Funky Pigeons

Revealing the biology of inheritance and selection

Student Worksheets

Linnean Learning

DARWIN INSPIRED LEARNING

Picture courtesy John Ross: www.darwinspigeons.com

Contents

This pack contains all the student worksheets required for the Funky Pigeons module.

If an activity is not listed in the contents list then it does not have a worksheet associated with it.

Lesson 1: Activity 1

Comparing natural and artificial selection

	Natural selection	Artificial selection
Cause		
Speed of change		
Reason for selection occurring		
Effect on fitness		

Lesson 1: Activity 3

Punnett square revision activity referring to Mendel's laws

The following Punnett square shows the outcomes of a pigeon breeding cross for the **s** or spread gene.

S s^+ **Black**	**S s^+** **Black**
s^+ s^+ **Blue-grey**	**s^+ s^+** **Blue-grey**

What are the genotypes of the parents?

What are the phenotypes of the parents?

Lesson 1: Activity 4

Pigeon genetics - Punnett square activity

Complete the Punnett square for a cross between a bird with the genotype **C c** and a bird with the genotype **c^+ c**.

Include the **phenotype** of the offspring.

Parental **genotypes** ____

Parental **phenotypes** ____

Parent 1 gametes

Parent 2 gametes

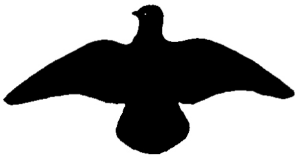
Lesson 2: Starter Activity

Quick quiz

A pigeon breeder has mixed up his birds and needs to work out which pigeons are the offspring of which parents. Look at the pigeon parents and their potential offspring below. Has the pigeon breeder got it right?

Parents		**Offspring?**

Family 1

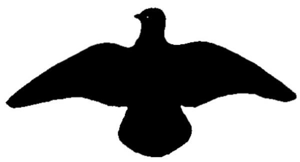


Family 2



Family 3





Lesson 2: Activity 1

Dominant epistasis

The table of data below is taken from a scientific paper in the journal Genetics from 1922. The scientist had carried out systematic breeding experiments in an attempt to unpick the genetic basis of wing patterning in pigeons. At this time scientists used the terms 'dominant' and 'epistatic' interchangeably, although dominance is a property of alleles and epistasis a property of genes.

Complete the table below by adding the expected values for the last 3 crosses (rounding up to 2 decimal places).

- You are given the observed ratios of phenotype for the offspring.
- The expected ratio of phenotypes if the 2 genes are interacting epistatically is 12:3:1 (black: chequer: barred).

Male	Genotype	Female	Genotype	Observed			Expected			Notes
				Black	Chequer	Barred	Black	Chequer	Barred	
1033A	$Ss^+ Cc^+$	1033B	$Ss^+ Cc^+$	4	2	2	6.0	1.5	0.5	2 blacks not included, poor descriptions
1033D	$Ss^+ Cc^+$	1033E	$Ss^+ Cc^+$	7	2	1				3 blacks not included, poor descriptions
905B	$Ss^+ Cc^+$	864A	$Ss^+ Cc^+$	2	1	1				4 blacks not included, poor descriptions
962A	$Ss^+ Cc^+$	915B	$Ss^+ Cc^+$	2	1	0				1 black not included, poor description
Total				15	6	4				

 Genetics September 1, 1922 vol. 7 no. 5 466-507 STUDIES ON INHERITANCE IN PIGEONS. IV. CHECKS AND BARS AND OTHER MODIFICATIONS OF BLACK by Sarah Van Hoosen Jones. www.genetics.org/content/7/5/466.full.pdf+html.

You are going to use this data to investigate whether the above genes are epistatic.
State your null hypothesis.

Using the data in the table above, complete the chi-squared test using the equation below.

$$\chi^2 = \sum \frac{(O-E)^2}{E}$$

Answer = ____

Using the probability table below and your calculated value of chi-squared, do you accept or reject the null hypothesis?

____

____

____

Are the genes acting epistatically?

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Describe one possible reason for the observed numbers of offspring differing from the expected in these crosses.

