UNIVERSITY OF BRITISH COLUMBIA
Biology 121 Sections 221/224 Instructor: Lynn Norman
Midterm 1 Answer Guide-v1, February 7, 2023

Name :	**XXXXXXXXX**	**XXXXXXXXXX**
	LAST NAME	**FIRST NAME**
Student Number:	**_____XXXXXXXXXXXX_____**	

Instructions:

1. Answer all questions in the space provided. Answers on the page for rough work (pg. 2) will **NOT** be marked unless specifically indicated next to a question.
2. Writing can be in pencil or ink, but pencil, erasable ink or answers with white-out **cannot** be remarked.
3. Answers may be in sentences or point form. Illustrations are acceptable but must be annotated.
4. Students suspected of any of dishonest practices will be immediately dismissed from the examination and will be subject to disciplinary action.
5. Other than **a one-page** (double-sided) study sheet (8.5" x 11"), no other memory devices are permitted. Study sheets that exceed the size limit may be confiscated and may be considered as cheating.
6. Students may not speak or in any other way communicate with other students while in the examination room.
7. Students may not expose their written paper to other students. The excuse of accidental exposure, forgetfulness, or ignorance will not be accepted.
8. Make sure you have 12 pages (6 pieces of paper) including this cover page.
9. Question and mark breakdown in on the back page (pg. 12)

Positive possum says –
"You got this!!!"

Question 1 (Mitosis & Meiosis) – 10 marks

Q1.1 Consider a 2N=6 animal. Fill in the blanks below: (**2 marks; 0.25 each**)

a. Meiosis I followed by cytokinesis produces _2_____ cells. Each cell is

____haploid / 1n_____-ploid and has _3 / 1n=3____ chromosomes and __6___ chromatids.

b. Meiosis II followed by cytokinesis produces _4_ cells in total. Each cell is

___ haploid / 1n_____-ploid and has __3 ___ chromosomes and __0 or 1 chromatids.

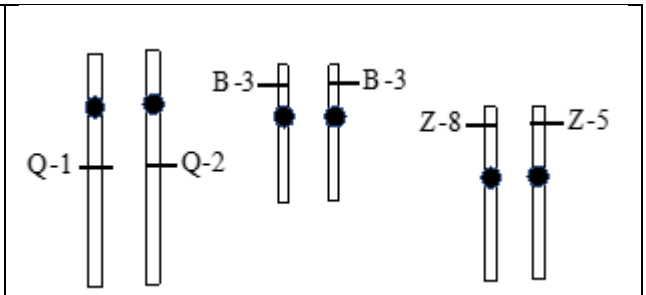
Q1.2 Which of the following statements apply only to MEIOSIS but not MITOSIS? Choose all that apply. **(1 mark)**

- Crossing over with genetic recombination happens.
- Independent assortment happens.
- Microtubules are responsible for moving the chromosomes during metaphase and anaphase.
- Chromosomes are replicated prior to division.

Q1.3 Which of the following statements about the X and Y chromosomes are correct? Choose all that apply. **(1.5 marks)**

- The X chromosomes can undergo crossing over in females.
- Males can be heterozygous for genes located on the X chromosome.
- Genes located on the X or Y chromosome are said to be 'sex-linked'.
- X and Y chromosomes don't pair during meiosis I.
- In males it is possible to determine genotype directly from phenotype for genes on the X chromosome.
- The X and Y chromosomes contain genes associated with determining the sex of the organism. (accept whether checked or unchecked)

The next 5 questions (Q1.4-Q1.8) are related to the figure below

A G1 cell from an individual is shown (right). Given this individual's genotype, answer the following questions:	

Q1.4 How many different genotypes can be produced by multiple **mitotic** divisions of this cell? (**0.5 marks**)

One / 1 (also accept zero)

Q1.5 The haploid number of this cell is: (**0.5 marks**)

_3 / n=3

Q1.6 If this cell contains 1.4 pg (picograms) of DNA, how much DNA would be in the cell at anaphase 1 of meiosis? (**0.5 marks**)

2.8pg (units not required)

Q1.7 What are the expected genotypes of cells that could be produced by this cell following multiple **meiotic** divisions? Indicate the frequencies of each of the genotypes. (**2 marks**)

Q1 B3 Z8 , Q1 B3 Z5, Q2 B3 Z8, Q2 B3 Z5
¼ or 25% each, or 1:1:1:1 ratio
Genotypes must be haploid – ie. only one copy of each allele.

