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.

Grading Explanation

1

2

3

4

	Oldest			Most Recent
Answers:	4	3	2	1

____ /2

0.5 marks per correct answer. No part marks.

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

In all the images location A is light coloured. In three of the images location B is dark coloured, but in one of the images it is light coloured. The dark background represents dried lava flows, and so the likelihood is that location B started off as light, as in image 4, but then a volcanic eruption led to the environment becoming dark. So, number 4 is first. Since most of the mice in image 4 are white, it stands to reason that the most mice in the dark environment would initially be white as well. Image 3 is the one with the most white mice for location B, and so this comes next. The expectation would be that dark mice would be better camouflaged against the dark background than light mice, and so you expect the frequency of these to increase in location B, while the light mice should decrease. Image 2 has less white mice, while image 1 has the least, and so these two come next, in this order.

1 mark for correct explanation of why #4 is first (B is pre-lava), 1 mark for correct explanation of how selection leads to more dark mice and less white mice in location B. Part marks are possible.

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

As the image clearly displays, light mice are well camouflaged against a light background, while dark mice are well camouflaged against a dark background. Since many predators consume these mice, it is a big advantage to be well camouflaged, because it allows you to survive long enough to reproduce successfully. Thus, white mice are more successful in a light background than dark mice, and vice versa for the dark background.

1 mark for correct explanation. 0.5 marks for simply mentioning camouflage, full marks for tying in to avoiding predators, extended survival, and greater reproduction.

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

_____ /2

The dark phenotype arises because of a mutation in MC1R (or in another gene; there are numerous ways to produce a dark mouse). Mutations are rare and random events, but they are impossible to stop. Thus, even in a light background, dark mice will continue to be born. However, these dark mice are unlikely to survive and reproduce as effectively as the light mice, and so the dark phenotype never becomes very prevalent in the population.

1 mark for mentioning mutation and that it will always produce new dark mice. 1 mark for mentioning that selection will keep numbers of dark mice low. Part marks possible.

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

_____ /1

As mentioned above, mutation is rare and random, and occurs because of unpredicatable and unavoidable errors in DNA replication or transcription (DNA can actually even just get damaged while not being manipulated). Where mutations occur within the genome is completely random, however, and so there is no way to determine which phenotypes will be produced in the future. On the other hand, natural selection is not random, and is usually entirely predictable, because it is based on differential survival and reproduction. It is possible to estimate which traits will result in increased survival and reproduction (for example dark colouration on a dark background), and to predict that natural selection will result in an increase of these traits within the population.

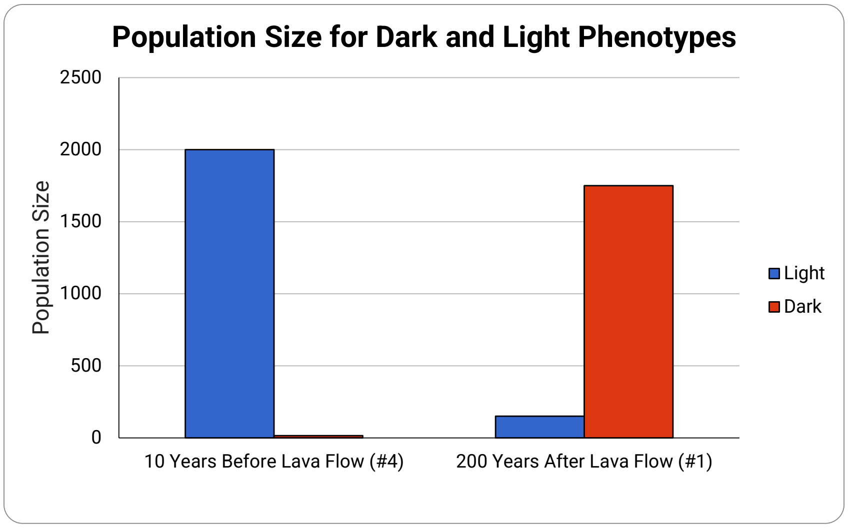
0.5 marks for some vague mention that mutations are unpredictable and unavoidable, 0.5 marks for correct description of how natural selection is predictable because it is based on differential reproduction.

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)	2000	15
200 Years After Lava Flow (#1)	150	1750

_____ /2

0.5 marks for correct placement of axes, 0.5 marks for corrext axis labels, 0.5 marks for correct data labels, and 0.5 marks for visually appropriate graphical display which presents data properly. Graph does not need to be a bar (or column) graph, but does need to properly present the data.



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

1 mark for correct answer. No part marks. No explanation necessary.

Directional selection, because there is a clear shift in predominant phenotype from light to dark.