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Number of classes	Degrees of Freedom	Probability							
		0.99	0.75	0.50	0.25	0.10	0.05	0.02	0.01
2	1	0.00	0.10	0.45	1.32	2.71	3.84	5.41	6.64
3	2	0.02	0.58	1.39	2.77	4.61	5.99	7.82	9.21
4	3	0.12	1.21	2.37	4.11	6.25	7.82	9.84	11.34
5	4	0.30	1.92	3.36	5.39	7.78	9.49	11.67	13.28
6	5	0.55	2.67	4.35	6.63	9.24	11.07	13.39	15.09

Lesson 2: Activity 2

Recessive epistasis

If you consider 2 parents who are both heterozygous for the normal and mutated copies of **MC1R** and **TYR**.

The alleles are as follows:
M = normal MC1R allele – dark hair EUMELANIN
m = mutant MC1R allele – red hair PHAEOMELANIN
T = normal TYR allele – coloured hair MELANIN
t = mutant TYR allele – albino/white hair NO MELANIN

What is the genotype and phenotype of the parents?

The following Punnett square shows the possible genotypes of their offspring. Complete it to show the phenotype below each genotype. Remember that M is dominant to m and that **TYR** is epistatic to **MCR1**.

Father

Mother	MT	Mt	mT	mt
MT	MMTT	MMTt	MmTT	MmTt
Mt	MMtT	MMtt	MmtT	Mmtt
mT	mMTT	mMTt	mmTT	mmTt
mt	mMtT	mMtt	mmtT	mmtt

Lesson 2: Activity 3

Sex linked inheritance

Ash-red is dominant to blue-grey which is dominant to brown. The possible genotypes and phenotypes are shown below. Complete the phenotypes not shown.

Males

B^A B^A = Ash-red

B^A B^+ =

B^A b = Ash-red

B^+ B^+ = Blue-grey

B^+ b =

b b = Brown

Females (only one Z chromosome)

B^A/ - = Ash-red

B^+/- =

b/ - =

Complete the Punnett square for a cross between a heterozygous blue-grey male with the genotype shown and an ash-red female. Include the phenotype and sex of the offspring.

Parental genotypes B^A b ______________

Parental phenotypes Blue-grey Ash-red

Father's gametes

Mother's gametes

Explain why the cross between a brown female and a homozygous blue-grey male would never give rise to brown female progeny?

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Lesson 3: Activity 2

Finches in the news

- Read the article below and, in pairs, design a cartoon strip that describes what the article is saying.

Birth of New Species Witnessed by Scientists by Brandon Keim, Wired Science, November 16, 2009. Reproduced with permission. www.wired.com/2009/11/speciation-in-action

On one of the Galapagos islands whose finches shaped the theories of a young Charles Darwin, biologists have witnessed that elusive moment when a single species splits in two.

In many ways, the split followed predictable patterns, requiring a hybrid newcomer who'd already taken baby steps down a new evolutionary path. But playing an unexpected part was chance, and the newcomer singing his own special song.

This miniature evolutionary saga is described in a paper published Monday in the Proceedings of the National Academy of Sciences. It's authored by Peter and Rosemary Grant, a husband-and-wife team who have spent much of the last 36 years studying a group of bird species known collectively as Darwin's finches.

The finches — or, technically, tanagers — have adapted to the conditions of each island in the Galapagos, and they provided Darwin with a clear snapshot of evolutionary divergence when he sailed there on the HMS Beagle. The Grants have pushed that work further, with decades of painstaking observations providing a real-time record of evolution in action. In the PNAS paper, they describe something Darwin could only have dreamed of watching: the birth of a new species.

The species' forefather was a medium ground finch, or Geospiza fortis, who flew from a neighboring island to the Grants' island of Daphne Major, and into their nets, in 1981. He "was unusually large, especially in beak width, sang an unusual song" and had a few gene variants that could be traced to another finch species, they wrote. This exotic stranger soon found a mate, who also happened to have a few hybrid genes. The happy couple had five sons.

In the tradition of finches, for whom songs are passed from father to son and used to serenade potential mates, the sons learned their immigrant father's tunes. But their father's vocalizations were strange: he'd tried to mimick the natives, but accidentally introduced new notes and inflections, like a person who learns a song in a language he doesn't understand.

These tunes set the sons apart, as did their unusual size. Though they found mates, it may only have taken a couple generations for the new lineage to ignore — or be ignored by — local finches, and breed only with each other. The Grants couldn't tell for certain when this started, but they were certain after four generations, when a drought struck the island, killing all but a single brother and sister. They mated with each other, and their children did the same.

