General scenarios for 2 alleles

Table 6.4 The general categories of relative fitness values for viability selection at a diallelic locus. The variables *s* and *t* are used to represent the decrease in viability of a genotype compared to the maximum fitness of 1 ($1 - w_{xx} = s$). The degree of dominance of the A allele is represented by *h* with additive gene action (sometime called codominance) when $h = 1/2$.

Category	Genotype-specific fitness		
	w_{AA}	w_{Aa}	w_{aa}
Selection against a recessive phenotype	1	1	$1 - s$
Selection against a dominant phenotype	$1 - s$	$1 - s$	1
General dominance (dominance coefficient $0 \le h \le 1$)	1	$1 - hs$	$1 - s$
Heterozygote disadvantage (underdominance for fitness)	1	$1 - s$	1
Heterozygote advantage (overdominance for fitness)	$1 - s$	1	$1 - t$

Marginal Fitness $\overline{w}_i$

- the average fitness of all genotypes containing a given allele i weighted by the number of alleles contained in each genotype
- e.g., $\overline{w}_1 = pw_{11} + qw_{12}$
- therefore, $\Delta p = p(\overline{w}_1 - \overline{w})/\overline{w}$
- if marginal fitness of an allele is greater than the mean, its frequency increases

Equilibria: $\Delta p = 0$

- what conditions result in constant allele frequencies in an infinite population?
- are these equilibria stable in finite populations?
  - if genetic drift moves the population off the equilibrium - does it tend to move back?

Equilibria: $\Delta p = 0$

- locally stable: allele frequency returns to equilibrium as long as it is close
- globally stable: allele frequency returns to equilibrium regardless of starting point
  - e.g., balanced polymorphism
- unstable: allele frequency moves away from equilibrium if perturbed
- neutrally stable: allele frequency has no tendency to change regardless of initial value (changes by drift only)
  - *HWE*

Selection against *aa* phenotype

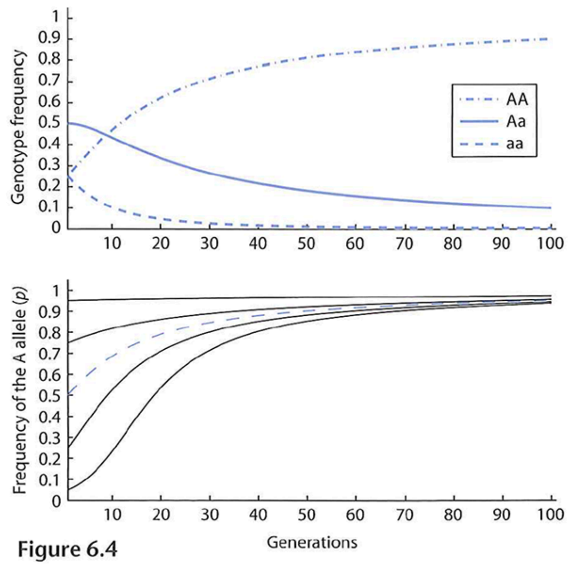


Figure 6.4

Favored Allele, $w_{11} \geq w_{12} \geq w_{22}$

- p = 0 is an unstable equilibrium
- p = 1 is a stable equilibrium

Selection against dominant phenotype (*AA*, *Aa*)

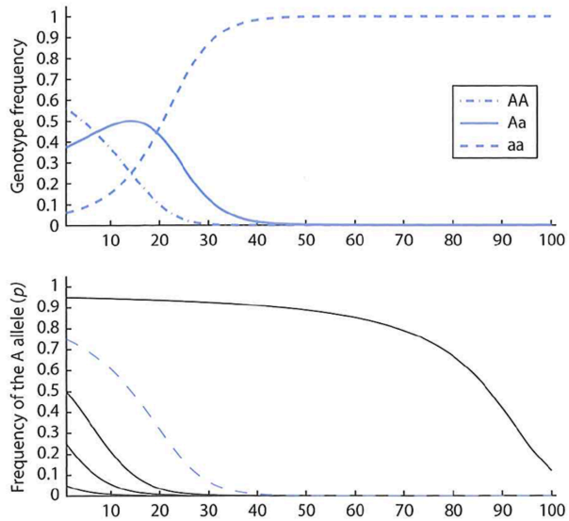


Figure 6.5

Fixation? – pgs. 196, 197

- Pg. 196 – "Does the dominant allele go to fixation when there is natural selection against the recessive homozygote?"
  - "The answer is no…"
- Pg. 197 – "Does the recessive allele go to fixation when there is natural selection against the dominant homozygote and heterozygote?"
  - "In this case yes, since… the dominant allele is not shielded from selection in the heterozygote."
- see also pg. 200

