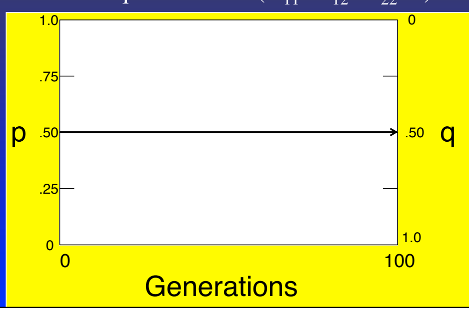
Lecture 17

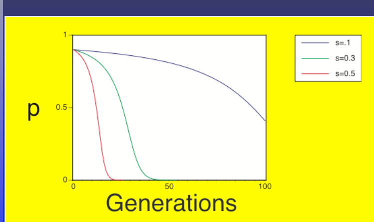
Re-cap 1 gene 2 allele model
Complete our 'cases'
Mendelian selection in nature

6 'Cases' of Selection

- Case 1: Equal fitnesses ($w_{11}=w_{12}=w_{22}=1$)



Case 2: Sel'n Against Dominant



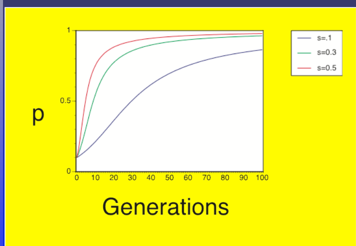
$w_{11} = 1 - s$

$w_{12} = 1 - s$

$w_{22} = 1$

Early selection: weak
End result: elimination of dominant allele (=fixation of recessive)
NOTE: 'Dominance' does not imply 'better' (in fitness terms!)

Case 3: Selection Against Recessive



$w_{11}=1$
$w_{12}=1$
$w_{22}=1\text{-}s$

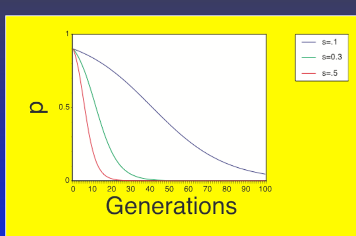
Early selection: strong
End result: difficult to eliminate recessive allele; 'masked' in heterozygotes

Case 4 - No dominance
Make a prediction!

Case	Genotype	Phenotype	Fitness	Selection coefficient
4	A_1A_1	Purple	$w_{11}<w_{12}$	$s_{11}>s_{12}$
	A_1A_2	Pink	$w_{12}<1$	s_{12}
	A_2A_2	White	1	0

(A) p will decrease, resulting in fixation of A_2
(B) p will decrease, and approach 0 asymptotically
(C) p will reach an equilibrium between 0 and 1
(D) p will increase, approaching 1 asymptotically
(E) p will increase, resulting in fixation of A_1

Case 4 - No dominance

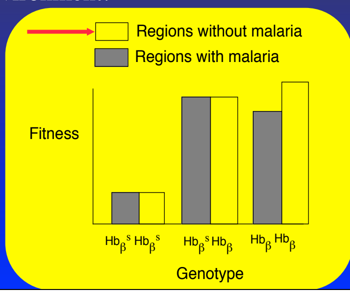


$w_{11}=1\text{-}s$
$w_{12}=1\text{-}0.5s$
(note: can write this way only in the case of a linear arr. of fitnesses. More generally, $w_{12}=1\text{-}s_{12}$ and $s_{12}>s_{11}$
$w_{22}=1$

Early selection: intermediate
End result: fixation of A_2, but slower than with Case 2

Human Example

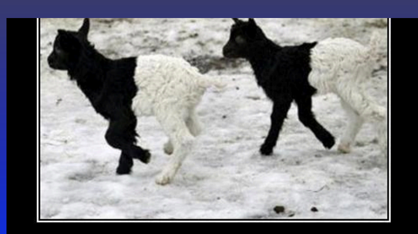
- Sickle cell anemia in a non-malarial environment.



Case 5 - Heterozygote superiority

Case	Genotype	Phenotype	Fitness	Selection coefficient
5	A_1A_1 A_1A_2 A_2A_2	Purple Pink White	w_{11} 1 w_{22}	s_{11} 0 s_{22}

Heterozygoat superiority…



Case 5 - Heterozygote superiority What will happen?

