UBC Biology 121

Practice Final Exam Answer Key, Summer 2020 Summer 2021 edits in red

1. On the on-line exam the integrity pledge will go here (This statement is only included so that the question numbers are consistent with the Gradescope practice exam).

2. A black female mouse with normal ears is crossed with a brown male with small ears. All the F1 are black with normal ears. All the F1 are self-crossed (5 crosses) and the following F2 are obtained:

F2s
62 black females with normal ears
18 brown females with normal ears
31 black males with normal ears
30 black males with small ears
10 brown males with normal ears
9 brown males with small ears

In the subquestions below you will determine how the traits black and brown fur and small and normal ears are inherited. (**10 marks**)

2.1 Which phenotype in ear size is dominant, if applicable? (3 marks)

(X) normal ears
( ) small ears
( ) cannot determine based on the information

Use no more than 4 sentences, describe how you came to your decision; please include relevant information in the scenario or your reasoning to support your statement.

F1s, being heterozygous, all have normal ears; or the F2 show 75% normal ears and 25% small ears

2.2 Identify the mode of inheritance for the ear size of mice in this scenario: (2 marks)

( ) autosomal
(X) sex-linked
( ) cannot determine based on the information

Use no more than 4 sentences, describe how you came to your decision; please include relevant information in the scenario or your reasoning to support your statement.

There is a sex bias in the F2 generation; there are no females with small ears. In F1, all individuals have normal ears

2.3 Which phenotype in fur colour is dominant, if applicable? (3 marks)

(X) black fur
( ) brown fur
( ) cannot determine based on the information

Use no more than 4 sentences, describe how you came to your decision; please include relevant information in the scenario or your reasoning to support your statement.

F1s, being heterozygous, all are black; or the F2 show 75% black, 25% brown

2.4 Identify the mode of inheritance for the fur colour of mice in this scenario: (2 marks)

(X) autosomal
( ) sex-linked
( ) cannot determine based on the information

Use no more than 4 sentences, describe how you came to your decision; please include relevant information in the scenario or your reasoning to support your statement.

Male and female offspring do not differ in the expression of this trait

PUNNET SQUARES for questions 2.1-2.4

MODE OF INHERITANCE FOR <u>EAR SIZE</u>

Scan data: There is a sex bias in the F2 generation; there are no females with small ears. In F1, all individuals have normal ears
Suspected mode of inheritance = X-linked with normal ears dominant to small ears
Define alleles: X^E = normal ears, X^e = small ears

The initial cross is:

P_1 Female with normal ears X Male with small ears

Genotypes: X^EX^E x X^eY

Parental Cross

	X^e	Y
X^E	X^EX^e	X^EY

Predict: All F1s have normal ears, no sex bias, which is what was observed.

F1 Cross

	X^E	Y
X^E	X^EX^E	X^EY
X^e	X^EX^e	X^eY

In F2s expect all females with normal ears and 50% of males with normal ears and 50% of males with small ears.

F2 Observed:

	Normal Ears	Small Ears
Female	62 + 18 = 78	0
Male	31 + 10 = 41	30 + 9 = 39

All females with normal ears (n=78)
Approximately 1:1 ratio of males with normal ears (41) and small ears (39). Consistent with X-linked inheritance with normal ears dominant to small ears

MODE OF INHERTIANCE FOR FUR COLOUR:

Scan data: No sex bias; all F1s have black fur
Mode of Inheritance = autosomal with black fur dominant to brown fur
Alleles B=black, b=brown the initial cross is:

P1 Black female X Brown male
Genotypes BB x bb

	B	B
b	Bb	Bb
b	Bb	Bb

F_1 Expect all black individuals

F1 cross

	B	b
B	BB	Bb
b	Bb	bb

F2 Expect a 3:1 phenotypic ratio of black to brown fur, no sex bias

F_2 Observed
Black Females 62
Brown Females 18
Black Males 61
Brown Males 19

= observed ratio is ~ 3:1 black fur to brown fur (123:37), which is consistent with the predicted values if fur colour is determined by a single autosomal gene with two alleles. The B (black allele) is dominant to the b (brown allele)

ears dominant to small ears.