Q1.8 What process would result in the expected frequencies of the genotypes you listed for products of many meiotic divisions? (**0.5 marks**)

independent assortment of homologous chromosomes

Q1.9 What cellular process generates new combinations of alleles of genes when the genes are on the same chromosome? Indicate the process and when it occurs. (**1 mark**)

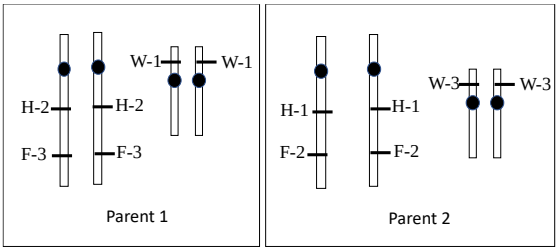
Crossing over (recombination alone is not acceptable, it is the outcome of the processes of crossing over and independent assortment). Occurs in Prophase I.

Q1.10 Following gamete formation, what process generates genetic variation among offspring? **(0.5 marks)**

Random fusion of gametes – just saying fusion of gametes is not sufficient for credit

Question 2 (Meiosis) – 6 marks

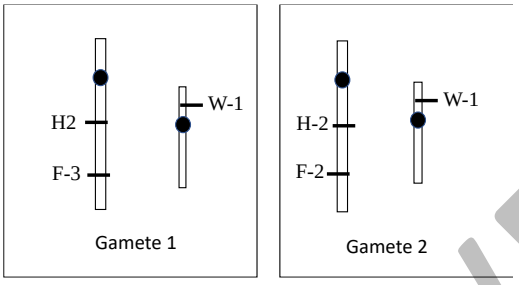
Consider a diploid salamander species. A salamander breeder chooses two individuals to breed. The genotypes and chromosomal compliments of two parents are given in the figure below. These individuals mate and produce a baby salamander that the breeder nicknamed Axol.

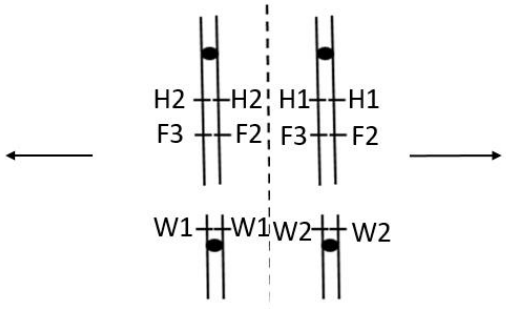


Q2.1 What is the genotype of Axol? (**1 mark**)

H1/H2;F2/F3;W1/W3
- order of genes/alleles does not matter; nor does notation; must be diploid and heterozygous for all genes

Q2.2 A single cell in Axol undergoes meiosis to produce gametes. Two gametes are shown below. Diagram the arrangement of chromosomes in a cell at Metaphase I that would produce these gametes. Add gene and allele labels and the direction of movement of the chromosomes at Anaphase I. In this species, only a single crossover event can occur per chromosome per meiosis. (**5 marks**)





- correct arrows showing movement at anaphase (it was not necessary to show both metaphase and anaphase)
- chromosomes are shown as replicated (i.e. composed of two chromatids)
- homologous chromosomes clearly and correctly arranged along the metaphase plate (i.e. cell is clearly at metaphase of meiosis I) - note there are other options that the example shown above.