No exact rule exists for deciding when a group of animals constitutes a separate species. That question "is rarely if ever asked," as speciation isn't something that scientists have been fortunate enough to watch at the precise moment of divergence, except in bacteria and other simple creatures. But after at least three generations of reproductive isolation, the Grants felt comfortable in designating the new lineage as an incipient species.

The future of the species is far from certain. It's possible that they'll be out-competed by other finches on the island. Their initial gene pool may contain flaws that will be magnified with time. A chance disaster could wipe them out. The birds might even return to the fold of their parent species, and merge with them through interbreeding.

But whatever happens, their legacy will remain: New species can emerge very quickly — and sometimes all it takes is a song.

Lesson 3: Activity 3: Reviewing the evidence

Part 1: The finch's family tree

The immigrant founder finch is numbered **5110**. The Grants demonstrated it was an immigrant to Daphne Major by looking at its DNA sequence. Its DNA was shown to be more similar to the ground finches of the nearby island of Santa Cruz than to the ground finches of Daphne Major.

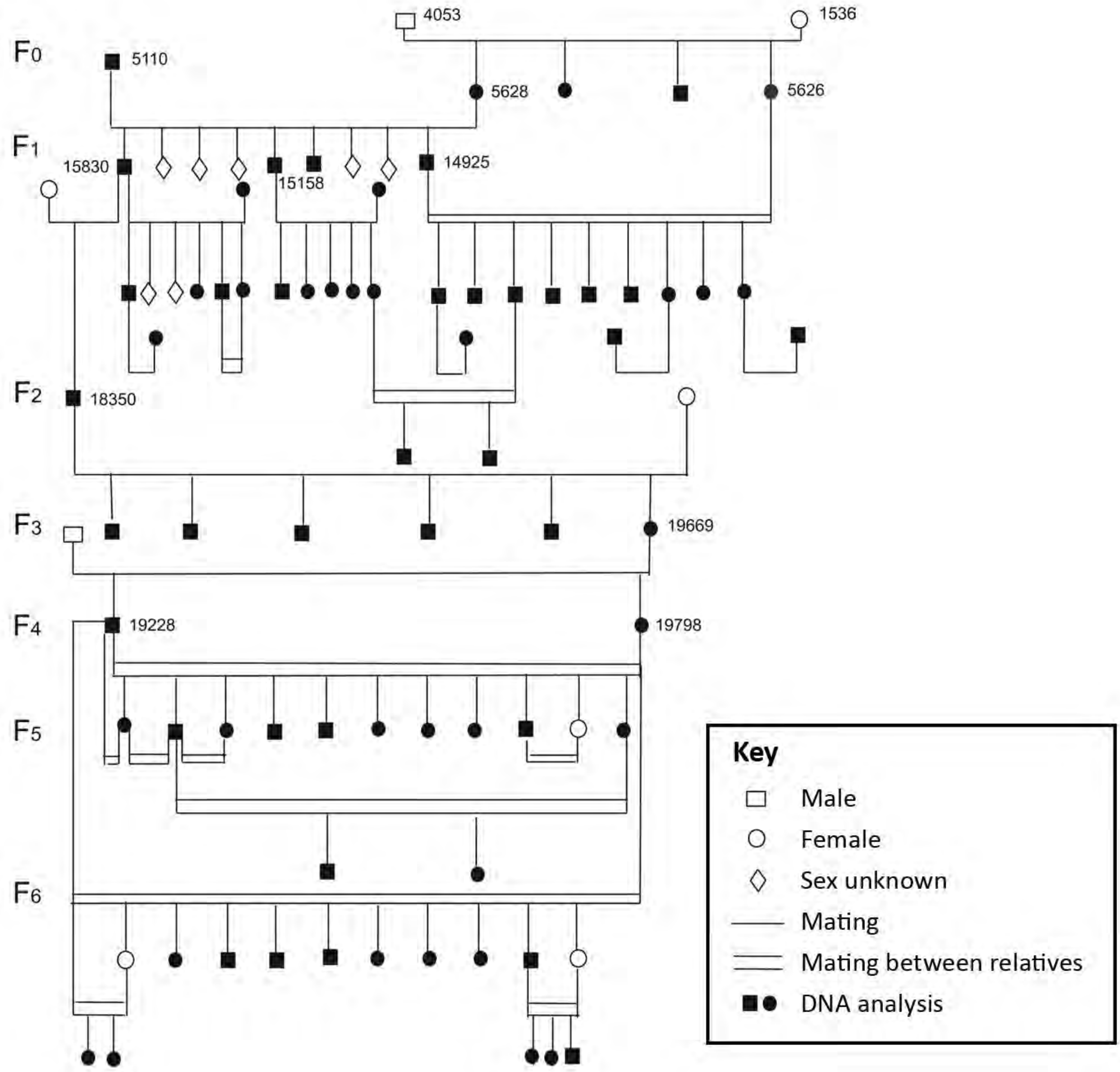

Figure taken, with permission, from: Grant, P. R. and Grant R. B. (2009) The secondary contact phase of allopatric speciation in Darwin's finches. *Proceedings of the National Academy of Sciences, 106(46)*