**Could combine traits into one Punnett Square (not preferred), e.g.*

Black fur is dominant (B) to brown fur (b)
Normal ears is X-linked dominant (X^E) to small ears is X-linked

(X^e) P1 BB X^E X^E x P2 bb X^e Y
F1 females Bb X^E X^e 1 mark; males Bb X^E Y

Ratio as above

female male	B X^E	B X^e	b X^E	b X^e
B X^E	BB X^E X^E black normal♀	BB X^E X^e black normal♀	Bb X^E X^E black normal♀	B b X^E X^e black normal♀
b X^E	Bb X^E X^E black normal♀	BB X^E X^e black normal♀	bb X^E X^E brown normal ♀	bb X^E X^e brown normal ♀
BY	B B X^E Y black normal♂	BB X^eY black small♂	Bb X^EY black normal♂	Bb X^e Y black small ♂
bY	Bb X^EY black normal♂	Bb X^eY black small ♂	bb X^EY brown normal♂	bb X^e Y brown small♂

3. The Vancouver Island marmot is a large ground squirrel, related to the groundhog, that lives in burrows in high-elevation alpine meadows. It has a very limited distribution (see Figure 4) and is one of the rarest mammals in the world, with only 21 individuals in the wild as recently as 2003. Vancouver Island marmots had disappeared from about two-thirds of their historic natural range. Thanks to captive breeding and releases, the population has rebounded to over 400 individuals. Marmots mainly eat greens and many types of grasses, berries, lichens, mosses, roots, and flowers. (**10 marks total**)

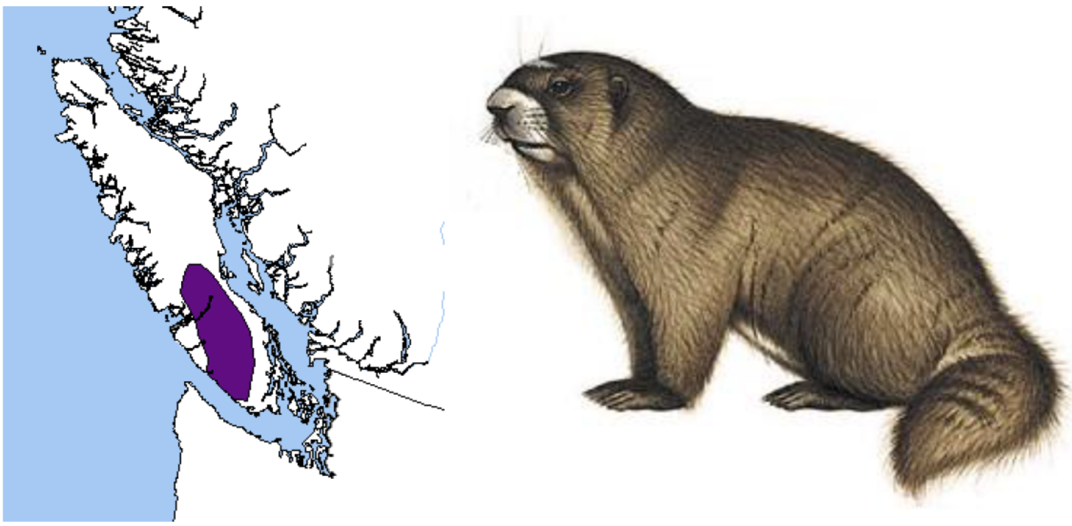


Figure 4. Distribution of the Vancouver Island marmot (*Marmota vancouverensis*)

3.1 List one abiotic factor that could have determined the distribution of this species and explain specifically how it could have impacted their survival or reproduction. (3 marks)

1 mark for factor and 2 marks for explanation of abiotic factors that could affect distribution: temperature, precipitation, soil, etc. 2 marks for how it is related to the tolerance of the marmot, presence of their food, locations for them to live or reproduce.

For example: Marmots have a tolerance for a certain range of temperatures. If the temperature is too warm, they will overheat and this will lower their chance of survival. If the temperature is too cold they will not be able to feed as much and female reproduction could be lowered. Their distribution will be partially determined by their temperature tolerances.

3.2 List one biotic factor that could have caused their initial change in abundance and explain how it could have affected the distribution of these marmots. (3 marks)

1 mark for factor and 2 marks for explanation of e.g. loss of vegetation for food because of climate change. Increase in predators. Other biotic factors are also acceptable. Human impact is also acceptable as biotic.

For example: Warmer temperatures have allowed trees to survive at higher elevations. As alpine meadows turn into forests there will be less habitat for marmots. This could determine which mountains they can live in and shift their entire range further north.

3.3 Explain how the genetics of Vancouver Island marmots could be an important factor in recovering from their population bottleneck. (4 marks)

Example answer: These small populations likely have less genetic variation (2) therefore when a change in abiotic conditions occurs, there are fewer different allele combinations (1) in the population that might enable some marmots to withstand the new environmental conditions (1). Could get partial marks if just answer in more general terms i.e., why genetic variation is important, or discuss problems such as inbreeding depression in small populations.