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

1 mark for reasonable hypothesis (i.e., testable explanation for question) about sexual selection. Does not need to

Widowbirds have evolved elaborate mating physiology and complex behaviour as a result of intra- and inter-sexual selection, and so males with the brightest epaulets, the longest tail feathers, and the most elaborate bouncy and 'wing-beaty' flight display are best able to establish and defend a territory against other males, and attract the most females, resulting in a production of the greatest amount of offspring.

mention both intra and inter. 0.5 marks for simple mention of sexual selection, without elaboration on either success in defending territories and/or attracting females.

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

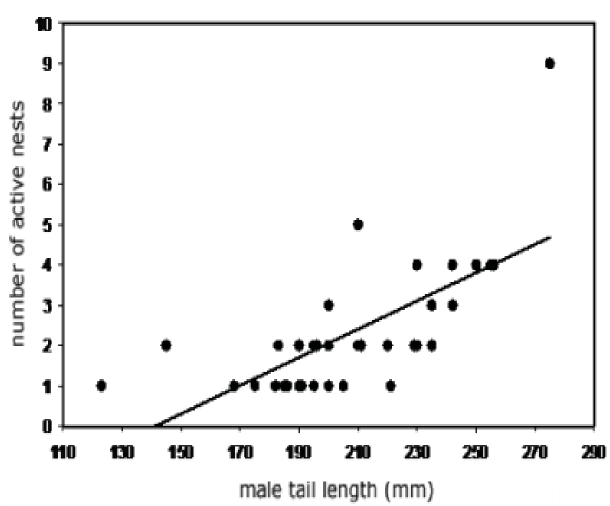
The male widowbird mating traits are detrimental to the survival of these males, as they carry a large cost: they result in the birds being very conspicuous for predators, they require large inputs of energy, and they hamper the birds' abilities to fly and thus capture their own food. Thus, natural selection by itself should actually work AGAINST these traits, as males that do not display the traits should survive longer and have more energy to reproduce. Thus, the only explanation for why these traits do exist in the population is that they have evolved based on sexual selection. The fact that these traits do incur such a high cost means that being able to display them is a clear indicator for females of the male's overall quality as a mate. These are thus honest signals based on the handicap hypothesis, preventing females from making mating "mistakes", and so will be sexually selected FOR, as females will choose the males that are best able to display these traits, providing them with greater reproductive fitness. Simultaneously, since males apparently defend their territories against other males, having bright colouration likely confers some form of social status with the population (the birds do not engage in direct physical competition, as the cost of this would be too high). Therefore, in this example, natural selection and sexual selection are working against each other in opposite directions, with selection working to reduce the elaborate traits and sexual selection working to increase them.

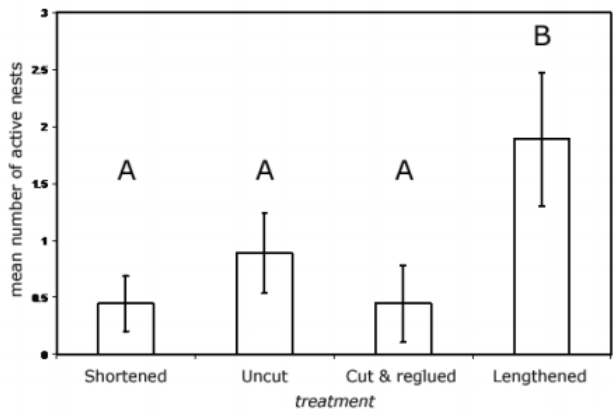
1 mark for proper rationale for sexual selection which incorporates correct explanation for why natural selection should work against long feathers (high cost). Full mark here for correct explanation about natural selection and cost, even if this isn't tied back to sexual selection. Part marks possible.

1 mark for explanation of honest signalling (or handicap hypothesis), which prevents female mistakes and leads to sexual selection for the feathers. Again, full mark for proper explanation without perfect tie-in back to original hypothesis. Part marks possible.

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

In both studies the hypothesis being tested is that male tail length has an effect (or has a positive effect) on the number of active nests a male is able to establish on his territory.

However, the first graph represents the results of what is called an analytical study, where the independent variable (tail length) is not directly manipulated by the researchers, but rather is just examined based on natural variation. In contrast, the second graph reflects a true experimental context, where tail-length is directly manipulated by the researchers. Both studies contribute valuable information, and together provide a much more complete answer than each on its own. The analytical study shows that the expected results are indeed observed in uncompromised natural contexts, but leaves open the possibility that unknown variables are driving the observed results. The experiment accounts for any unknown variables, because these are (theoretically) washed out by the randomization of study samples and the rigorous experimental controls. Of course, the experiment on its own is not a natural setting, and so requires the results of an analytical study to confirm that these results would be observed in nature. These two approaches are often used together to provide an understanding of natural systems.

