

Hardy-Weinberg Equilibrium

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MSU Teaching Demonstration

Ferruginous Hawks

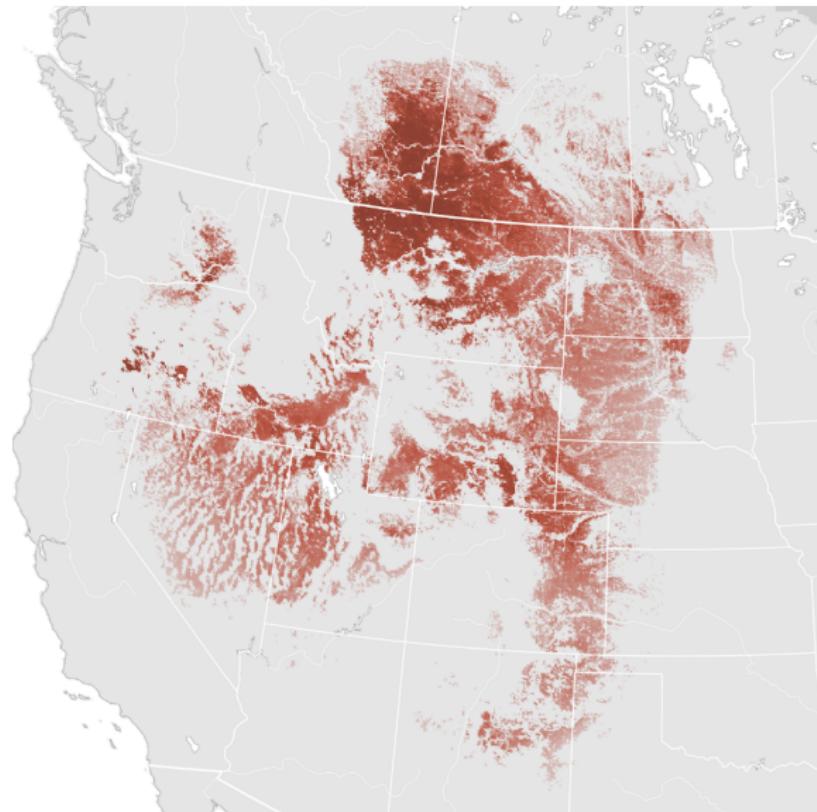


light morph



dark morph

Ferruginous Hawks



Ferruginous Hawks



genotype aa



genotypes Aa, AA

Today's Question: How can we figure out if the dark morph Ferruginous Hawks eventually become more common than light morph Ferruginous Hawks?

Today's Answer: Hardy-Weinberg Equilibrium

Learning Outcomes: Hardy-Weinberg Equilibrium

- 1) Calculate expected genotype frequencies from observed allele frequencies, random mating, and no evolution
- 2) Calculate observed allele frequencies based on observed genotype frequencies
- 3) Use Hardy-Weinberg Equilibrium as a null model to evaluate whether interesting biology is happening