4 Today two species of shore crab, *Hemigrapsus nudus* (the purple shore crab) and *Hemigrapsus oregonensis* (the hairy shore crab) live in the intertidal region around Vancouver. *H. nudus* is widely distributed along the west coast of North America. *H. oregonensis* is common along the coast of Oregon and Washington and its range is expanding northward. 1975 was the first time that these species could be found together on Wreck Beach. Both crab species are scavengers, consuming dead organic material, and both play a similar ecological role in the intertidal area of the marine ecosystem. In 1975 first-year Biology students did a survey of shore crab abundance at Tower Beach as a function of substratum size (e.g. on what size of rocks and pebbles were the crabs found) as seen in graph A. In 2005 another group of first-year students repeated the survey; their data are presented in graph B. (**10 marks total**)

*Hemigrapsus nudus*_________ *Hemigrapsus oregonensis*

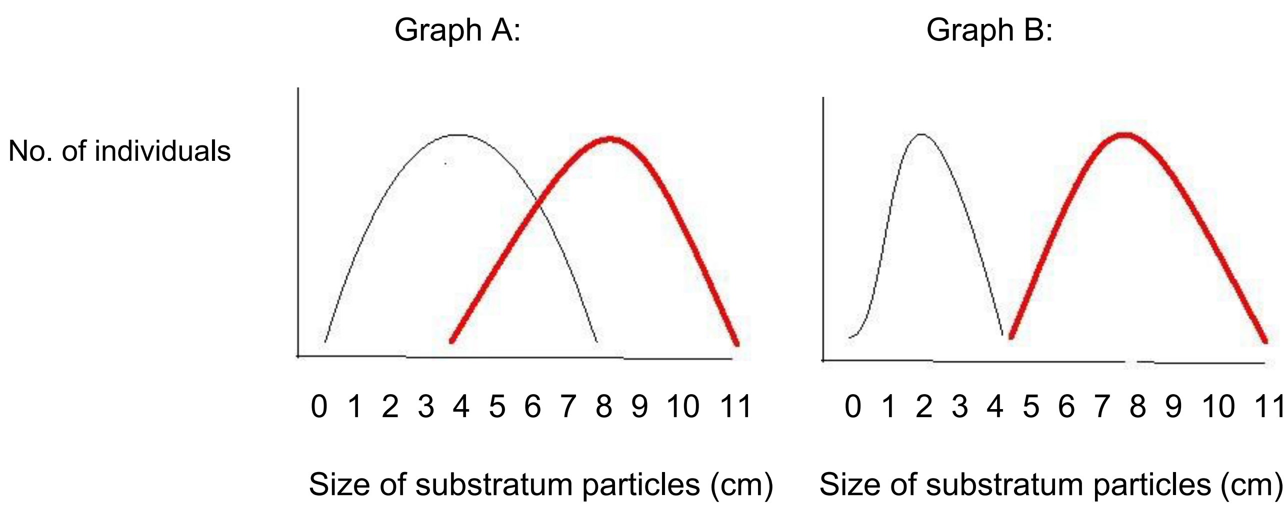


Fig. 1 the relative abundance of *H. nudus* and *H. oregonensis* as a function of substratum size at Tower Beach in 1975 (Frame A) and 2005 (Frame B).

4.1 Are the curves illustrated in the graph in **graph A** examples of the fundamental or realized niches of these organisms? Explain your answer. (2 marks)

*fundamental (1) because they illustrate the range where each species **can** be found (1) in other words, this graph shows the distribution of each species when they are alone*

4.2 What interaction (be specific) would you expect between the two species where their distribution overlaps in **graph A**? Why would you expect this interaction to occur? (3 marks)

competition (1) for one of: space (under rocks), food (on or under rocks) accept any reasonable answer (1) two species with the exact same niche means competition will occur (1)

4.3 Describe the effect of this interaction on the distribution of the two species in this area over 30 years between 1975 and 2005 (**graph B**). What is the name of this ecological process (be specific)? (3 marks)

In the area of niche overlap H. nudus decreases until it is no longer present (1) Its range is decreased to smaller particles (1) could either suggest fundamental niche > realized niche OR evolutionary change in fundamental niche

Called resource partitioning or niche partitioning (1) we suspect competitive exclusion is not happening because the distribution of both species changed (OR difference in H. oregensis is too small to be noticeable, in which case competitive exclusion has occurred)

4.4 List one possible characteristic of *H. oregonensis* and *H. nudus* that could have led to the results observed and indicate how this characteristic could have led to the results observed. (2 marks)

Anything reasonable that explains why H. oregonensis could be a better competitor; 1 mark for characteristic and one for reason e.g., larger – better competitor for food, space. Better camouflaged – more protection from predators, etc.

