101-NYA Class 15: Natural Selection

Marks

Group:

Total Score: 0 /16

Bonus Score: 0 /7

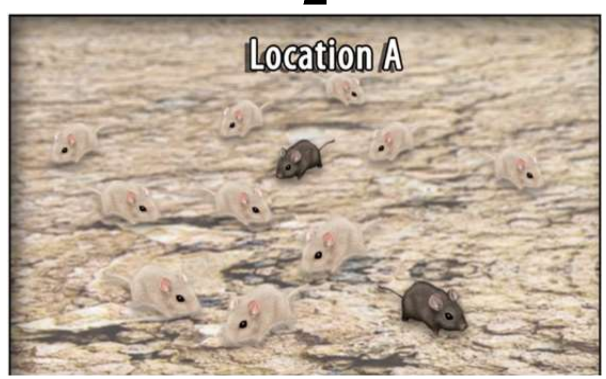
Part A: 25 Minutes

In the module review activities for the first three modules of this course you were introduced to the rock pocket mouse and the MC1R protein receptor molecule. In the following activity you will examine the evolutionary significance of the two MC1R phenotypes you have encountered: dark and light fur colouration.

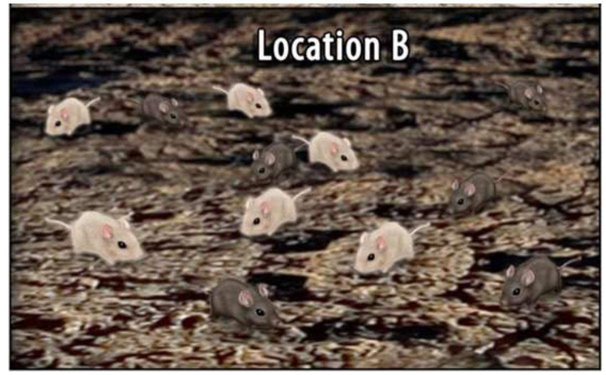
The illustrations that follow represent snapshots of two pocket mouse populations through time. Each illustration shows the colour variation at two different locations, A and B, at a particular moment in time over a period of several hundred years. The images are out of order; place the illustrations in what you think is the correct order from oldest to most recent, by entering the image number in the appropriate location within the answer boxes beneath all of the images.

1

2




Location B


Location B

3


Location A
Location B

4


Location A
Location B

	Oldest			Most Recent
Answers:				

_____ /2

Explain how you decided which illustration represents the most recent pocket mouse population and why you positioned the others in the sequence as you did.

_____ /2

Explain why a pocket mouse's color influences its overall success. Remember that "success" is defined by an organism's ability to survive and produce offspring.

_____ /1

Explain the presence of dark-coloured mice at Location A. Why didn't this phenotype become more common in the population?

_____ /2

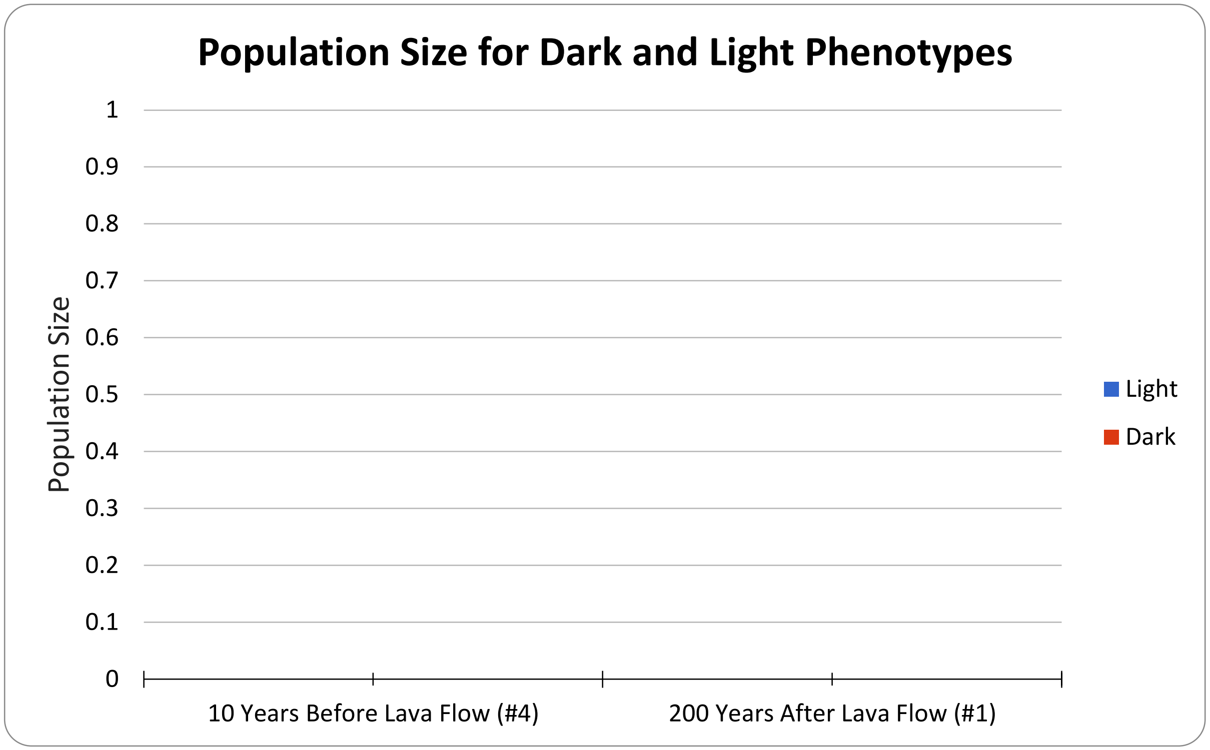
Use the data and what you've learned about evolution to explain how mutation is random, but natural selection is not random.