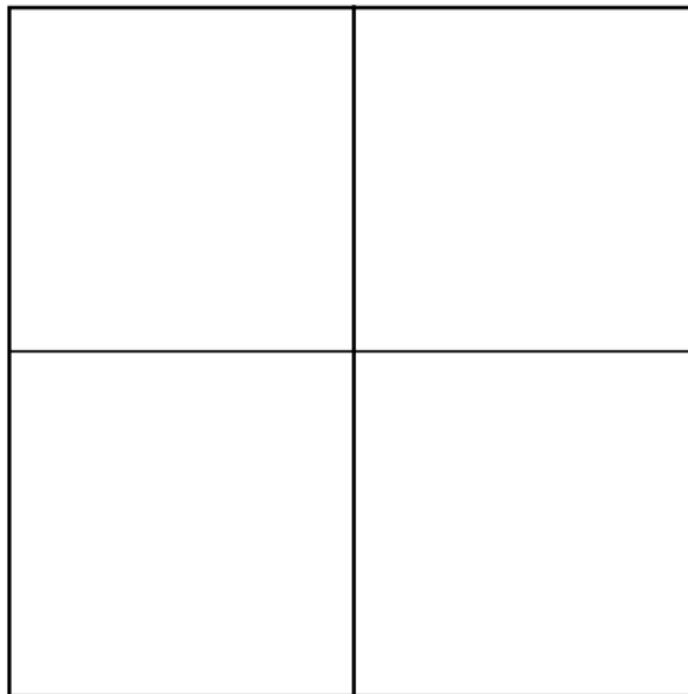
Key Vocab

- ▶ *locus*: a location on a chromosome
- ▶ *allele*: one of two or more variants at a locus
- ▶ *genotype*: the alleles an individual carries
- ▶ *diploid*: containing two sets of chromosomes (1 per parent)
- ▶ *null hypothesis*: what we expect in the absence of an effect
- ▶ *evolution*: a change in allele frequencies over time

Q_1 : How do we predict the possible genotypes of offspring from a particular mating event ($Aa \times aa$)?