5. Point Grey, where UBC is situated, has many paths down to the beach. One of these paths, Beach trail #3, leads to Tower Beach. The cliffs surrounding the beach are made of sand and are quite unstable. In Jan. 1935, 37 cm of rain and snow fell in the Lower Mainland over four days. The subsequent flooding washed 100,000 tonnes of material down one bank above Tower Beach, forming a gulley. All soil and vegetation were swept away down the gulley. In 1965 a survey of the vegetation in the disturbed area and the adjacent undisturbed area next to the gulley was completed. (**7 marks total**)

The following plant species were found at the two sites:

Species	Number at undisturbed site	Number at disturbed site
Sword fern	5	0
Alder	3	5
Mature Douglas fir	15	0
Douglas fir seedling	5	5
salmonberry	8	20
Mnium (moss)	5	15

Maple	3	0
hemlock	5	5

5.1 Which site has the greatest number of species? (1 mark)

Undisturbed site (1)

5.2 Which species is the most likely to be a pioneer species at the disturbed site? (1 mark)

salmonberry (1)

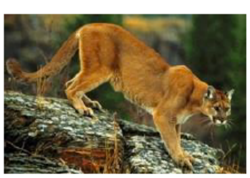
5.3 List two features that are characteristic of a good pioneer species. (2 marks)

Any two for 1 mark each e.g., good dispersers, can survive extreme abiotic conditions, produce lots of offspring, grow and mature quickly. Other answers may be acceptable.

5.4 Compare the importance of abiotic and biotic factors in communities that are in earlier and later successional stages. Explain using examples from the data presented above. (3 marks)

Abiotic are more important than biotic in earlier succession (1) because pioneer species for e.g. salmonberry, moss, can tolerate a hostile environment (1)
Biotic are more important in later communities because species prominent here are usually better competitors e.g., Douglas fir shade alder (and other species) so they die back (1)

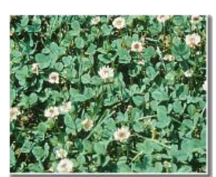
6 The following species are found in a forest ecosystem: (**14 marks total**)



Felis concolor (cougar)

Lepus capensis (brown hare)

Odocoileus virginianus



Trifolium repens

Boletus edulis

6.1. What are the different trophic levels represented by these species? Use a list to describe the direction of flow of energy through this community. (5 marks) (5 marks) note to summer 2021 students – I would not expect you to look at a picture and be able to assume anything about the organism's trophic level. I would have to give you more information (e.g. biomass, energy source)

Energy in this community flows from:

1. *Producer – clover (Trifolium(*
2. *to primary consumers (herbivore OK) – hare, deer*
3. *to secondary consumer (carnivore OK) - cougar*

Energy flows from all levels to decomposer – Boletus (mushroom)

6.2 Which species would have the most biomass? Give one reason why. (2 marks)

clover (1) plus any reason, e.g. they are the lowest trophic level, responsible for first energy transformation (1).

6.3 Explain what would happen to each of the trophic levels in (a) above, if brown hares were removed from the food web. (4 marks)

One mark for each; each level has to follow logically from the previous one
Cougars may decrease or they may consume young deer
Deer may decrease if cougars consume them or deer will increase if there is less competition for the clover
Clover may increase because hares are gone or may decrease if deer increase.
Bolete(mushroom) may stay the same (if other biomass stays the same) or decrease (if total biomass decreases)

6.4. In any stable community or ecosystem on Earth, large predators are rare. Use your knowledge of ecosystem ecology to explain why this might occur. (3 marks)

Higher tropic levels require a lot of biomass to sustain their numbers; it would be rare to find an ecosystem with so much biomass at lower levels to support large numbers of top predators, since energy and biomass are lost in transfer to each level because not all of it is available to consume, energy is used for metabolism and some is lost as waste.

7 Two species of fish that live around Caribbean reefs have a unique type of interaction. The Caribbean cleaning gobies (*Elacatinus evelynae*) eat parasites (gnathiids) found on the skin of the longfin damselfish (*Stegastes diencaeus*). (**14 marks total**)

7.1 What type of interaction is occurring between these two species? (1 mark)
mutualism

7.2 Explain specifically how each member benefits or is harmed in this interaction. (2 marks)
Caribbean cleaning gobies get food (the parasites) longfin

damselfish are rid of parasites

7.3 Karen Cheney and Isabelle Côte studied two aspects of this interaction. First they counted the number of parasites (gnathiids) on longfin damselfish in areas with or without cleaner fish. The results are shown in Figure 1.