_____ /1

The table below presents fictional data of population sizes for location B from images 4 and 1 above. Use the graphing function of Google Sheets to produce a reasonably appealing visual rendition of these data (i.e., make a graph), and insert this in the space below.

Mouse Colour	Light	Dark
10 Years Before Lava Flow (#4)		
200 Years After Lava Flow (#1)		

_____ /2



Keep Scrolling Down for Next Question

What pattern of natural selection can reasonably be observed from these data? /1

Part B: 25 Minutes

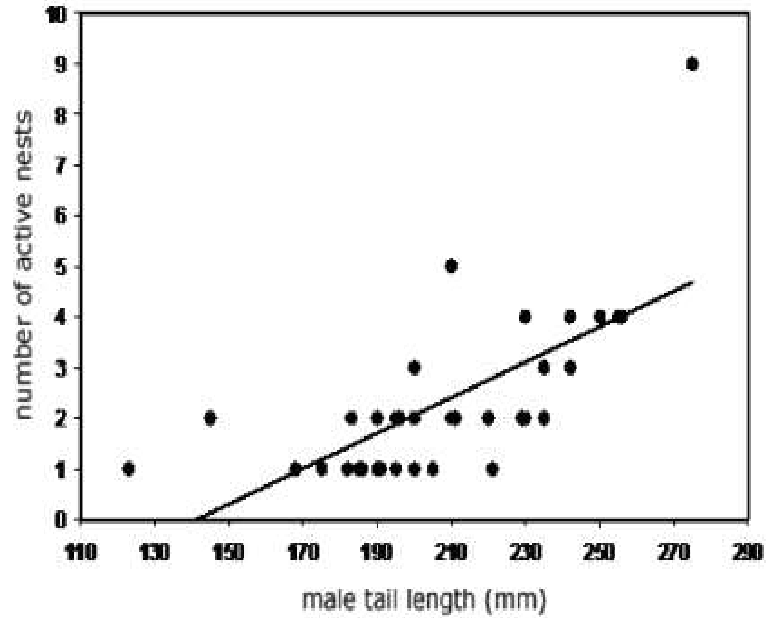
Widowbirds are small, finch-like birds in the genus Euplectes. They are striking members of the bird community in grasslands and shrubby savannas of southern and eastern Africa. This group is noted for the pronounced sexual dimorphism between males and females. During the non-breeding season, both male and female widowbirds have a brownish or buff coloration that blends with the grass and other vegetation. During the breeding season, however, males molt and produce black feathers on most of their body. Males also produce characteristic bright red and/or yellow epaulets and chevrons on their wings. Additionally, males grow elaborately long tail feathers that can be up to half a meter in length.

During the breeding season, males secure and defend a territory from other males where they then build multiple nest frames. Males then perform a flight display that has a "bouncy rowing" appearance with loops and exaggerated wing beats to attract females to their territory. Females choose a male for breeding, line a nest frame in his territory with fine grass, and then incubate the eggs and feed the nestlings in that frame. After the breeding season, males molt to return to their pre-breeding coloration and appearance. Beyond initially building the nest frame, males do not participate further in raising their offspring.