Examine the finch family tree and answer the following questions:

1. How many birds in the F1 generation had offspring? ____

2. Which F2 bird outbred with a finch from the local population? ___________________________________

3. A drought occurred during the F4 generation killing all but 2 finches that went on to breed with each other. Did any outbreeding with the resident ground finch population occur from that point? ________

4. How many inbred matings occurred from the F4 generation onwards? ____________________________

Part 2: Evidence of differences in beak morphology (size and shape) between the inbreeding group and the native Daphne Major ground finches.

Examine the graphs showing the beak size of the immigrant and native finches.

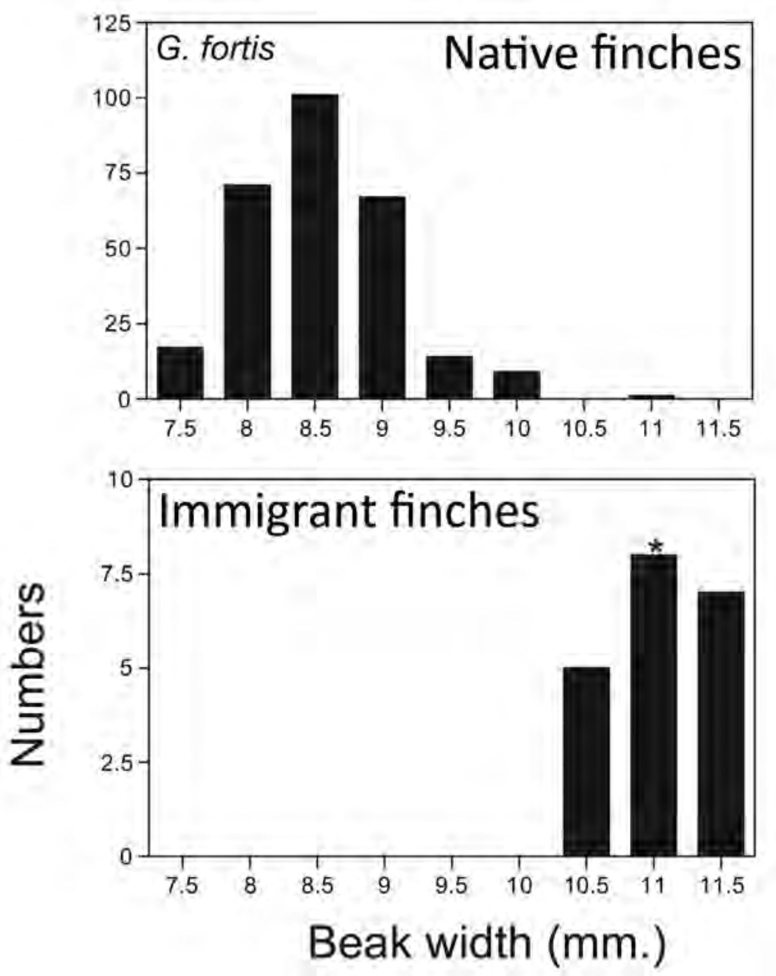

Figure 6. Morphological contrast between the immigrant lineage (*n* = 20) with other *G. fortis* (*n* = 280) on Daphne Major Island in the years 2005– 09. The position of the original immigrant (5110) is indicated by an asterisk.
Figure taken, with permission, from: Grant, P. R. and Grant R. B. (2009) The secondary contact phase of allopatric speciation in Darwin's finches. *Proceedings of the National Academy of Sciences, 106(46)*

1. Calculate the mean beak width of both the immigrant and native finch.

____

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2. Why might finches on the island of Santa Cruz have larger beaks than Daphne Major ground finches?