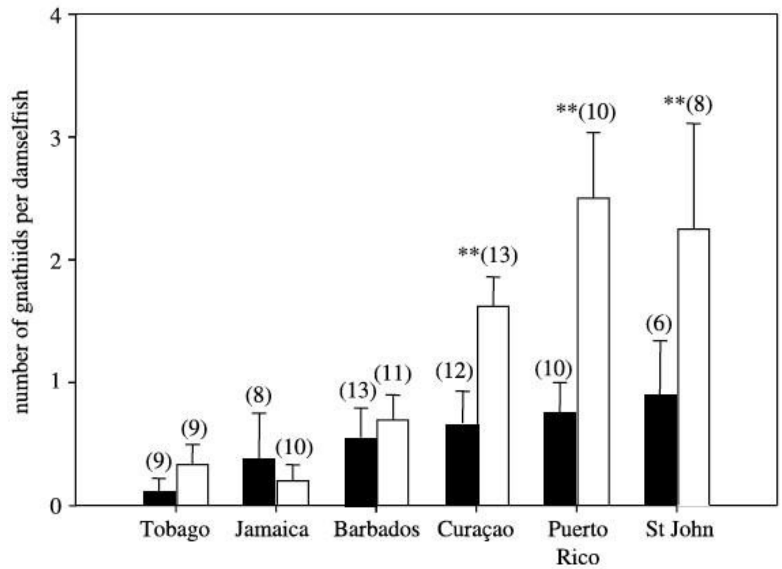


Figure 1. The number of gnathniids (parasites) per damselfish found at various locations in the Caribbean. Black bars indicate parasite numbers on damselfish in areas with cleaner fish. Open (white) bars indicate parasite numbers on damselfish in areas without cleaner fish. The numbers in brackets indicate the sample size. The stars (**) indicate where the number of parasites on damselfish significantly differed between treatments (cleaner fish present, cleaner fish absent).

Describe the results shown in Figure 1 above. (2 marks)

Damselfish have fewer parasites in areas where there are cleaning gobies on Curacao (~.7 vs ~1.5), Puerto Rico (~.8 vs ~2.5) and St. John (~.9 vs ~2.2) (1) but not on islands where there are fewer (~1.5 or less) parasites: Tobago, Jamaica, Barbados (1).

7.4 What can you conclude from this graph about the effect of cleaner fish on the number of parasites found on damselfish. (2 marks)

The greater the number of parasites in an area (1) the greater the benefit from cleaner fish (1). There may be other valid answers.

7.5 How would you describe the type of interaction where the cleaner fish eats more scales, mucus and tissue from the damselfish than parasites? (1 mark)

Parasitism or consumerism or predation

7.6 Explain specifically how each member benefits or is harmed in the interaction described in 7.5). (2 marks)

cleaner fish benefits as they have an alternate food source if the number of parasites is low, damselfish may be harmed by the cleaner fish consuming scales, etc.

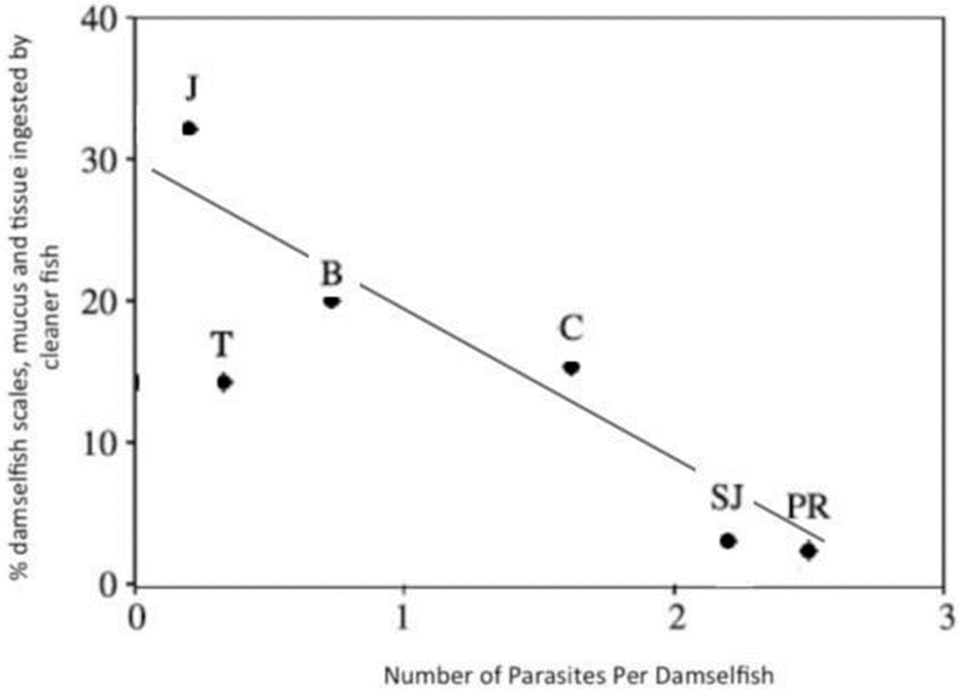


Figure 2. The % of damselfish material ingested when compared with the number of parasites on the damselfish. Vertical and horizontal lines show the amount of variation in the data.

7.7 Describe the results shown in Figure 2 above. (2 marks)

There is a negative correlation between the number of parasites per damselfish and the amount of damselfish scales, mucus and tissue the cleaner fish eat. When, the number of parasites per damselfish is high (e.g. above 2 parasites/fish), the cleaner fish's diet contains a low proportion of damselfish scales, tissues and mucus (e.g. <5%). However, when the parasite load is low (e.g. <1 parasites/fish), the cleaner fish's diet contains a higher proportion of damselfish scales, tissues and mucus (e.g. ~15%-30%).