Figure 1. Long-tailed widowbirds showing breeding and non-breeding plumage. (Long-Tailed Whydah, 1899. Chromolithograph after Frederick William Frohawk, printed by Brumby & Clark Ltd. in Hull and published in Frohawk's *Foreign Finches in Captivity*, 1899. Image courtesy of ancestryimages.com.)

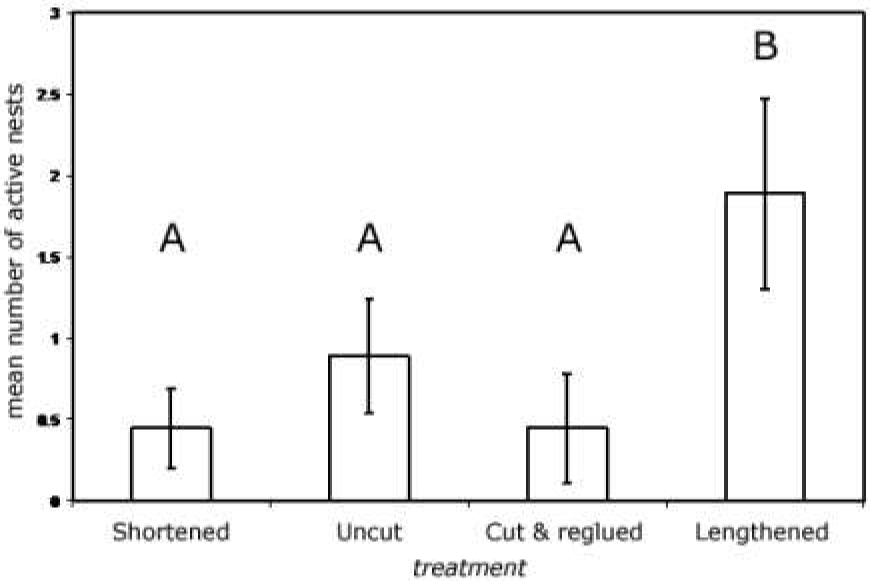
Develop a hypothesis that could be used to test why widowbirds have evolved such elaborate mating physiology and behaviour. /1

Explain the reasoning behind this hypothesis. How is natural selection acting in your hypothesis? What mechanisms prevent females from making "mistakes" when choosing a male for breeding? /2



In an initial field study, researchers compared the number of active nests among males with different tail lengths. Results of the study are displayed in the upper graph to the right (from Pryke et al. 2001).

In a different study, researchers manipulated four groups of males by shortening the tails of some, leaving some uncut, cutting some tails and re-gluing them, and finally by elongating tails from the last group. Results of this study are displayed in the lower graph to the right (from Andersson, 1982).



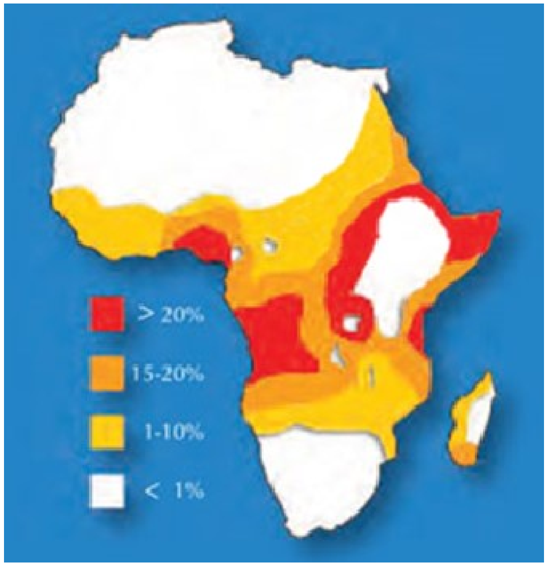
What hypotheses are being tested in EACH of these studies? /2

Explain how the results for EACH of these studies either provide support for or against these hypotheses. /2

Bonus: 5% on Unit Test II

Click on the following link to watch a video on sickle cell anemia (or go through the link on Moodle). The video is edited from a longer version produced by the Howard Hughes Medical Institute.
http://www.youtube.com/watch?v=4y1NudP3lt8

The map on the right illustrates estimated frequencies of the sickle cell allele (HbS) in various parts of Africa. In other words, in some parts of Africa, the sickle cell allele makes up 20% of the total beta hemoglobin subunit alleles in the population, while the remaining 80% of the alleles are normal (HbA). These numbers have remained reasonably constant since they were first estimated, and it is actually believed that these allele frequencies have not changed significantly in centuries.