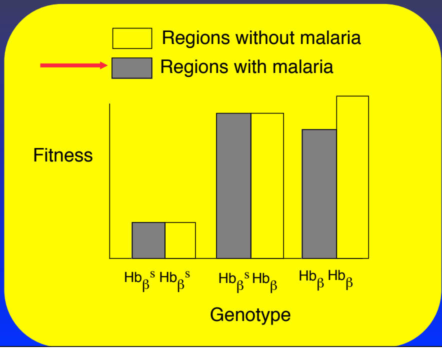
Case	Genotype	Phenotype	Fitness	Selection coefficient
5	A_1A_1	Purple	w_{11}	s_{11}
	A_1A_2	Pink	1	0
	A_2A_2	White	w_{22}	s_{22}

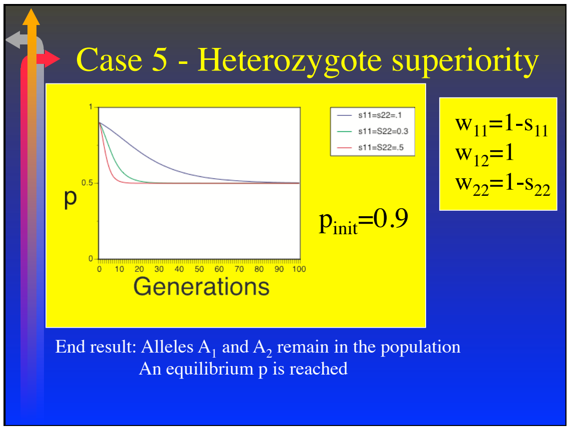
(A) p will decrease, resulting in fixation of A_2
(B) p will decrease, and approach 0 asymptotically
(C) p will reach an equilibrium between 0 and 1
(D) p will increase, approaching 1 asymptotically
(E) p will increase, resulting in fixation of A_1

Case 5 - Heterozygote superiority

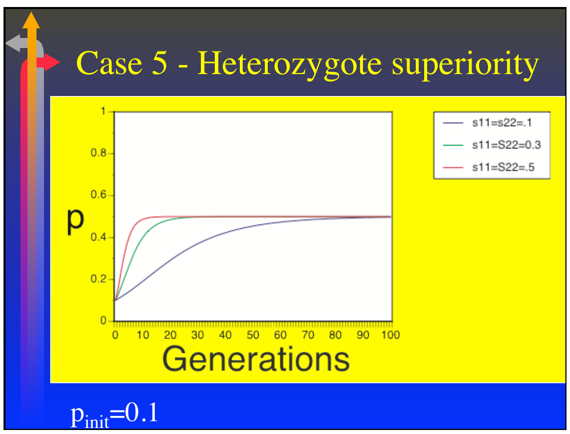
- With heterozygote superiority, what is the eventual equilibrium p?

Human Example

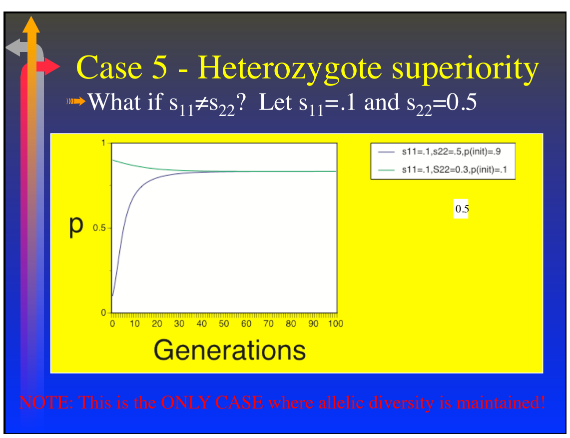




Case 5 - Heterozygote superiority
p
Generations
0 10 20 30 40 50 60 70 80 90 100
s11=s22=.1
s11=S22=0.3
s11=S22=.5
p_{init}=0.9
w_{11}=1-s_{11}
w_{12}=1
w_{22}=1-s_{22}
End result: Alleles A_1 and A_2 remain in the population
An equilibrium p is reached



