UNIVERSITY OF YORK
BSc Stage 3 Degree Examinations 2017-18

Department:
BIOLOGY

Title of Exam:
Ecological Genetics

Time allowed: 2 hours
Total marks available for this paper: 100

Section A: Short Answer (50 marks)
Answer all questions in this section in the spaces provided on the examination paper.

Section B: Essay question (marked out of 100, weighted 50 marks)
Answer either question A or question B
Write your answer on the separate paper provided and attach it to the back of the question paper using the treasury tag provided

Instructions:
The marks available for each question are indicated on the paper
A calculator will be provided

For marker use only:

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SECTION A: Short Answer / Problem / Experimental Design questions

Answer all questions in the spaces provided

Mark total for this section: 50

1. a) Explain how the transmission mode of a pathogen will affect the evolution of the interaction with its host.  

Vertically transmitted parasites usually evolve to be more benign and less virulent (1 mark), because they depend on survival of the host in order to be passed on to the next generation (1 mark). Horizontally transmitted parasites often cause more damage and possibly even death (1 mark) as they do not rely on the host for transmission (1 mark). 

b) Briefly outline an experiment to test the prediction in (a).  

Use a system where it can be manipulated whether the pathogen is transmitted vertically or horizontally (1 mark). Passage the pathogen for several generations either horizontally or vertically using multiple replicate lineages for each transmission mode (2 mark). Measure damage done to the host at the end of the experiment (1 mark). 

LO addressed:
4. assess, using examples, the importance of genetic drift and selection in causing population divergence and adaptation.

This question was generally answered well. Many students did not mention replication in the selection experiment.

2. A reciprocal transplant experiment has been conducted with Arabidopsis thaliana from an Italian and a Swedish site, where seeds or seedlings were transplanted every year for five years. Figure 2A shows the number of fruit produced per planted seed or seedling across several experimental years. Closed circles represent the Italian genotypes while the open circles represent the Swedish genotypes. The asterisks indicate a significant difference at the site in that year. Figure 2B shows the survival of
the Italian genotypes at the Swedish site depending on the minimum soil temperature in the winter of the experimental year.

Figure 2A

Figure 2B

a) Discuss whether there is evidence for local adaptation in these populations. 3 marks
There is evidence for local adaptation in this experiment (1 mark), the local genotypes perform better than “foreign” genotypes in eight of the ten comparisons (1 mark). In the other two comparisons, there is no difference between the populations from Italy and Sweden (both in Sweden, 2006/07 and 2010/11) (1 mark).

b) Compare the overall suitability of the two transplant sites and discuss the role of winter temperatures in determining this. 7 marks

The Italian site appears overall more suitable for *A. thaliana*, the Italian genotypes perform better there in all years, and the Swedish genotypes also perform better in Italy in two of the five years (2 marks). There is only one year (2010/2011) where the Swedish genotypes are performing best at the Swedish site (1 mark).
The Italian genotypes are performing worst at the Swedish site after very cold winters in terms of survival and fruits produced (2004/05, 2005/06), the Swedish genotypes also suffer but to a lesser extent (2 marks). After warmer winters the number of fruits at the Swedish site does not differ between Italian and Swedish genotypes (1 mark). This suggests that minimum winter temperatures play an important role in determining the quality of the site (1 mark).

c) Discuss the processes that may have led to the two populations displaying a different degree of phenotypic plasticity. 4 marks

The Italian genotypes display greater phenotypic plasticity, shown by greater differences in the number of fruits between the two sites and the Swedish genotypes are generally less plastic (1 mark). It is likely that the Swedish population has adapted to the (cold) conditions at the Swedish site while retaining its ability to perform well under universally more favourable conditions such as those at the Italian site (1 mark), which suggests that this adaptation does not carry a major cost (1 mark). In contrast, the Italian population appears to have adapted to the conditions in Italy and the poor performance at the Swedish site is likely to due the lack of selection for these extreme conditions (1 mark). Other sensible interpretations will be given credit.

LO addressed:
2. interpret and assess data presented in phylogenies, phylogeographic analysis, genetic clustering analysis and other forms of data presented in ecological genetics scientific papers.
4. assess, using examples, the importance of genetic drift and selection
in causing population divergence and adaptation.

Part (a) was generally answered well. Part (b) was answered well by some students, but many students did not use the data effectively to answer this question, a good answer should have highlighted patterns in the graphs. Many students also only answered the first or the second part of the question. A few students misinterpreted the question and answered whether the two sites were suitable for a reciprocal transplant experiment rather than for the plants, some credit was given for this. Part (c) was often answered quite generically, and again a good answer should have included clear references to the data.