Based on the information above, as well as the information presented in the video, do you believe natural selection is occuring in these African populations with regard to the beta hemoglobin gene? If so, what pattern of selection is at play? Explain your reasoning.

_____ /2

Sickle cell anemia is a condition that is relatively prevalent in Americans of Afrian descent. In fact, as noted in the bonus Genetics lab case study, approximately 1/12 African Americans carry the sickle cell allele, which means the HbS allele is at a frequency of about 4%. This compares against the frequency of sickle cell allele in Caucasian Americans, which is <0.001%.

Even though the prevalence of HbS in current African American populations seems high, it actually appears that the frequency of this allele used to be even higher. Using medical records of conditions corresponding to sickle cell anemia, researchers have estimated that the allele frequency in African American populations from 80 years ago used to be about 6%.

Based on the information from the paragraphs above and the video, develop a hypothesis to explain why the frequency of the sickle cell allele has decreased in African American populations over the past 80 years. /1

What pattern of natural selection is evident from the paragraphs above (and presumably from your hypothesis)? /1

As described in the activity from class 11, it is now possible to treat people with sickle cell anemia and extend their lives well into, and past, reproductive years. With that in mind, do you expect the frequency of the sickle cell allele to continue decreasing in the population? Explain your answer. /2

Would it ever be possible for natural selection to completely eliminate the HbS allele from a population? Why or why not? /1

101-NYA Class 16: Mechanisms of Evolution

Marks

Group:

Total Score: 0 /17

Part A: 40 Minutes

In rock pocket mice, the Mc1r allele for dark-coloured fur (called D here for simplicity) is dominant to the wild-type Mc1r allele for light fur (d). Therefore, individual pocket mice can have one of three genotypes and one of two phenotypes, as summarized in the table below.

	Genotype	Phenotype
Homozygous Dominant	*DD*	Dark
Heterozygous	*Dd*	Dark
Homozygous Recessive	*dd*	Light

Dr. Nachman and colleagues collected pocket mice across 35-kilometers of the Arizona Sonoran Desert that included both dark, rocky lava outcrops and light rocky granite areas. Substrate colour and coat colour frequencies were recorded for each location. Each site was separated from any of the others by at least 8 kilometres. A total of 207 mice were trapped and their genomes sequenced. The data are summarized below:

Collecting Site	**Substrate Colour**	**Number of Mice**	**Phenotype and Genotype**		
			Light (dd)	**Dark (Dd)**	**Dark (DD)**
1	Light	85	80	5	0
2	Dark	45	3	26	16
3	Dark	77	2	41	34

Source of data: Hoekstra, H, K. Drumm, and M. Nachman. Source: Ecological Genetics of Adaptive Color Polymorphism in Pocket Mice: Geographic Variation in Selected And Neutral Genes.2004. Evolution, 58(6), pp. 1329-1344.

Assuming that 8 Km is enough distance to establish each collecting site as an isolated population, calculate p and q for each population, where p is the frequency of D and q is the frequency of d: _____ /3

1)	$p =$		$q =$	
2)	$p =$		$q =$	
3)	$p =$		$q =$	

Using your answers for the question above, calculate the expected Hardy-Weinberg genotype frequencies for each of the populations: _____ /4.5

1)	$DD =$		$Dd =$		$dd =$	
2)	$DD =$		$Dd =$		$dd =$	
3)	$DD =$		$Dd =$		$dd =$	

Now, using the original data, calculate the actual frequency of each genotype within each of the populations: _____ /4.5

1)	$DD =$		$Dd =$		$dd =$	
2)	$DD =$		$Dd =$		$dd =$	
3)	$DD =$		$Dd =$		$dd =$	

Are the populations in Hardy-Weinberg equilibrium for the Mc1r gene? Write 'Y' or 'N' for each in the space below ______ /1

1)	
2)	
3)	

Describe the rationale you employed to answer the previous question ______ /1

For the populations above which you determined were not in Hardy-Weinberg equilibrium with respect to the Mc1r gene, why do you believe they are not in equilibrium? In other words, what evolutionary mechanism is working to ______ /2

If all the mouse predators were somehow removed from the Sonoran Desert environment, what do you predict would happen with regard to evolution of mouse coat colour, specifically with regard to the allele and genotype frequencies

/2

Part B: Extra

The numbers from the table above only represent small samples from each of the collecting sites. In reality, the mouse population numbers from each of these collecting sites are likely in the thousands, or even the tens of thousands.