A₁: Punnett's Squares

Punnett's Squares

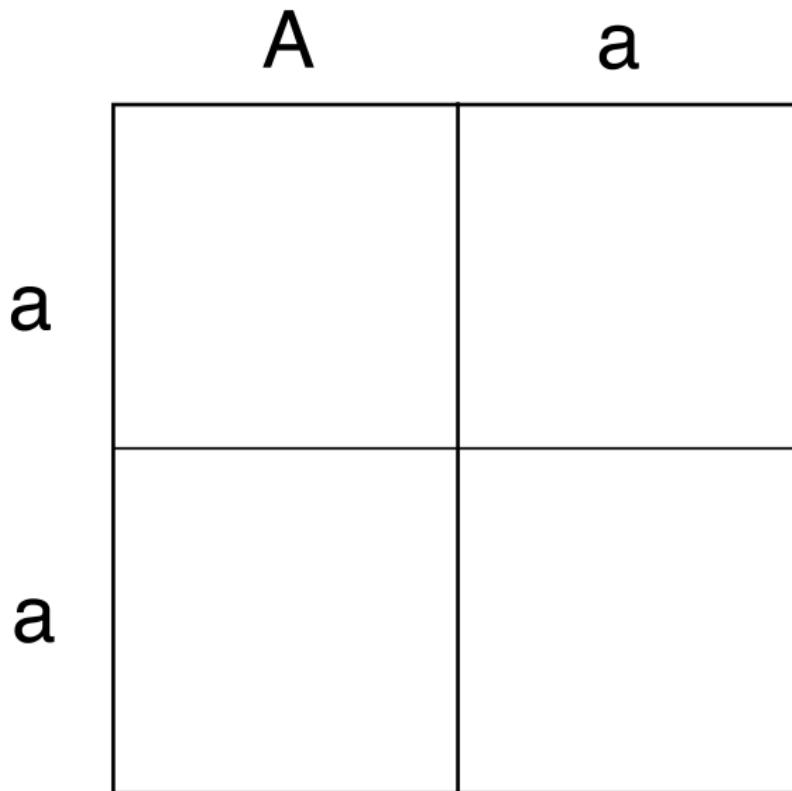


Punnett's Squares

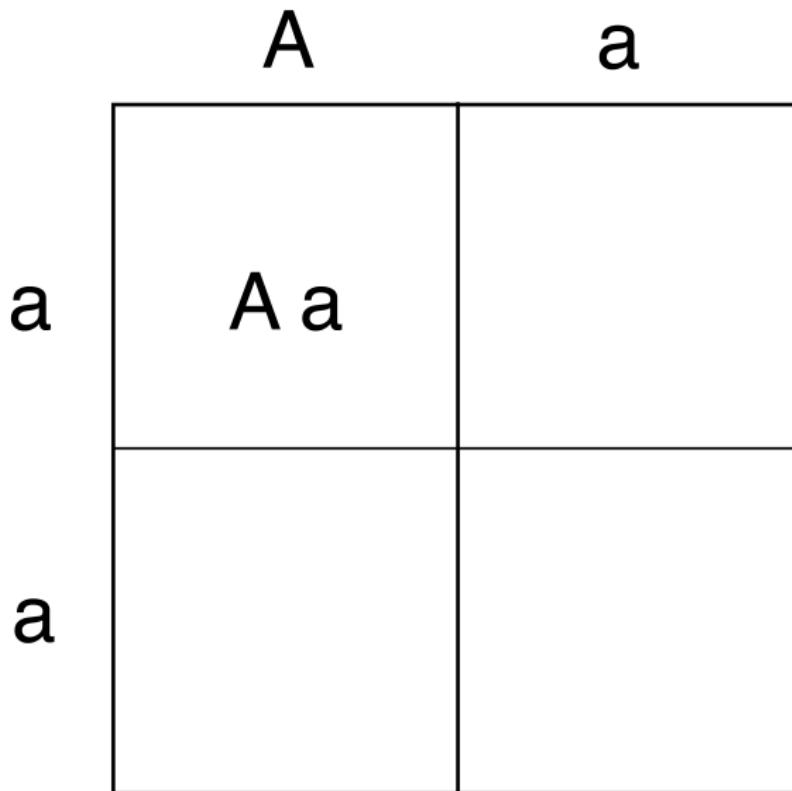
A

a

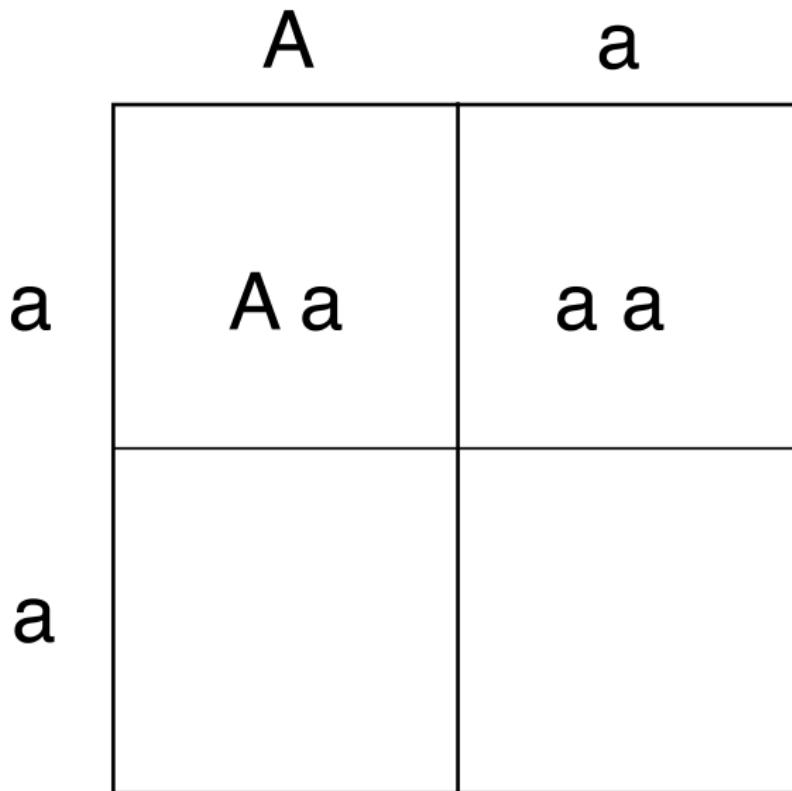
Punnett's Squares



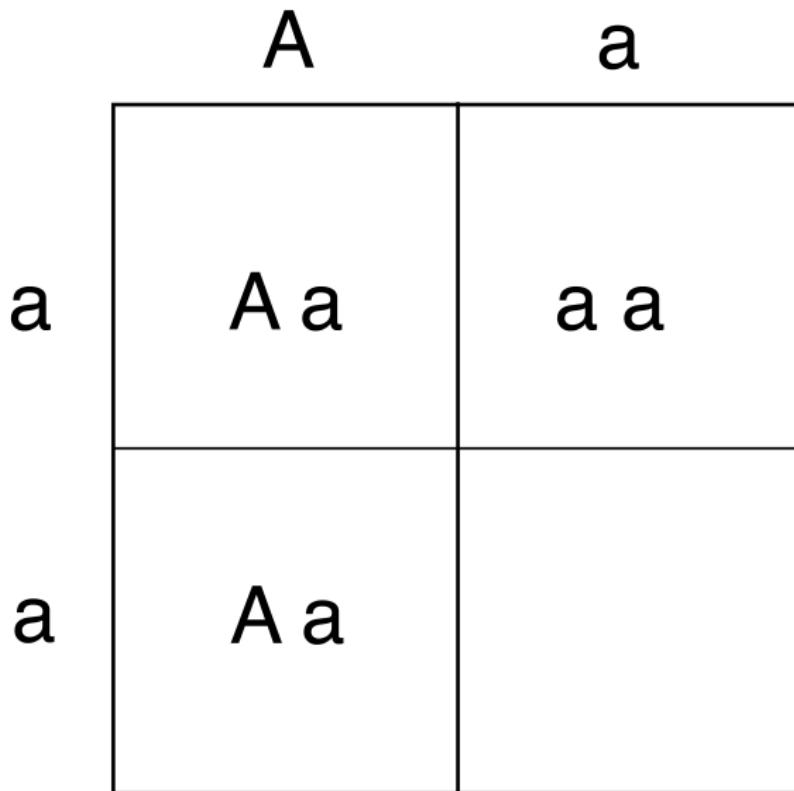
Punnett's Squares



Punnett's Squares



Punnett's Squares

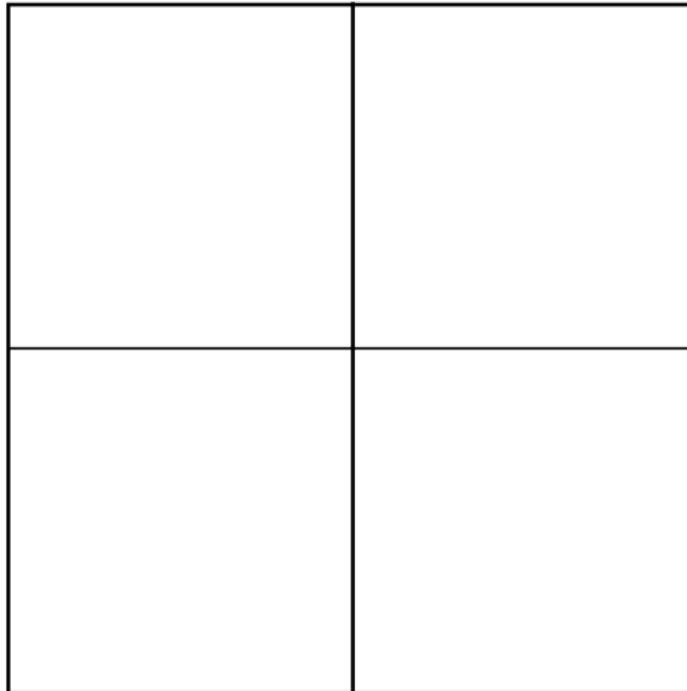


Punnett's Squares

	A	a
a	A a	a a
a	A a	a a

Q₂ How do we predict the expected *frequency* of genotypes from a generation of random mating events ($f(A) = p$, $f(a) = q$)?

Population Punnet's Squares



Population Punnet's Squares

p

q

Population Punnet's Squares

	p	q
p		
q		

Population Punnet's Squares

	p	q
p	p^2	
q		

Population Punnet's Squares

	p	q
p	p^2	qp
q		

Population Punnet's Squares

	p	q
p	p^2	qp
q	pq	

Population Punnet's Squares

	p	q
p	p^2	qp
q	pq	q^2

$$p^2 + qp + pq + q^2 = 1$$

$$p^2 + 2pq + q^2 = 1$$

Q_3 : 5 AA dark morph hawks, 10 Aa dark morph hawks, and 35 aa light morph hawks mate randomly and produce 120 chicks. How many will be dark morphs?