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Part 3: Evidence of differences in song between the inbreeding group and the native Daphne Major ground finches.

- Male ground finches only have one song which they learn from their father.
- Female ground finches do not sing but do choose mates based on their song.
- The Daphne Major finches have a song that is distinct from the Santa Cruz finches.
- The immigrant finch sings a variant of the Daphne Major finches, an imperfect copying of it.

The scientists analysed the song of the new finch population and the native one using a sonograph.

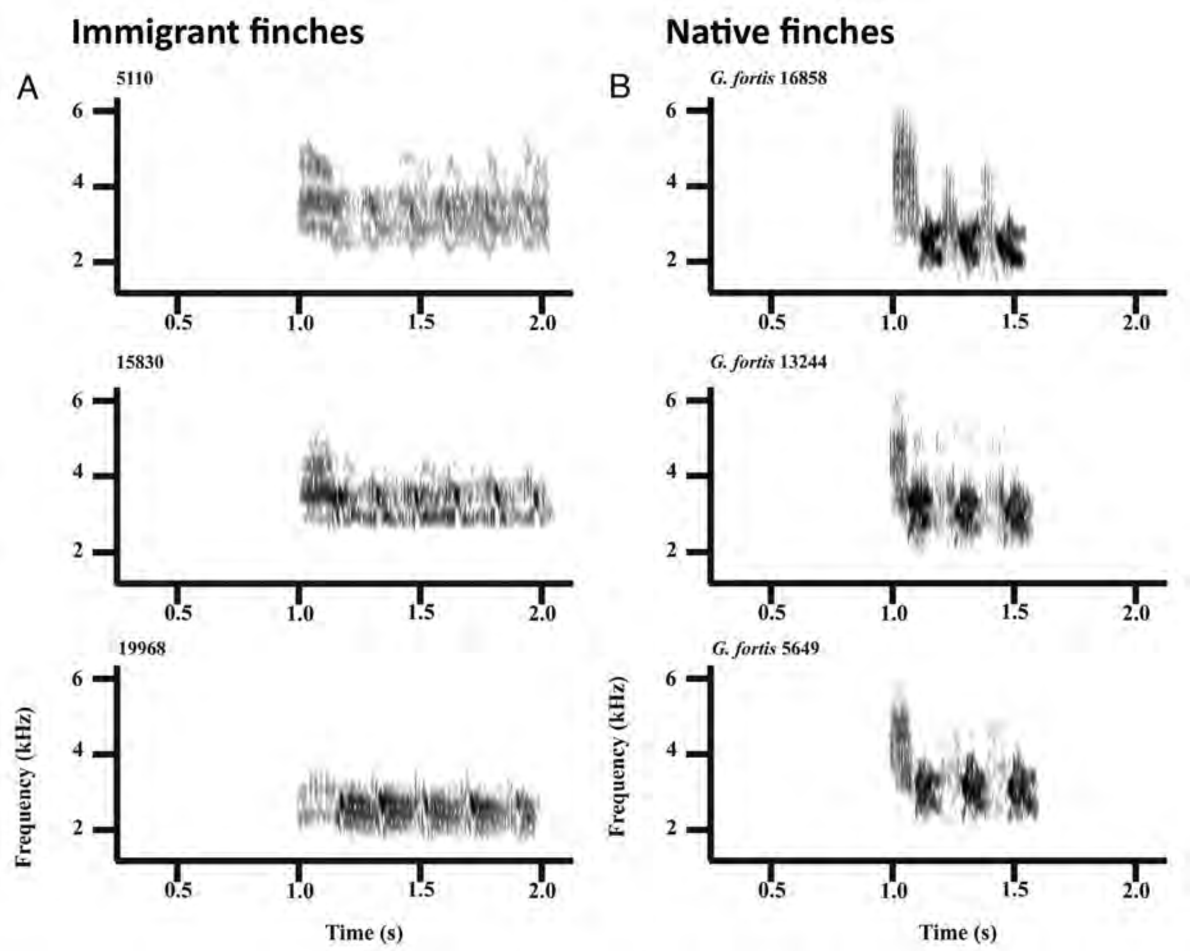

Figure 4. Songs of the original immigrant (5110), a son (15830) and a fifth generation descendant (19668), compared with three Daphne *G. fortis* individuals that sang a standard form of type III. Immigrants differ from residents statistically in lower maximum frequency and higher note repetition rate. A wideband setting and a Hamming window with DFT 256 were used.
Figure taken, with permission, from: Grant, P. R. and Grant R. B. (2009) The secondary contact phase of allopatric speciation in Darwin's finches. *Proceedings of the National Academy of Sciences, 106(46)*

Read the figure legend/description. Describe what you think this data is showing.

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Summarising the evidence

Summarise **all** the evidence from Part1, Part 2 and Part 3 of this activity that supports the behavioural and physical isolation of this group of birds, including:

- Immigration of the population founder (the male from Santa Cruz)

- Inbreeding of his descendents

- Beak size and song differences between this new population and the local population.

Lesson 3: Activity 4

A summary of the paper

Grant, P. R. and Grant R. B. “The secondary contact phase of allopatric speciation in Darwin’s finches.” *Proceedings of the National Academy of Sciences, Vol. 106, No. 46*, Nov. 16, 2009.

Read the following information:

Problem:

Are the Grants and their team witnessing the birth of a new species?

In brief:

Peter and Rosemary Grant are studying the ground finches of the small island of Daphne Major. A ground finch from a neighbouring island with a larger beak and different song than the resident ground finches of Daphne Major found a mate on this island. His offspring tended to mate with relatives because finches choose a mate like themselves. This reproductive isolation is resulting in the emergence of a new species, different from the other ground finches on the island in beak size and song.

A summary of the paper:

In 1981, scientists Peter and Rosemary Grant observed the arrival of an immigrant medium ground finch to the small Galápagos Island of Daphne Major. It was larger than the resident finches, especially in beak width, and sang a different song. The Grant’s studied this bird and its descendants over a period of 28 years. In the fourth generation, after a severe drought, there was only a single brother and sister left. They bred with each other and the family became reproductively isolated as the descendants, who had inherited the larger beak and unusual song, only bred with each other.

The Grant’s observations agree with a theory of speciation (the process whereby two species form from one) that involves assortative mating. This is a non-random mating where individuals mate with other individuals on the basis of phenotype. In this case, female ground finches prefer to mate with males who have a similar beak size to themselves and have a particular song. The original immigrant male attempted to copy the local song, but didn’t get it quite right, in the same way that a non-native speaker of a new language may speak in a technically correct way but with a strong accent. This reproductive isolation persisted and may now be resulting in the formation of a new species of finch.

Conclusions:

- Geographical separation of finch populations resulted in variation in beak size between the populations.
- A single immigrant individual bred with a resident which created a physically, genetically and behaviourally distinct subpopulation
- Assortative mating resulted in inbreeding and behavioural isolation of the subpopulation.

1. Review your cartoon explanation in the light of the evidence you evaluated in Activity 3 and the research paper summary you have just read.
2. Rewrite and expand on your description incorporating the evidence from the research data and any new knowledge gained from reading the paper summary.
3. Apply the following key words appropriately to your cartoon:

Selection pressure	Reproductive isolation	Allopatric speciation
Stabilising selection	Genetic drift	Inbreeding
Geographical isolation	Sympatric speciation	Assortative mating

Lesson 3: Extension Activity

Evidence for immigration and inbreeding

Genetic analysis revealed that all 25 genotyped members of the **immigrant** finch family from the F4 generation onwards were homozygous for an unusual allele at the locus *Gf.11*. Homozygosity at this locus is unusual in the Daphne Major finches. In 249 genotyped **native** finches only 1 was homozygous for the **a** allele.

The unusual allele is given the symbol **a** and the common Daphne Major allele is given the allele **A**.

1. Use the Hardy-Weinberg equation to calculate the number of carriers or heterozygotes for alleles at this locus that you would expect in the **native** finch population.