/1

In the scenario described for the previous question, what would be the effect on genetic variation within the population? Would the allele frequencies for the 'D' gene in the population remain the same after passage of the

/2

In the scenario from above, what evolutionary mechanism(s) would be most likely to lead to changes in the 'D' gene allele frequency within the new small population? Is there any way that the genetic variation in the population could

/2

101-NYA Class 17: Speciation

Marks

Group:

Total Score: 0 /19

Part A: 25 Minutes

In the activity from the previous class (Class 17: Evolutionary Mechanisms) you were presented with genotype and phenotype data on rocket pocket mice sampled from separate populations in the Arizona Sonoran Desert. In this activity we will only consider two of these populations, one of which is based on rocky dark lava substrate, while the other lives on a light sandy and granite background. In each population, over 99% of the mice have fur colouration which matches the background substrate colour. These populations are separated by almost 10 Km, and are each over 20 Km away from their next nearest pocket mouse population. Thus, for all intents and purposes, these populations are physically isolated from one another, and gene flow is essentially non-existant.

From the very beginning of our examination of pocket mouse colouration, we have considered the dark and light mice to both be members of the same species. However, imagine that you were a biological researcher that was new to the area and was unfamiliar with the local mice. What pieces of evidence would you use to try and determine whether the mice from the two populations belonged to one or two species? Would any pieces of evidence suggest that they are actually separate species? In your answer to this question, define and make reference to any specific species concepts that could and would be useful towards making a decision. /5

Imagine for a moment that the two populations of mice were in fact considered to belong to different species. In this hypothetical context, phylogenetic and genome analysis would no doubt indicate that the mice had shared a common /1

The reality is that, while the two populations are geographically isolated and phenotypically different, it's unlikely that enough time has elapsed since the two populations were established for sufficient genetic variation to accumulate between the groups to lead to them being meaningfully reproductively isolated, and thus considered two separate species. Still, the mice are different, and there are no doubt potential fitness consequences for a camouflaged mouse that mates with another mouse whose colouration does not match the background, in that they might produce offspring that are not well camouflaged.

Imagine now that a freak seismic event brought both populations together, such that the dark population, still living on the dark lava rocks, was now immediately adjacent to the light population, which was still living on the sandy granite. In this scenario, mice living on the edges of their respective habitats could easily venture into the other habitat and back again, and matings between the two groups could be quite prevalent, especially for mice on the borders of the two habitats.

Based on the potential fitness consequences of mating with a different colour mouse, do you believe that reproductive isolation would arise between these two groups? If no, why not? If yes, why, and what mechanisms might evolve to prevent the mice from mating? /3

From the question above, if we assume that reproductive isolation was going to evolve, in which group do you believe these mechanisms might evolve first, and why?

/2

Part B: Extra (You should have time to do at least some of this, though)

Hawthorn trees (genus Crataegus) are native to North America, and grow throughout the continent. They produce a small fruit that ranges in size from 5mm to 20mm, with an average of 12.6mm. This fruit is eaten by larvae of the hawthorn maggot fly, Rhagoletis pomonella.

Apple trees (genus Malus), on the other hand, are not native to North America. They were introduced to North America by European settlers in the 1600s, but have since become the most widely grown fruit on the continent. In contrast to the small hawthorn fruit, a typical commercial apple has a diameter of 70mm. These fruit are also consumed by the larvae of fly pests called apple maggot flies. Despite the different name, though, these flies are actually currently considered the same species as the hawthorn maggot fly, i.e., Rhagoletis pomonella. It seems as though when apples were first introduced here, some Rhagoletis pomonella maggot flies began to shift their food source, and the first infestation was actually noted in 1864.

Rhagoletis pomonella has a fairly elaborate life cycle. Female flies first lay eggs in their fruit of choice (be it hawthorn or apple). Maggots, or larvae, emerge from the egg, feed on the fruit, and go through several molts. Healthy maggots drop from the tree with the fruit, and then burrow into the soil. They then pupate overwinter, and the metamorphisis occurs into the adult fly. During the following summer, adult maggot flies emerge and fly to the fruit trees, where mating occurs on the surface of the fruit. The cycle then repeats itself.