number of *A* alleles: $2 * 5$ homozygotes + $1 * 10$ heterozygotes = 20

number of *a* alleles: $2 * 35$ homozygotes + $1 * 10$ heterozygote = 80

$$f(A) = 0.2, \; f(a) = 0.8$$

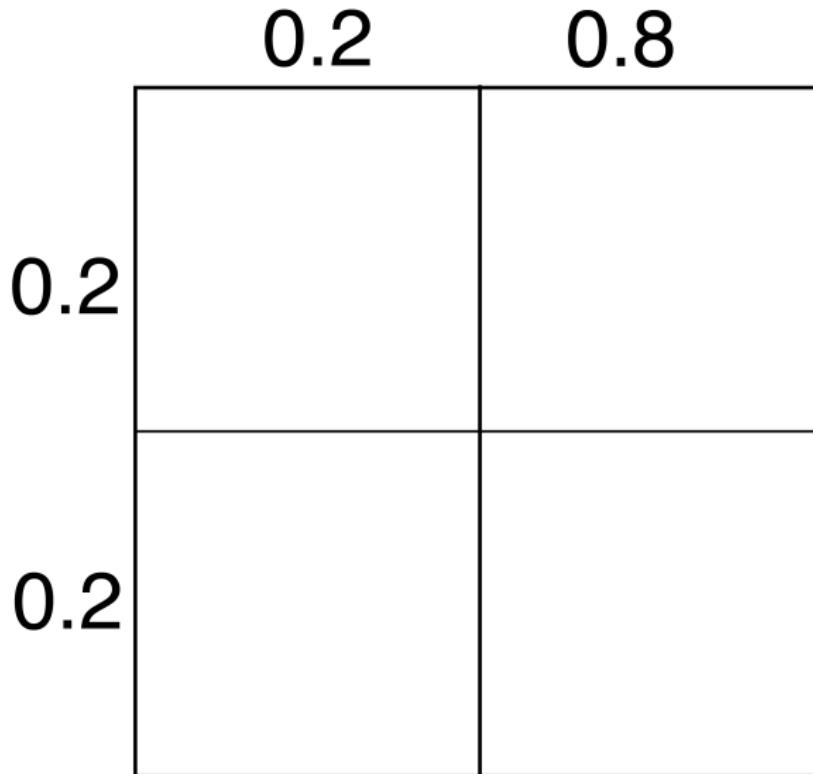
$$p = 0.2, q = 0.8$$

Expected Genotype Frequencies

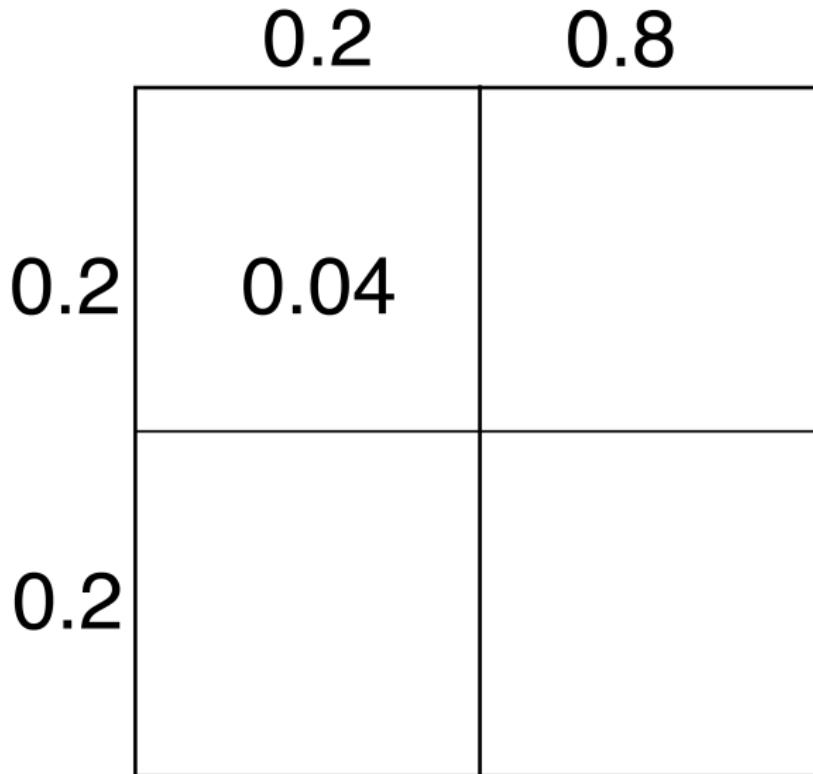
Expected Genotype Frequencies

0.2 0.8

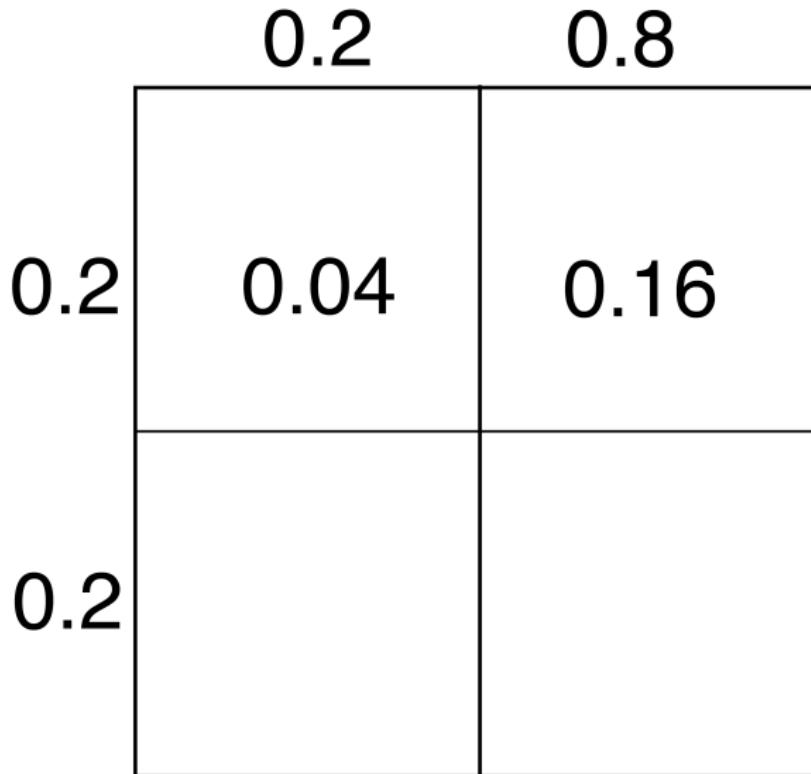
Expected Genotype Frequencies



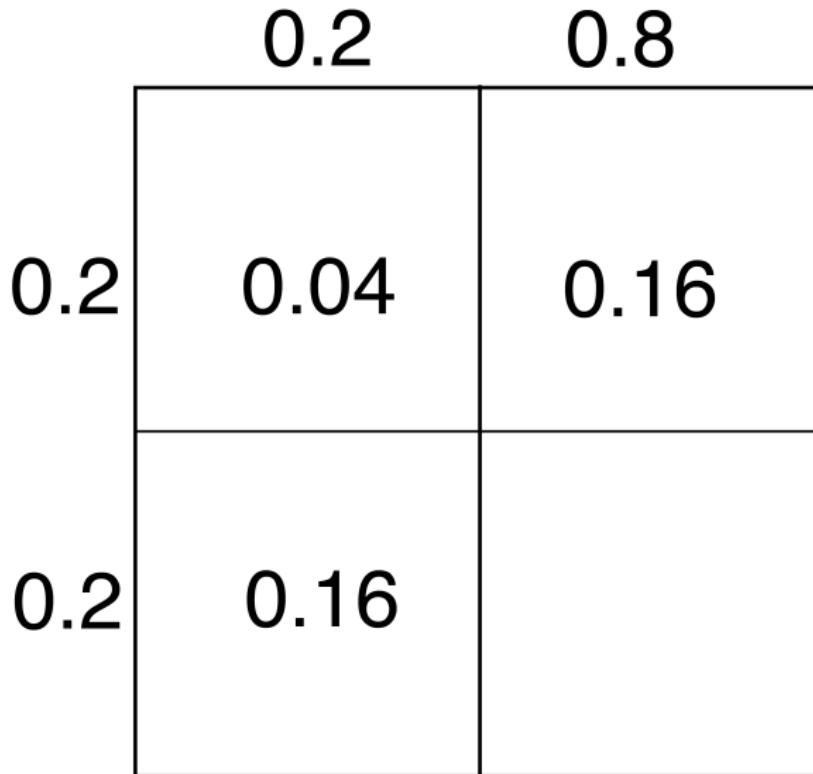
Expected Genotype Frequencies



Expected Genotype Frequencies



Expected Genotype Frequencies



Expected Genotype Frequencies

	0.2	0.8
0.2	0.04	0.16
0.2	0.16	0.64

$$p^2 + qp + pq + q^2 = 1$$

Expected Genotype Frequencies

$$0.2^2 + 2(0.8 * 0.2) + 0.8^2 = 1$$

$$0.04 + 0.32 + 0.64 = 1$$

$$f(AA) = 0.04$$

$$f(Aa) = 0.32$$

$$f(aa) = 0.64$$

Expected Color Morphs

$$n(AA) = 0.04 * 150 = 6 \text{ dark morph homozygotes}$$

$$f(Aa) = 0.32 * 150 = 48 \text{ dark morph heterozygotes}$$

$$f(aa) = 0.64 * 150 = 96 \text{ light morph homozygotes}$$

Q_3 : 5 AA dark morph hawks, 10 Aa dark morph hawks, and 35 aa light morph hawks mate randomly and produce 120 chicks. How many will be dark morphs?

A_3 : 54 dark morph chicks!

Q₄: Has the frequency of allele *A* increased?

number of *A* alleles: $2 * 6$ homozygotes + $1 * 48$ heterozygotes = $60/300$

number of *a* alleles: $2 * 96$ homozygotes + $1 * 48$ heterozygote = $240/300$