7.8 How do parasite numbers on damselfish change the interaction between cleaner fish and damselfish? (2 marks)

When parasites are more plentiful the cleaner fish will consume the parasites and the interaction is a mutualism (1); when parasite numbers are low, they will consume *material such as scales, mucus and tissue from the damselfish and the interaction become parasitism (1).*

8 *Tetrahymena* are unicellular eukaryotic ciliates (not photosynthetic) that are easily grown in a flask in the lab containing a standard liquid medium that consists of all the nutrients they require. Under optimum conditions it takes 2 hours for the cells to grow and divide. If cell number is graphed against time the following curve is obtained (Figure 3): (**12 marks total**)

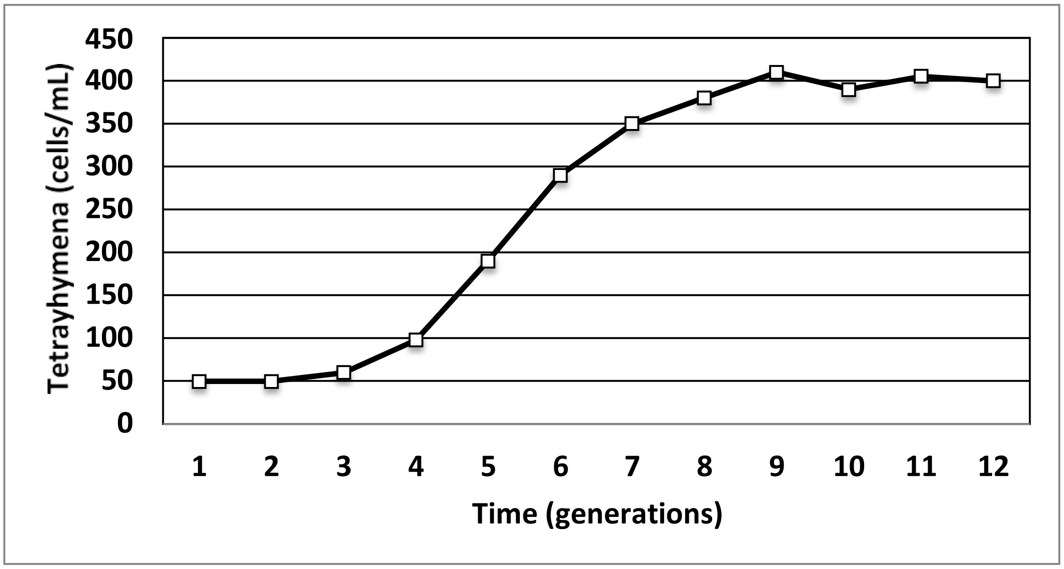


Figure 3. The number of *Tetrahymena* (cells per mL) over time.

8.1 What is the carrying capacity of this flask for *Tetrahymena*? (1 mark)

~400 cells/mL.

8.2 How do birth rate and death rate compare to each other at these time points?
(3 marks)

a) Generation 2-3: *Birth rate > death rate; (1)*
[even at the start of exponential growth, there is still growth]
b) Generation 5-6: *Birth rate > death rate (1)*
c) Generation 11-12: *Death rate = birth rate; (1) [Okay if you said death rate is slightly higher, but the concept is when the population hits carrying capacity, the birth and death rates are approximately equal and the population size stabilizes]*

8.3 Describe how the number of individuals changes through time (3 marks)

Number of individuals in the population is initially low, the numbers increase slowly at first (constant rate, but small size), with the fastest change in growth in the middle and then number of individuals added decreases as the population approaches the carrying capacity. This is a sigmoidal (s-shaped) logistic growth curve.

8.4 You are interested in identifying the impact of high amounts of heavy metals on *Tetrahymena*. You decide to conduct an experiment to assess the impact of copper (Cu^{2+}) on *Tetrahymena* growth. You measure growth of 2 populations of *Tetrahymena*: one population is incubated in Cu^{2+} (100 mg/L), the other has no Cu^{2+} added (control). Your results are depicted in Figure 4 below:

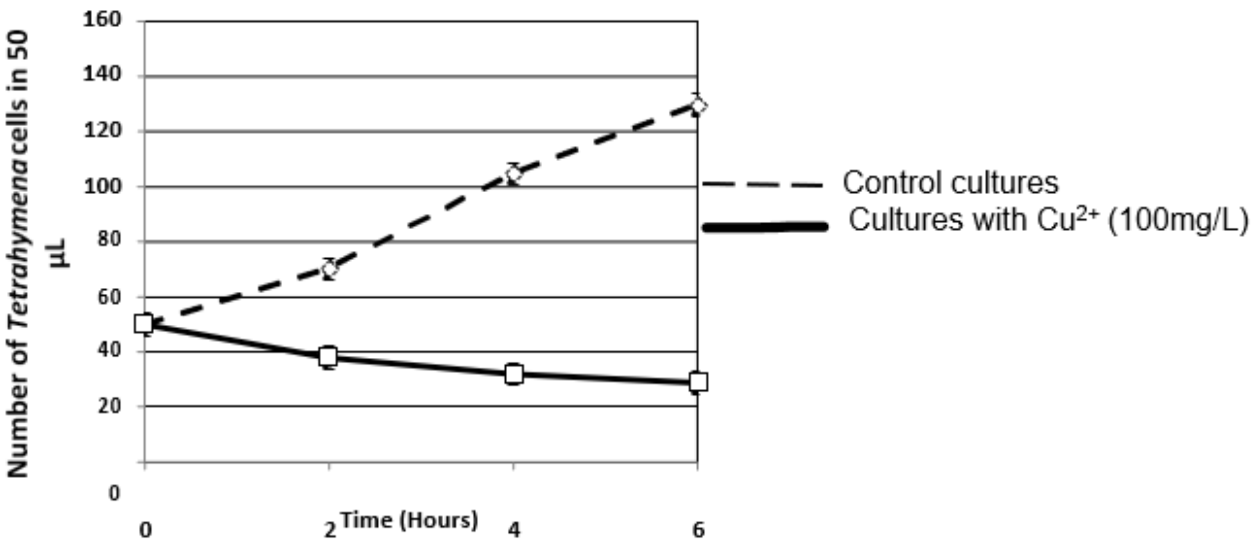


Figure 4: Mean number of *Tetrahymena* cells plotted against time for two populations: one control (dashed line) and one treated with Cu^{2+} (100 mg/L; solid line). N=3 measurements of cell number per time point. Error bars are 95% confidence intervals.

What effect has Cu^{2+} had on the growth of *Tetrahymena*? (1 mark)
Copper has a negative effect on Tetrahymena growth.

8.5 You leave the lab at the end of the day (time 6 in Figure 4), and when you come in the next morning, you count the number of cells in a 50 µL sample. You data are shown below:

	Number of *Tetrahymena* in 50 µL the next morning.	
	Control cultures (standard medium)	**Experimental cultures (standard medium + 100 mg/L Cu^{2+})**
Mean of 3 replicates	1050	433

What has happened to the *Tetrahymena* population in the experimental (Cu^{2+}containing) cultures that has allowed its numbers to increase from ~30 to 433 cells/50µL? (4 marks)

One of two possible things has happened:

Either a mutation occurred randomly in a single Tetrahymena that allowed it to tolerate high Cu^{2+} levels, and then this allele increased in frequency over generations as a result of increased fitness (natural selection OK if explained)
or
An allele already existed in the Tetrahymena population prior to Cu^{2+} treatment that conferred a degree of tolerance to high Cu^{2+} levels. Over time (over night!), this allele increased in frequency due to increased fitness (natural selection OK if explained).1 mark for random mutation (pre-existing or randomly occurring), 1 mark for results in tolerance to copper, 1 mark for increased fitness, 1 mark for allele frequency change in this population.
Maximum of 2 marks if they say the copper caused a mutation but fully explain how selection acted to change the frequency of the copper tolerance allele.

9 The white-handed gibbon (*Hylobates lar*) is a kind of ape that lives in South-East Asia. Suppose the length of their adult arms is either long (over 0.5m) or short (less than 0.5m) and this trait is controlled by two alleles of a single gene. (13 marks total)

9.1 The allele for long arms (*A1*) is dominant to the allele for short arms (*A2*). In a population of 100 apes, 49 had short arms. Assume the Hardy-Weinberg (HW) equilibrium is in effect and calculate p for the long *A1* allele and q for the short *A2* allele. No need to show your work in Gradescope. (3 marks)

Assuming the population is in HW equilibrium:
q^2 = frequency of *A2*/*A2* homozygotes = 49/100 = 0.49
$q = \sqrt{(q^2)} = \sqrt{(0.49)} = 0.7$
$1 - q = p = 0.3$

9.2 What is the frequency of long-armed heterozygous individuals in this population? Show all your work. (2 marks)

Assuming the population is in HW equilibrium:
$2pq$ = frequency of *A1*/*A2* heterozygotes p =
0.3 q = 0.7
$2pq = 2 \times 0.3 \times 0.7 = 2 \times 0.21 = 0.42$

9.3 **Scenario text copied for reference:** The white-handed gibbon (*Hylobates lar*) is a kind of ape that lives in South-East Asia. Suppose the length of their adult arms is either long (over 0.5m) or short (less than 0.5m) and this trait is controlled by two alleles of a single gene. (13 marks total)

In subquestion 9.1 above you were told to assume the HW equilibrium is in effect. Is this a reasonable assumption in this example? Explain two reasons why it is or isn't. (4 marks)