    - Common Errors
        - Non-homologous chromosomes paired
        - too many or too few chromosomes
        - not in meiosis 1 (cell diagrammed at metaphase of mitosis or meiosis II)

- gene and allele copies correct
    - Common Errors
        - More than two of each allele
        - Alleles missing
        - Extra chromosome copies with extra alleles
- A single crossing over event resulted in recombination of P alleles on a replicated chromosome

- If crossing over on the "W" chromosome, the haploid products won't be correct
- Marks were deducted if recombination of H alleles since it requires 2 crossovers
- Arrangement of alleles and crossovers do not receive credit if the chromosomes are not shown in metaphase of meiosis I
- The arrangement of alleles must result in the predicted gametes – this requires that the cell is shown in metaphase I and the gene and allele labels are correct
    - A common error here is simply generating chromosomes with only the haploid genoytpes

Question 3 (Mode of Inheritance) - 10 marks

Zilla manilla is a species of lizard. In this species, females are XX and males are XY. Their scale colour may be green, yellow, or brown, and in rare cases blue or golden. Some individuals have tails without spots some individuals have spots on their tails.

You cross pure breeding male lizards with green scales and without spots with pure-breeding female lizards with yellow scales and spots. The F1s were then crossed with each other. The results are shown in the table below.

Cross #1 (P generation): Males: green scales with no spots x Females: yellow scales with spots

F1 Generation:

F1 males	F1 females
275 males all green with spots	280 females all green with spots

Cross #2: F1 males x F1 females

:

	Green, no spots	**Green, spots**	**Yellow, no spots**	**Yellow, spots**
Males	125	131	45	41
Females	0	225	0	76

Q3.1a Which allele for scale colour is dominant in these lizards? **(0.5 marks)**

- **allele for green scales**
- **allele for yellow scales**

Q3.1b Use the outcome from **either** cross #1 (P generation) or cross #2 (F1 cross) to support your claim about which scale colour allele is dominant (circle your choice below). As part of your explanation, compare observed and expected offspring phenotype frequencies for your chosen cross. If you think the gene for scale colour is autosomal, use "R" and "r" for the alleles. If you think the gene for scale colour is X-linked, use "X^R"and "X^r" for the alleles. There is space at the top of the next page if needed. **(3 marks)**

Cross #1 (P-generation cross) OR Cross #2 (F1 cross)

Note: for this question, it is not required to justify that the trait is autosomal but autosomal nomenclature for genes/alleles must be used. The question only asks you to justify conclusion related to scale color.

Both crosses:

- Correctly describe predicted phenotype(s) and their frequencies.
- Provide a reason for prediction; must include predicted genotypes of parents and F1s (could be in Punnett Square),
  - Marks are deducted if prediction is incomplete (e.g. missing genotype), or if X-linked nomenclature is used
- Correctly describe observed phenotypes (must be quantified for full marks)
- Statement that observed phenotype frequencies = predicted phenotype frequencies
- Clear link to claim about allele for green scales

Cross #1

RR (green male) x rr (yellow female)
Rr (green F1s)

F1 predicted phenotype frequencies - all green

Reason: A cross between a green male (RR) and a yellow female (rr) will produce hybrid offspring (Rr) with the dominant phenotype.
A Punnett Square can form part of prediction – there must be a clear link between genotype and predicted phenotype (e.g. just saying Rr is not sufficient; need an explicit statement that Rr is expected to result in green individuals).

F1 observed phenotype frequencies – all green (275 males and 280 females)

Predicted phenotype frequencies and observed phenotype frequencies are consistent

Reasoning, if allele for green scales is dominant to the allele for yellow scales all heterozygous F1s are expected to be green, this is what is observed therefore green is dominant to yellow.

Cross #2

Rr x Rr

	R	r
R	RR	Rr
r	Rr	rr

F2 predicted phenotype frequencies – 3:1 phenotypic ratio of green to yellow scales (does not need to distinguish between males and females since this is not relevant to determining which is dominant)

Reason: A cross between two heterozygous parents (Rr) will produce offspring with the genotypes RR, Rr (2) and rr
- can accept correct punnet square as part of prediction need to clearly link genotypes to phenotypes

- F2 observed phenotypes:
  - ~3:1 green to yellow phenotypic ratio (may be broken down by sex or not)
  - 225:76 female green to yellow; 256:86 male green; or 481: 162 green to yellow.
- Predicted phenotype frequencies and observed phenotype frequencies are consistent.
- Reasoning: if allele for green scales is dominant to the allele for yellow scales we expect a 3:1 ratio of green to yellow scales, this is what is observed, therefore green is dominant to yellow.