$$f(A) = 0.2, \; f(a) = 0.8$$

A_4 : The frequency of allele A has stayed the same

Q₅: Has the population evolved?

Q₅: No!!!

Q₆: Would your answer to *Q₄* and *Q₅* change if dark morph birds were under apostatic selection and had greater hunting success due to their scarcity?

1. No, because the number of offspring does not depend on the allele frequency for color.
2. No—the frequency of the alleles would be different, but it would not result in a change in frequency from one generation to the next.
3. Yes, because if dark morphs have higher fitness, then light morphs would be dominant and not recessive—therefore proportions would switch.
4. Yes, because the recessive allele for dark color would appear more often due to higher fitness.

Q₇: Would your answer to *Q₄* and *Q₅* change if a mutation produced a third allele impacting color morphs?

1. Yes and no. It depends if the new allele is dominant or recessive.
If recessive, then the same. If dominant, then different.
2. Yes. It would decrease initial frequencies but not subsequent frequencies.
3. No—mutations add new variations in the population but don't change existing frequencies.
4. No, because a new allele would change the frequencies of the alleles in a population.

Q₈: Would your answer to *Q₄* and *Q₅* change if 60 light morph birds flew in from Alberta?

1. Yes, because originally the frequency would change, but the new frequency would stay constant with subsequent generations.
2. Yes, because the number of individuals won't change the frequency in a population.
3. No, because the population would have more recessive alleles.
4. No, because the dark allele is still recessive and therefore ratios would be the same.

Q₉: Would your answer to *Q₄* and *Q₅* change if color morphs mated preferentially?

1. No—the dark morphs would be carriers of a light morph allele, so the allele frequency would remain unchanged.
2. No—as long as dark morphs and light morphs produce the same number of offspring, allele frequencies will stay the same.
3. It depends on whether the individuals are heterozygous or homozygous, but the frequencies would still be changing.
4. Yes, since the frequency in *Q₄* was based on random outcrossing.

Q₉: Would your answer to *Q₄* and *Q₅* change if by chance many more *A* alleles ended up in offspring during independent assortment than predicted?

1. Yes, because the population has not been changed.
2. Yes—the randomness of sperm and egg combination is independent from this prediction.
3. No—the frequency has changed, even though it occurred by chance.
4. No, because it was just by chance. So later generations would balance out.

Hardy-Weinberg Assumptions

- 1) no selection
- 2) no mutation
- 3) no migration
- 4) random mating
- 5) no genetic drift

A null model for evolution and population genetics

Activity: HWE Worksheet (~15 min)