1 mark for each correct hypothesis. Since the hypotheses are both the same, the answer here is sufficient.

The extra explanation is only FYI, not for marks.

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

Top: The results appear to provide support for the hypothesis, are there seems to be a clear correlation between male tail length and active nest sites. No statistical values are included with this graph to provide a numerical perspective, but a visual assessment suggests that males with longer tails had a higher probability of having more nests. There is of course a decent amount of variation, but this is always observed in natural systems, as many other uncontrolled variables are always at play.

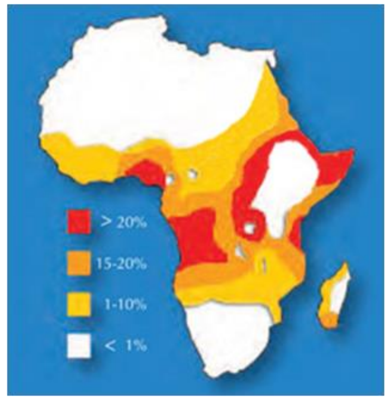
Bottom: These results clearly provide support for the hypothesis, as the males with experimentally longer tails has significantly more mating success. It's unclear whether cutting the tail feathers has an effect, as the males with reglued feather had lower mating success. Still, there appears to be strong support for the hypothesis that male tail length has a positive effect on the number of active sites.

1 mark each for proper explanation. Explanations do not need to be this elaborate, and can be fairly simplistic, reflecting only a basic reading of the graphs. Part marks possible for misconceptions or misunderstandings.

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

1 mark for correct mention of either stabilizing or balancing selection, 1 mark for correct explanation. Not necessary to specifically mention heterozygote advantage. Explanations do not need to be this elaborate, and part marks possible.

The answer for this will depend on whether you did the readings. If you did not do the readings, then you should answer stabilizing selection, as the extreme phenotypes are being selected against, while the average or intermediate phenotype is being selected for. That selection is occurring might be counterintuitive based on the definition of microevolution, which is a change in allele frequencies within a population over time. In this case, the allele frequencies are not changing, which might lead you to believe that the population is not evolving, and therefore that natural selection is not occurring. However, a key feature here (which we'll see more of in the next class) is that, while allele frequencies are not changing, the genotype frequencies do change, because the extreme phenotypes are selected against. It just happens, in this particular context, that the extremes are the two homozygotes, while the intermediate is the heterozygote. Removing equal frequencies of the homozygotes while maintaining the heterozygotes won't skew allele frequencies, which leads to the scenario observed here. So, in the end, stabilizing selection is occurring, this has an effect on genotype frequencies, but allele frequencies remain the same.

If you did do the readings, however, you should be answering BALANCING SELECTION. Frankly, this is a completely new characterization, and isn't described in older textbook versions (or the videos). The term balancing selection appears to have been created very recently to specifically address the issue described above, which is the result of a process called heterozygote advantage. In an scenario like above, where a particular trait is coded for by only one gene with two alleles, and in which homozygotes are selected against and heterozygotes are selected for, the result is allele frequencies remaining stable but genotype frequencies being affected. Since this doesn't really fit properly within the context of stabilizing selection (which eliminates extreme alleles and results in a decrease in genetic variation), a new term appears to have been created. So, natural selection is occurring, and it is BALANCING SELECTION.

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

1 mark for appropriately elaborated hypothesis, elaborating on lack of benefit but maintained cost. Part marks possible.

The sickle cell allele is detrimental to humans, but is maintained through heterozygote advantage in populations exposed to malaria, because it confers resistance to this parasite. Since the malarial parasite is not found in North America, people of African descent living in North America would not enjoy the benefit of malaria protection, and so the inherent cost of this allele (producing offspring with sickle cell anemia) leads to it being selected against and decreasing in frequency within the population.

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

1 mark for correct answer. No part marks.

Directional

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

Full marks for answering stable with an appropriate explanation. 1.5 marks for choosing decrease with an acceptable explanation. Part marks for poor explanations.

This is a difficult question to answer. From the information in the question itself, you might expect the frequency of the allele to stay reasonably stable, because there may no longer be strong selective pressure against the sickle cell allele. However, genetic counselling, pre-natal screening, and early term abortions could provide a new form of selection against the allele, as couples at risk of having babies with sickle cell could take means to prevent this from happening. So, overall, I would still expect the frequency of the allele to decrease, even though people with sickle cell can now live long enough to have children of their own (that will obviously at least carry the allele).

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

1 mark for correct explanation. No marks just for writing 'No'. Part marks possible.

No. Sickle-cell results from a single point-mutation. It will therefore be impossible to keep this mutation from re-occurring in populations. Further, because it is a recessive mutation, it can be masked in heterozygotes, which dramatically decreases the selection pressure against the allele.