Q3.2a What is the most likely mode of inheritance for the tail spot phenotype in these lizards? **(0.5 marks)**

- **Autosomal**
- **X-linked**

Q3.2b Use the outcome of **either** cross #1 (P-generation cross) or cross #2 (F1 cross) to support your claim about the likely mode of inheritance for the tail spot phenotype in these lizards (circle your choice below). As part of your explanation, compare observed and expected offspring phenotype frequencies for your chosen cross. If you think the gene for tail spot phenotype is autosomal use "T" and "t" for the alleles. If you think this gene is X-linked, use "X^T" and "X^t" for the alleles. **(3 marks)**

Cross #1 (P-generation cross) OR Cross #2 (F1 cross)

Not possible to determine location of gene from cross 1; so no credit for only referring to cross 1

General mark breakdown:

- Predicted F2 phenotype frequencies (broken down by sex)
- Reason for prediction; must include predicted genotypes of parents and F1s (could be in Punnett Square),
  - marks are deducted if incomplete (e.g. missing genotype) or using autosomal nomenclature
- Observed phenotypes (must be quantified, and broken down by sex)
  - can receive partial marks if not quantified, but state that there is a difference in phenotype between F2 males and females frequencies
- Compare predicted and observed phenotype frequencies.
- Link back to claim about tail spot phenotype being an X-linked trait.

Marks may be deducted for incorrect statements

Example answer:

Predict all F2 females - spots and expect ~1:1 ratio for males spots to no spots

Reason for prediction (can accept a Punnett Square along with clear connection between genotype and phenotype)

	X^T	X^t
X^T	X^T/X^T female, 10 spots	X^T/X^t female, 10 spots
Y	X^T/Y male, 10 spots	X^tY male, no spots

Observed phenotype frequencies

- Females: 301 spots;
- Males: 172 –spots: 170 no spots;

Observed and expected frequencies are similar

Difference in phenotype between sexes indicate tail spots is an X-linked trait.

Q3.3 A rare population of *Zilla manilla* with golden scales was recently found and a sample of males and females was sent to your lab. During transport the lizards mated and laid eggs. 60 days after arrival the young hatched. 25% of the offspring have yellow scales, 50% of the offspring have golden scales, and 25% have brown scales.

What do these results suggest about the genotypes of the parents with the golden scales? Select all that apply. **(1 mark)**

A. The parents were true-breeding

B. One parent was homozygous dominant and the other parent homozygous recessive

C. The parents were heterozygous

D. The alleles for yellow and brown scale colour have a non-dominant relationship

E. The allele for gold and brown sale colour have a dominant/recessive relationship

Q3.4 Researchers discovered a third gene (Q gene) that is linked on the same chromosome as the allele for scale colour. The allele for long claws (Q) is dominant to the allele for short claws (q).

In a new experiment, researchers crossed lizards that were pure-breeding for green scales and short claws with pure-breeding lizards with yellow scales and long claws. All F1s had green scales and long claws.

The F1s were then crossed with lizards with yellow scales and short claws. If no crossing-over occurred during meiosis, what would be the predicted F2 offspring phenotypes and in what ratio? Select all that apply. **(2 marks)**

- Green scales and long claws
- Green scales and short claws
- Yellow scales and long claws
- Yellow scales and short claws
- 1:1 phenotypic ratio
- 3:1 phenotypic ratio
- 1:1:1:1 phenotypic ratio
- 9:3:3:1 phenotypic ratio