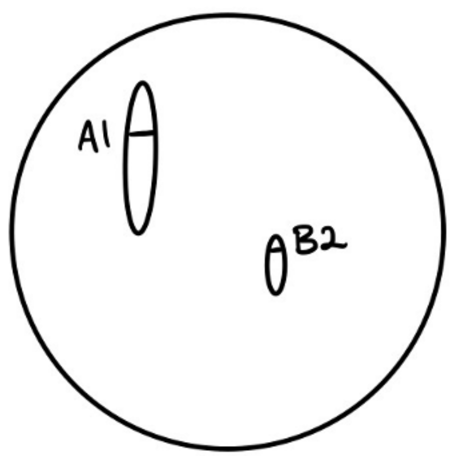
No [or "Yes", only if very well defended] (1 mark).
Reason 1 (0.5 mark for assumption, 1 mark for reason why it wouldn't be met)
Reason 2 (0.5 mark for assumption, 1 mark for reason why it wouldn't be met)

Example answer:
No, the population is not likely to be in HW equilibrium (1 mark).

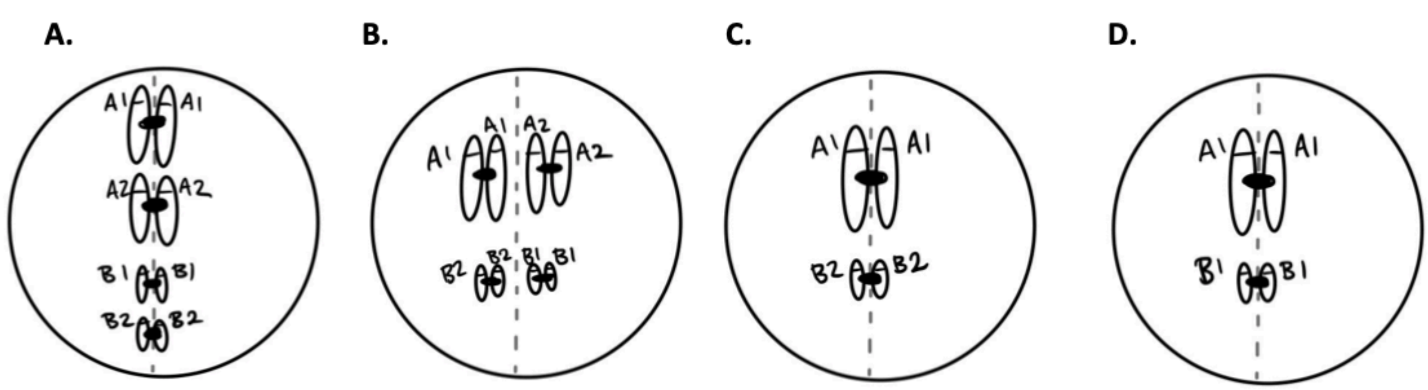
Reason 1: It is not very likely that the gibbons are mating randomly (0.5 mark); there is probably some form of mate choice going on, which means that some individuals might not get mates and/or individuals might be more likely to chose mates that are more similar or more different from themselves (1 mark).
Reason 2: The gibbon population is not infinitely large (0.5 mark). This means it is possible that some level of genetic drift is occurring at the locus in question (1 mark).

[*Note*: the five assumptions of the HW equilibrium model are: random mating, no natural selection, no genetic drift (infinitely large population), no migration/gene flow, and no mutation.]

9.4 'A1' is the dominant allele for the production of arm length and 'B1' is the dominant allele for the production of dark fur. The two genes in question are on different chromosomes. A male gibbon who is heterozygous (A1/A2; B1/B2) for both genes produces a sperm cell with the nucleus shown below. The locus for each allele is marked on the appropriate chromosome.



Which of the student drawings below (a through d) shows the chromosomes of the pre-gamete cell that produced the sperm shown above in Metaphase I of meiosis? Briefly explain your response. (2 marks)



Drawing B is correct since it shows:

- homologous chromosomes lined up across from one another on either side of the metaphase plate (0.5 mark)
- each chromosome with two sister chromatids (0.5 mark)
- genotype of cell is *A*/*a*; *B*/*b* (0.5 mark)
- position of the gene is the same for all sister chromatids and homologous chromosomes (0.5 mark)

9.5 If you sampled many sperm from this male gibbon, what would the expected genotypes and genotypic ratio of the combinations of these two genes be? (2 marks)

[*Note:* The genes are on different chromosomes, so they will assort independently.]

Should get 1:1:1:1 (or 25% of each):
- *A*; *B*
- *A*; *b*
- *a*; *B*
- *a*; *b*

0.5 mark for *A*; *B* and *a*; *b* (0.5 mark for equal frequencies of these two genotypes)
0.5 mark for *A*; *b* and *a*; *B*
0.5 mark for 1:1:1:1 or 25% of each