromosomally normal male cats do not show the mosaic phenotype, but XXY male cats can be calico.

Answer:
Because of dosage compensation, one of the X chromosomes randomly "turns off" early in development, such that one X chromosome may be active in one cell and the other X chromosome may be active in another cell. Once such a chromosome is inactivated, it remains so in daughter cells. Recessive alleles on the remaining active X chromosome are expressed because their normal allele (on the inactive X chromosome) is not capable of expression. Because males typically have only one X chromosome, X chromosome inactivation does not occur; however, in XXY males that are heterozygous for certain coat color genes, such inactivation and mosaicism are possible.

(15) Give the sex-chromosome constitution (X and Y chromosomes) and possible genotypes of offspring resulting from a cross between a white-eyed female (Xw XwY) and a wild-type male (normal chromosome complement) in *Drosophila melanogaster*. Include all zygotic combinations whether viable or unviable.

Answer:
X+XwXw = unviable (dies at third instar stage)
XwXwY = white-eyed female
X+Y = wild-type male
YY = unviable (dies at egg stage)
X+XwY = wild-type female

XwYY = white-eyed male
X+Xw = wild-type female
XwY = white-eyed male

(16) Assume that investigators crossed a strain of flies carrying the dominant eye mutation Lobe on the second chromosome with a strain homozygous for the second chromosome recessive mutations smooth abdomen and straw body. The F_1 Lobe females were then backcrossed with homozygous smooth abdomen, straw-body males, and the following phenotypes were observed:

smooth abdomen, straw body	820
Lobe	780
smooth abdomen, Lobe	42
straw body	58
smooth abdomen	148
Lobe, straw body	152

(a) Give the arrangement of alleles of the F1 Lobe females
(b) Which gene is in the middle?
(c) Determine the distances in map units for these three loci.
(d) What is the coefficient of coincidence and interference values?
(e) Is there positive, negative, total or no interference?

Answer:
(a) + + L/ sa sb +
(b) Lobe is in the middle.
(c) smooth abdomen---5---Lobe----------15----------straw body
(d) CC = 0; I = 1.0
(e) total interference (explains the observance of only six instead of the eight possible phenotypes in the offspring)

(17) In the fruit fly, *Drosophila melanogaster*, a spineless (no wing bristles) female fly is mated to a male that is claret (dark eyes) and hairless (no thoracic bristles). Phenotypically wild-type F_1 female progeny were mated to fully homozygous (mutant) males, and the following progeny (1000 total) were observed:

Phenotypes	*Number Observed*
spineless	321
wild-type	38
claret, spineless	130
claret	18
claret, hairless	309
hairless, claret, spineless	32
hairless	140
hairless, spineless	12

(a) With respect to the three genes mentioned in the problem, what are the genotypes of the homozygous parents used in making the phenotypically wild-type F_1 heterozygote?
(b) Which gene is in the middle?
(c) What are the map distances for the three genes? A correct formula with the values "plugged in" for each distance will be sufficient.

(d) What is the coefficient of coincidence? A correct formula with the values "plugged in" will be sufficient.
(e) What is the value for interference? Is there positive, negative, total, or no interference?

Answer:
(a) *cl h* +/*cl h* + and + + *sp*/+ + *sp*
(b)) *hairless*
(c) *cl*-------30-----*h*---10---*sp*
(d) 0.03/0.03 = 1
(e) I = 0; no interference

(18) Explain the composition and use of minimal medium in the study of bacterial genetics.

Answer:
Minimal medium consists of an organic carbon source such as glucose or lactose and a variety of inorganic ions: Na^+, K^+, Mg^{++}, Ca^{++}, and NH_4^+. It is useful in isolating bacterial strains (auxotrophs) that are incapable of synthesizing more complex nutritional requirements.

(19) Assume that one counted 67 plaques on a bacterial plate where 0.1 ml of a 10^{-5} dilution of phage was added to bacterial culture. What is the initial concentration of the undiluted phage?

Answer:
$67 \times 10^5 \times 10 = 6.7 \times 10^7$ pfu/ml (pfu = plaque-forming units)

(20) If the linker DNA between nucleosomes is 103 base pairs in length, how many H4 proteins are expected in a stretch of DNA 30,000 base pairs long?

Answer:
The nucleosome core particle (147 bp) combined with a linker region (103 bp) would total 250 bp. The total DNA length (30,000 bp) divided by 250 bp equals 120. Each of the 120 regions would contain one nucleosome with two H4 proteins each for a total of 240 H4 proteins.

(21) Describe the role of chemical modification in the generation of CpG islands. Predict where CpG islands are likely to be found within the genome.

Answer:
Not to be confused with histone methylation, the nitrogenous base cytosine within the DNA itself can also be methylated, forming 5-methyl cytosine. Cytosine methylation is usually negatively correlated with gene activity and occurs most often when the nucleotide cytidylic acid is next to the nucleotide guanylic acid, forming what is called a CpG island (Chapter 11, Page 211). Since CpG islands play a role in regulating expression, they are likely to be located in relative proximity to genes and regulatory regions such as promoters.

(22) Describe a difference between the RNA polymerases of eukaryotes and prokaryotes.

Answer:
In eukaryotes, three polymerases (I, II, III) have been identified; only one has been described in prokaryotes.

(23) In eukaryotes, which three factors appear to encourage the specific association of RNA polymerase(s) to a specific region of DNA?

Answer:
Promoters, enhancers, and transcription factors

(24) Describe the basic structure of normal adult hemoglobin and the abnormality observed in sickle-cell hemoglobin.

Answer:
The predominant form of adult hemoglobin is composed of two α and two β chains. In sickle-cell hemoglobin, the sixth amino acid in the β chain is valine instead of glutamic acid.

(25) In what ways do the amino acid side chains interact to influence protein function?

Answer:
Higher-level folding of proteins is dependent on a variety of interactions (ionic, covalent, hydrogen, hydrophobic, hydrophilic, etc.), which determine the functional three-dimensional structure of proteins.

(26) Under which condition(s) might one have an amino acid substitution in a protein that does not result in an altered phenotype?

Answer:
The possibility of a change in protein function, therefore phenotype, depends on the location and chemical properties of the involved amino acid(s). For example a silent mutation would produce no resultant effect and theoretically a nonpolar to nonpolar amino substitution would be less impactful than a nonpolar to polar.

(27) Three major types of RNAs are mRNA, rRNA, and tRNA. For each of the conditions below, predict the consequences in terms of the population of proteins being synthesized in a particular cell. What qualitative and quantitative changes, if any, are expected in the individual protein involved (if one is involved) and in the population of proteins produced in that cell?
(a) A frameshift mutation in mRNA. The condition is heterozygous in the involved cell.
(b) A deletion (homozygous) that removes approximately half of each type of rRNA genes.

Answer:
(a) Population of proteins: Half of the protein products of that gene will be defective, and the other half will be normal. Individual protein: The protein should show multiple amino acid substitutions "downstream" from the point of the mutation. If a nonsense triplet is introduced, the protein would be shortened in the substituted region.
(b) Population of proteins: There would be an overall reduction in protein synthesis. Individual

protein: All the proteins would be made in their normal form, but at reduced levels.

(28) Imagine that an Ames test was performed on a new red dye to determine if it will be safe for consumers. For this *his*$^-$ mutants are grown in growth media and the disk is soaked in the red dye. The results show that the reversion rate is not significantly above the spontaneous rate. Would you conclude that this dye is safe? Explain why or why not.

Answer:
No because we don't know if the liver metabolizes this dye into an unsafe mutagenic metabolite. We would need to incubate in liver enzymes to determine safety accurately.