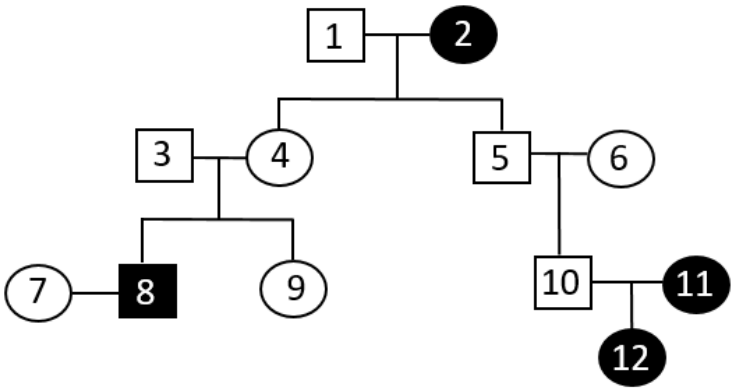
For this question, you must first get the phenotypes correct to get credit for the phenotypic ratio. If the phenotypes are incorrect, no credit is given for the ratio even if correct.

Note – this is the tomato cross worksheet question, where genes for stem thickness and flower colour are linked with no crossing-over, and you do a test cross on a heterozygote.

QUESTION 4 (Pedigree) – 8 marks

Bendii Syndrome is a rare, heritable disease in Vulcans (a species of humanoid from a popular Science Fiction Series). In this species females are XX and males are XY. The symptoms are sudden bursts of emotion and irrational anger.

Below is a pedigree for a family that has some family members affected by Bendii Syndrome.



Q4.1 Explain why X-linked dominant is an impossible mode of inheritance for Bendii Syndrome. In your explanation, refer to a specific cross that demonstrates that this mode of inheritance is impossible. In your explanation, refer to specific individuals, their phenotype and predicted genotype. Please use "X^B" for the dominant allele and "X^b" for the recessive allele. **(3 marks)**

Note – only individuals 3, 4 and 8 are the only individuals for ruling out X-linked dominant inheritance.

Must refer to individuals:

- by number, genotype, and phenotype

individual 4 is X^bX^b and unaffected

individual 8 is X^BY and affected

Clear, convincing reasoning/ explanation as to why this mode of inheritance is not possible

e.g. If the mode of inheritance for Bendii Syndrome was X-linked dominant, for individual 8 to be affected, their genotype must be X^B/Y. However, the female parent (individual 4) is unaffected; so, 4 must have the genotype X^b/X^b. This means they would not have a dominant allele to pass to their affected male offspring. Therefore this mode of inheritance is not possible.