Case 5 - Heterozygote superiority
p
Generations
0 10 20 30 40 50 60 70 80 90 100
s11=s22=.1
s11=S22=0.3
s11=S22=.5
p_{init}=0.1



Case 5 - Heterozygote superiority
What if s_{11}≠s_{22}? Let s_{11}=.1 and s_{22}=0.5
p
Generations
0 10 20 30 40 50 60 70 80 90 100
s11=.1,s22=.5,p(init)=.9
s11=.1,S22=0.3,p(init)=.1
0.5
NOTE: This is the ONLY CASE where allelic diversity is maintained!

Case 6 - Heterozygote inferiority

- $W'_{11}=1+s'_{11}$
- $W'_{12}=1$
- $W'_{22}=1+s'_{22}$
- S' is a selective 'favor' coefficient (for this case only) because….

Case 6 - Heterozygote Inferiority

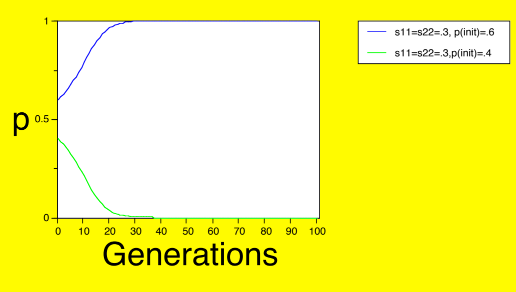
Case	Genotype	Phenotype	Absolute fitness	Oddly relativized fitness*
6	A_1A_1	Purple	W_{11}	$w_{11}'=1+s'_{11}$
	A_1A_2	Pink	W_{12} (lowest)	1
	A_2A_2	White	W_{22}	$w'_{22}=1+s'_{22}$

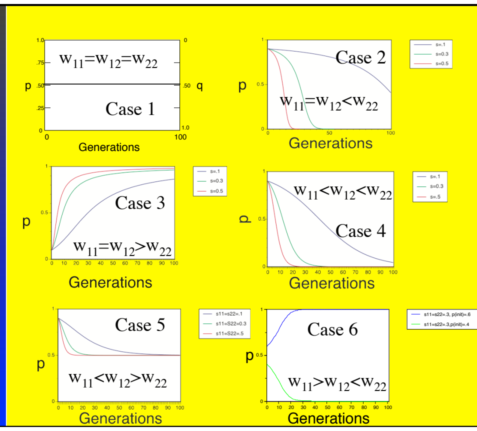
(A) p will decrease, resulting in fixation of A_2
(B) p will decrease, and approach 0 asymptotically
(C) p will reach an equilibrium between 0 and 1
(D) p will increase, approaching 1 asymptotically
(E) p will increase, resulting in fixation of A_1

Case 6 - Heterozygote inferiority

- What is the eventual fate of alleles A_1 and A_2?

Case 6 - Heterozygote inferiority





Be Able to Answer These Questions!

- When is the disfavored allele eliminated?
- When does the disfavored allele persist in low frequencies?
- When is allelic diversity preserved?
- When does initial p, q matter?

Real world selection

- Does evolution follow the pattern predicted by the selection equation in the real world?
- Most famous example: *Biston betularia* - peppered moth, of Britain, studied by H. B. D. Kettlewell.

Genetics of Melanism

- One gene, two alleles. M dominant over m. M produces dark pigmentation in dominant homozygote and heterozygote.
- MM=melanic
- Mm=melanic
- mm=typical

Demonstration of Selection

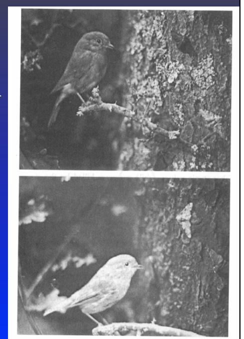
- Clarke and Sheppard (1966) experiment

Phenotype:	Melanic		Typical	
Environment	Exposed	Survived	Exposed	Survived
Dark Background	70	58	70	39
Pale Background	40	24	40	32

Biston betularia

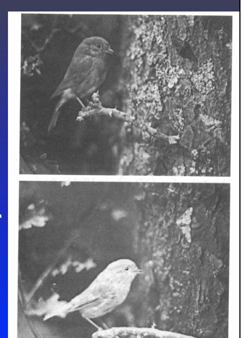
- Which case of selection is this?