3. A large road, the Interstate Highway 10 (I10), runs through the habitat of Western diamondback rattlesnakes in Arizona. Rattlesnake individuals were sampled from three populations I10E, I10W and CT. Figure 3A is a map of the area showing the locations of sampled individuals from these populations; I10W (orange squares), I10E (green circles) and CT (green triangles).

![Map of rattlesnake populations](image)

Figure 3A

The rattlesnake samples were also genotyped using 30 microsatellite markers. These genotypes were used in the program STRUCTURE to find the most likely number of genetic groups among the sampled individuals. Figure 3B below shows the probability that each individual belongs to each of three groups (red, yellow and green).
Figure 3B

a) Explain why the genetic evidence presented in Figure 3B is not sufficient to show that the highway itself poses a significant barrier to gene flow between rattlesnake populations. (4 marks)

Figure 3B shows that there is some genetic differentiation between I10W (individuals mostly assigned to the red genetic cluster) and I10E (individuals mostly assigned to the green and yellow genetic clusters) (1 mark). But these two populations are not only separated by the road, but also by a distance of ~5 km, and geographic separation by itself can cause genetic differentiation (1 mark). For example, I10E and CT (individuals mostly assigned to the green genetic cluster) are also appear genetically differentiated and are separated by ~8 km (1 mark). Membership of different genetic clusters also does not tell one how genetically distinct each cluster is from one another (1 mark).

b) What other analyses or experiments would you need to carry out to determine whether or not the highway itself poses a significant barrier to gene flow between rattlesnake populations? (4 marks)

Need to show that the genetic differentiation between I10E and I10W is greater than that expected given the geographic distance between the two (1 mark). Calculating pairwise genetic distance (such as Fst) and pairwise geographic distances between the three populations (2 marks). But ideally need to sample multiple populations across the road, as well as multiple populations separated only by distance (1 mark).

c) How could the results in Figure 3b be depicted in a more informative manner, and why would this be an improvement? (3 marks)

Individual's assignment probabilities could be depicted as pie charts and plotted on the sampling map (1 marks). Plotting assignment probabilities on the map would clearly show the location of for example green cluster individuals from I10W, and how the yellow and green cluster individuals from I10E were located (2 marks)
4. The Black-browed Tit (*Aegithalos bonvaloti*) and Sooty Tit (*A. fuliginosus*) are thought to be two closely-related species that occur in East Asia. *A. bonvaloti* inhabits high altitude habitats (1500-4400 m), whereas *A. fuliginosus* inhabits relatively lower altitudes (1000 to 2600 m). In Figure 4A the solid and dashed lines indicate the distribution ranges of *A. bonvaloti* and *A. fuliginosus* respectively. The overlapping region represents a contact zone in their distributions. The circles and triangles indicate the sampling localities of *A. bonvaloti* and *A. fuliginosus* respectively. All the samples were genotyped at a large number of SNPs which were then used to construct a phylogenetic tree (Figure 4B).
a) What is the evidence for hybridisation between *A. bonvaloti* and *A. fuliginosus*? (4 marks)

Current hybridisation should only be possible in the contact zone where the two taxa co-exist (1 mark). The individuals of both taxa from the allopatric populations form distinct monophyletic clades indicating that they are insulated from hybridisation (1 mark). Individuals from both taxa from the contact zone occupy intermediate positions in the tree (1 mark), and also render the taxa paraphyletic (1 mark).

b) Explain how the ABBA-BABA test could be carried out in this system to test for hybridization between the two taxa. (5 marks)

The ABBA-BABA test requires the use of four taxa in the following phylogenetic configuration (((P1, P2), P3), P4), to test for differential gene flow between P3 and either P1 or P2 (2 marks). In this system, an appropriate arrangement of taxa would be

either:
- P1: contact zone *A. bonvaloti*
- P2: allopatric *A. bonvaloti*
- P3: contact zone *A. fuliginosus*
- P4: *A. caudatus*

or:
- P1: contact zone *A. fuliginosus*
- P2: allopatric *A. fuliginosus*
- P3: contact zone *A. bonvaloti*
P4: A. caudatus
(2 marks for one correct arrangement, and 3 marks if both arrangements are shown)

b) Discuss whether or not these two taxa should be considered to be separate species. (3 marks)