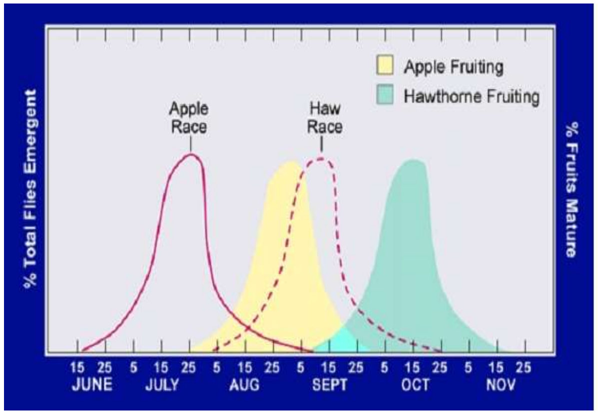
Finally, despite being burried within fruit, maggot fly larvae still face dangers. In particular, parasitoid wasps try to lay their eggs in the maggots' bodies, which paralyzes and ultimately kills the maggot.

Maggot Differences

From a maggot's point of view, the large apple fruit provides 220 times more food than a hawthorn fruit. However, the nutritional quality of the hawthorn fruit is superior, as 52% of maggots that develop in hawthorn fruits survive, compared to only 27% for a similar measure in apples. The apple does provide more protection from parasitoid wasps, though, because apple maggots can burrow more deeply into the apple and avoid the wasp's stinger, which isn't possible in the hawthorn fruit. Thus, apple maggots carry significantly fewer parasitoid wasp eggs than hawthorn maggots do.

Today, there are farely distinct apple and hawthorn maggot flies. However, the distinction isn't morphological (appearance), as the two types of flies are physically indistinguishable. Furthermore, the flies are not geographically or physically separated, as apple and hawthorn trees often grow side by each in the same areas. Where the flies do differ is in their genetic profiles. In other words, a fly researcher could not tell two flies apart just from looking at them, but could tell them apart if they sequenced the flies' genomes, because the flies are genetically distinct. These genetic differences emerged because the flies tend to mate with their own kind: hawthorn maggot flies strongly prefer to mate on and lay fertilized eggs on hawthorn fruit, whereas the same can be said about apple maggot flies and apples. Ultimately, there is only 4%-6% hybridization rate between hawthorn and apple maggot flies. However, it's important to note that when the flies do hybridize, the hybrids are perfectly viable and fertile, meaning there are no post-zygotic barriers to reproduction.

The final important point to make about apple and maggot flies is that they are generally temporally isolated. In other words, apple and maggot flies don't tend to be flying around each other at the same time very often. The reason for this stems from the ripening time of their host fruit. As the graph to the right indicates, apples fruit earlier than hawthorns, and this leads to the apple maggot flies emerging earlier than the hawthorn maggot flies. There is a small period of overlap, where flies of both 'races' can be obeserved together. However, for the most part, apple and hawthorn flies live their adult lives during separate time windows.



Recap:

Hawthorns	Apples
Native	Introduced ~1600
Small Fruit	Big Fruit
More Nutritious	Less Nutritious
More Parasitoid Attacks	Less Parasitoid Attacks
Fruit Ripens Late	Fruit Ripens Early

Hawthorn Maggot Flies	**Apple Maggot Flies**
Flies Look the Same	
Flies Live in the Same Areas	
Flies Have Same Life Cycle	
Flies are Genetically Distinct	
Mate and Reproduce on Hawthorns	Mate and Reproduce on Apples
Mate and Reproduce Late	Mate and Reproduce Early
Only 5% Hybridization Rate, Hybrids are Viable and Fertile	

The apple maggot flies and hawthorn maggot flies have historically been considered to be part of the same species. Based on all of the information presented so far, do you believe that this characterization is correct, or do believe that these two types of flies should be grouped as separate species? In your answer, outline the evidence in favour of both sides, and make reference to the particular species concepts which could be used to justify either position. /3

Class 17: Speciation

If the flies have recently become two separate species, or if they are in the process of becoming two separate species, what mode of speciation is taking or has taken place? Explain your answer.

/1

What specific reproductive isolating mechanisms are at play in the maggot fly study system? For each mechanism you define, identify whether this is pre- or post-zygotic. /2

Hawthorn and Apple maggot flies still hybridize, albeit rarely. Within what context do you believe the flies would eventually evolve to cease inter-breeding entirely? What mechanisms could theoretically evolve or develop to finally isolate these flies completely? /2