Answer = ____________________

2. Explain why this population may not be in equilibrium using the Hardy-Weinberg criteria.

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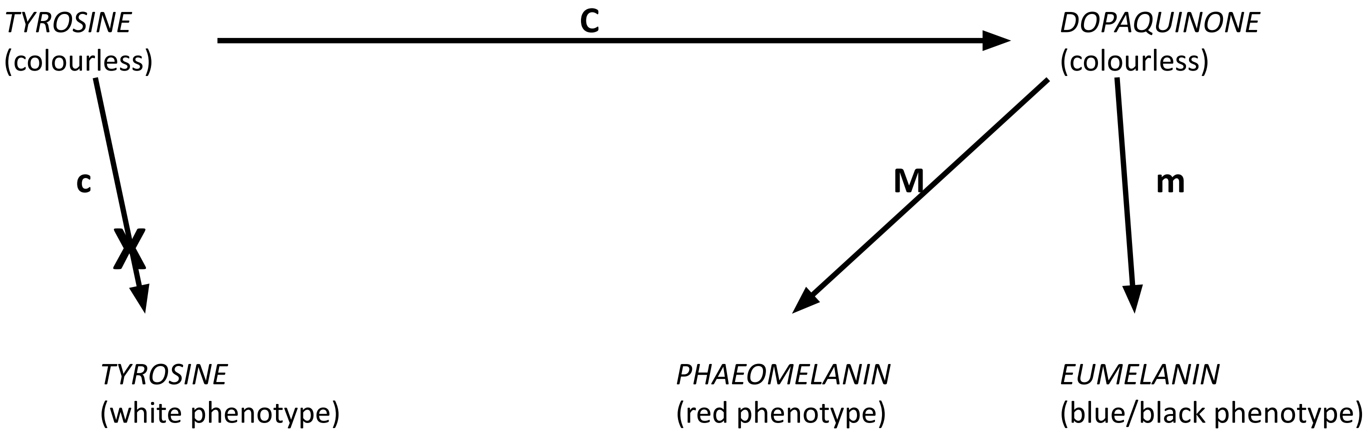
Exam style question

1 The black colour pigment is made from the amino acid tyrosine. A simplified metabolic pathway that describes how the pigment is thought to be made in birds is shown below.



1 (a) (i) Use the information in the figure to work out the phenotypes (the colour) of the pigeons with the following genotypes.

[4 marks]

1. CcMm____
2. ccmm____
3. ccMM____
4. Ccmm____

1 (a) (ii) What type of gene interaction is happening?

[1 mark]

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1 (b) A mutation in another gene in pigeons gives rise to ash-red (a grey red) and brown colours. The $\mathbf{B^A}$ allele gives rise to ash-red colour and is dominant to brown which is controlled by allele **b**.

A breeder crossed a brown male with an ash-red female expecting to get an F1 generation of ash-red pigeons. The offspring he got are shown in the table below. **Note: In birds the female is the heterogametic sex**.

Phenotype	Number
Ash red male	32
Ash red female	0
Brown male	0
Brown female	40

1 (b) (i) How might you explain the results observed by the breeder?

[2 marks]

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____

1 (b) (ii) In birds the females are the heterogametic sex, possessing 2 different sex chromosomes Z and W.

Draw a diagram to show how the results shown in the table could have been produced.

[3 marks]

Parental genotypes ____________________ ____________________

Gametes ____________________ ____________________

F1 genotypes ____________________ ____________________

1 (b) (iii) The chi-squared test can be used to analyse the results in the table. The expected ratio of ash-red females to brown males is 1:1.

Complete the table below and use the data to calculate a value for chi-squared.

[2 marks]

Phenotype	**O**	**E**	**O-E**	**(O-E)²**	$\frac{(O-E)^2}{E}$
Ash-red male					
Brown female					

Answer = ____________________________

1 (c) Use your calculated value of chi-squared and the table of probabilities at the bottom of this page to test the significance of the difference between the observed and expected results.

1 (c) (i) What is your null hypothesis?

[1 mark]

1 (c) (ii) Do you accept or reject your null hypothesis?

[1 mark]

Number of classes	**Degrees of freedom**	**Probability**					
		0.99	0.75	0.50	0.25	0.10	0.05
2	1	0.00	0.10	0.45	1.32	2.71	3.84
3	2	0.02	0.58	1.39	2.77	4.61	5.99

Lesson 1: Plenary