According to the strict Biological Species concept they may not be different species. (1 mark)
According to the genotypic clusters species concept they may not be different species as they cannot maintain distinct genetic clusters in sympathy. (1 mark)
But the names indicate that the two taxa are morphologically distinct and the two taxa also inhabit different niches (elevations). (1 mark)
More information is needed about pre- and post-zygotic reproductive barriers. (1 mark)
(Any three of the above)

LO addressed:
LO2: Interpret and assess data presented in phylogenies, phylogeographic analysis, genetic clustering analysis and other forms of data presented in ecological genetics scientific papers.
LO3: Describe, using examples, the different outcomes that can occur when two populations meet.
LO5: Explain what is a species, discuss the importance of reproductive barriers to maintain species integrity, and be able to assess the main drivers of speciation.

5. Define adaptive introgression and explain why it is so much more common among bacteria compared to eukaryotes? (5 marks)

The movement of beneficial genes from one species to another. (1 mark)
Bacteria have ways of acquiring genetic material not available to eukaryotes such as conjugation, transformation and transduction (3 marks). In contrast, eukaryotes need to hybridise and backcross for introgression to occur, a process made difficult by reproductive barriers (1 mark).

LO3: Describe, using examples, the different outcomes that can occur when two populations meet.
LO5: Explain what is a species, discuss the importance of reproductive barriers to maintain species integrity, and be able to assess the main drivers of speciation.
SECTION B: Essay question

Answer one question on the separate paper provided

Remember to write your candidate number at the top of the page and indicate whether you have answered question A or B

Mark total for this section: 50

EITHER

A) Discuss how the Pleistocene Ice Ages might have contributed to current phylogeographic patterns.

- Phylogeographic patterns are particular associations between the geographic distribution of a taxon and its population structure.
- Phylogeographic patterns can be informative as to past distributions and migration patterns.
- Ice Ages caused cyclical changes in the environment. In Europe this resulted in repeated expansions and contractions of ice sheets.
- For warm-tolerant species, the cold phases resulted in habitat shrinkage. Species were confined to southern refugia often in the Balkans, Iberian Peninsula and Italy. The reverse is the case for cold-tolerant species.
- Populations confined to different refugia may diverge from one another in allopatry due to genetic drift and adaptation to different habitats.
- Divergent populations expanding out of different refugia may meet.
- The outcomes of meeting will depend on how diverged the populations are, and will range from complete mixing, partial mixing, through to stable contact zones between species.
- The existence of refugia can be inferred from regions in the current distribution with high genetic diversity.
- Several examples were discussed in the lectures; brown bears, voles.
- As multiple taxa often shared the same refugia and expansion routes, correlated phylogenetic patterns are often observed, such as the existence of suture zones or multiple correlated contact zones.

LO3: Describe, using examples, the different outcomes that can occur when two populations meet.
LO4: Assess, using examples, the importance of genetic drift and selection in
causing population divergence and adaptation.

**LO5**: Explain what is a species, discuss the importance of reproductive barriers to maintain species integrity, and be able to assess the main drivers of speciation.

OR

**B)** Discuss how spatial variation might affect coevolutionary dynamics.

- Define coevolution as reciprocal evolution of two interacting species, e.g. victim/natural enemy, plant/pollinator.
- Both partner species are likely to occur in spatially separated and genetically distinguishable population and the interacting species might differ in their geographic ranges.
- The species might differ in their responses to other environmental conditions, such as climate, nutrient availability, presence of and interactions with other species (local adaptation). The interaction itself might also be sensitive to environmental conditions (e.g. the two species might have different tolerances to extreme temperatures).
- In the simplest scenario, it may be that one of the interacting species is absent in a particular habitat, and therefore no coevolution can take place.
- More interestingly, the abundance of the partners might differ and therefore the strength of selection on each other may be different. Similarly, interactions with other species might be more important in some populations. If these select for other trait values, selection by the focal species might not lead to the expected response.
- There may be multiple interacting species all selecting for the same response (e.g. multiple predator species all selecting for increased running speed), which might accelerate coevolution, although it will no longer be strictly pairwise.
- There might also be gene flow from other populations that vary in their adaptation to the interacting species, which could help or hinder coevolution.
- Examples can be used from many lectures to illustrate some of these interactions and principles discussed above.

**LO addressed:**

3. describe, using examples, the different outcomes that can occur when two
populations meet.

4. assess, using examples, the importance of genetic drift and selection in causing population divergence and adaptation.

This question was only answered by two students. Both answers described coevolution to an extent, and discussed the importance of space to a degree, but did to make a meaningful link between the two.