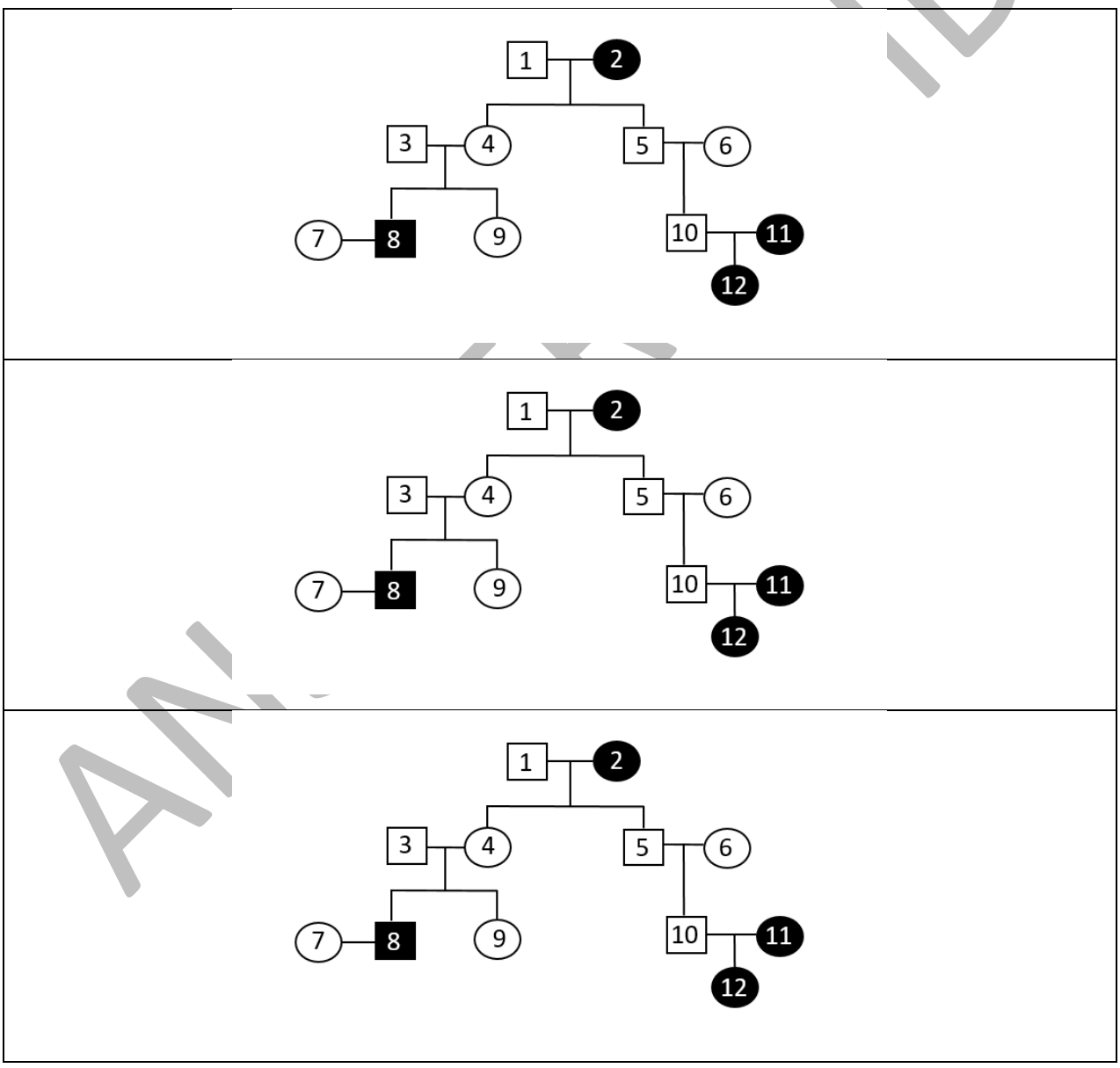
Q4.2 Which mode(s) of inheritance is/are possible for the "Bendii Syndrome" phenotype? Circle all answers apply. Note – incorrect choices will be subtracted from correct choices. The pedigree has been copied 3 times below. **(2 marks)**

The only possible mode of inheritance is autosomal recessive. Marks are deducted for incorrect answers (e.g. choosing both autosomal dominant and x-linked recessive is only worth part marks)

o Autosomal Dominant

o Autosomal Recessive

o X-linked Recessive



Q4.3 List one assumption that you made when using the pedigree to assess different modes of inheritance. **(1 mark)**

e.g.

- females (or round shape) are XX and males (or square shape) are XY

- Bendii syndrome is determined by one gene (two alleles); or alleles with a dominant recessive relationship

- Bendii syndrome only have two phenotypes (e.g. affected/unaffected),and it is easy to identify the different phenotypes.

- No individuals in the pedigree are adopted.

Q4.4 If individuals 10 and 11 were to have a second child, what is the probability that child would be a son that would not be affected by Bendii syndrome? Please show your work by providing a Punnett Square. **(2 marks)**

Probability = 0.25 or ¼ (no mark if correct probability, but calculated for an X-linked trait)

Work: ½ (probability of being unaffected) x ½ (probability of having a son) = ¼ or 25% or 0.25

Punnett Square for probability of being affected: Bb x bb

Bonus Question (1 mark)

If an individual with the genotype F1/F3; Q2/Q2; T5/T8 produced offspring by self-fertilization, what would be the expected frequency of offspring with the genotype: F1/F3; Q2/Q2; T5/T5?

Please show your work.

Probability of F1/F3 = ½ x Probability of Q2/Q2 = 1 x Probability of T5/T5 = ¼ = 1/8

Must show calculation for full mark (but P. Squares are not necessary)

	F1	F3
F1	F1F2	F1F3
F3	F1F3	F3F3

	T5	T8
T5	T5T5	T5T8
T8	T5T8	T8T8