(A) Selection against the dominant
(B) Selection against the recessive
(C) Heterozygote superiority
(D) Heterozygote inferiority



Biston betularia

- Which case of selection is this?



(A) Selection against the dominant
(B) Selection against the recessive
(C) Heterozygote superiority
(D) Heterozygote inferiority

Contrasting Patterns of Selection

- Selection acts in opposite directions in the two environments.
- Note: Multiple environments: This is an important way in which genetic diversity can be maintained by selection! (in addition to heterozygote superiority)

Sample Selection Problem

- Tadpoles with large tails are more effective at resisting predation than tadpoles with short tails. Let's imagine that large tails are due to a homozygous recessive genotype, B_2B_2.
- 1. Imagine an initial starting population is in Hardy-Weinberg equilibrium and the large-tailed tadpoles represent only 1% of the population. What is the frequency, p, of B_1 in the population (assume only 2 alleles exist)?
- (A) 0.1
- (B) 0.2
- (C) 0.5
- (D) 0.9
- (E) 0.99

Sample Selection Problem

- Tadpoles with large tails are more effective at resisting predation than tadpoles with short tails. Let's imagine that large tails are due to a homozygous recessive genotype, B_2B_2.
- 1. A predator is introduced to the pond containing this species of tadpoles, and small-tailed individuals are at a severe disadvantage. The selection coefficient against small-tailed tadpoles is 0.9! What change in p will be predicted in one generation as a result of this strong selection?
- (A) 0.9000
- (B) 0.8257
- (C) 0.6333
- (D) 0.0743
- (E) 0

Sample Selection Problem

- Tadpoles with large tails are more effective at resisting predation than tadpoles with short tails. Let's imagine that large tails are due to a homozygous recessive genotype, B_2B_2.
- 3. If the predator stays in the pond and continually acts as a selective force, what will the eventual frequency of B_2 be?
- (A) 0
- (B) it will approach 0, but not actually reach it
- (C) 1
- (D) it will approach 1, but not actually reach it
- (E) 0.5

Yet Another Sample Problem – Try It On Your Own!

- 1. A new allele (A_2) is produced via mutation in a bald eagle population that improves the visual acuity of the bird's eye because the delta crystallin form has better light transmission properties. Heterozygotes (A_1A_2) can see better (and therefore hunt for fish more effectively) than A_1A_1 homozygotes and A_2A_2 homozygotes have the best acuity. Which 'case' of selection is this?

Part 2 of Sample Prob 2

- 2. Over many generations, what would be the outcome of selection in this one gene, two allele system?

Part 3 of Sample Prob 2

- 3. Which condition in humans most closely resembles the selection that would occur in eagles?

Summary

- With selection in a 1 gene, 2 allele system;
- A. We can quantitatively predict changes in p due to selection using the equation:

$$p_{t+1} = \frac{w_{11}p_t^2 + w_{12}p_t q_t}{w_{11}p_t^2 + 2w_{12}p_t q_t + w_{22}q_t^2}$$

- B. We can predict the qualitative outcome of selection, knowing the whether dominance determines the phenotype, and knowing the relationship between phenotype and fitness.
- C. There are 6 'cases' of selection.

Mendelian selection and Darwin's model

- If a population has:
  - Phenotypic variation (A_1A_1, A_1A_2, A_2A_2; at least 2 phenotypes)
  - At least some of that variation is heritable (phenotype differences are directly genetic)
  - The phenotypic variation has fitness consequences (not all w=1)

$$p_{t+1} = \frac{w_{11}p_t^2 + w_{12}p_t q_t}{w_{11}p_t^2 + 2w_{12}p_t q_t + w_{22}q_t^2}$$

- Then the population will evolve ($p_{t+1} \neq p_t$)