Heterozygote advantage

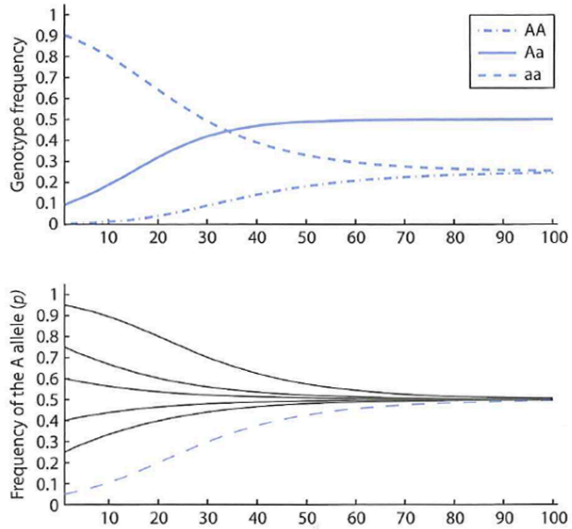


Figure 6.8

Overdominance, $w_{11} < w_{12} > w_{22}$

- a.k.a. heterozygote advantage
- $p = 0$ and $p = 1$ are unstable equilibria
- stable equilibrium occurs when $\Delta p = 0$

$$\overline{w}_1 - \overline{w}_2 = 0$$

$$(pw_{11} + qw_{12}) - (pw_{12} + qw_{22}) = 0$$

$$\hat{p} = \frac{w_{12} - w_{22}}{2w_{12} - w_{11} - w_{22}}$$

Overdominance, $w_{11} < w_{12} > w_{22}$

- a.k.a. heterozygote advantage
- $p = 0$ and $p = 1$ are unstable equilibria
- stable equilibrium occurs when $\Delta p = 0$

if w_{11}=1-s, $w_{12} = 1$, and $w_{22} = 1 - t$, then

$$\hat{p} = \frac{t}{s+t}$$

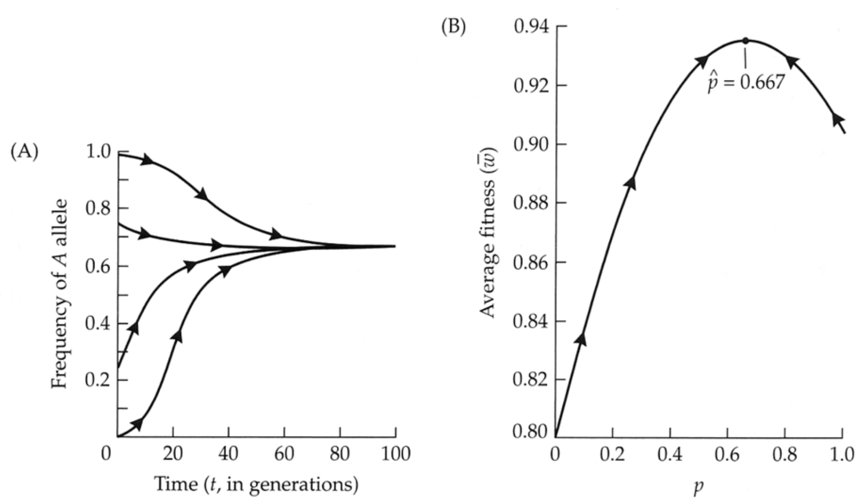
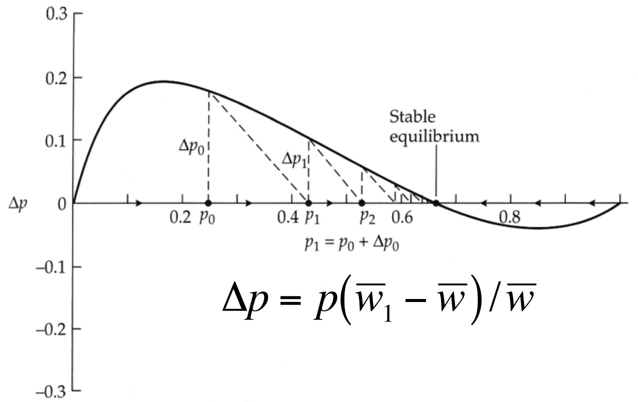


FIGURE 5.4 Selection when there is overdominance. (A) The allele frequencies converge to an equilibrium value irrespective of the initial frequency. In this example, $w_{11} = 0.9$, $w_{12} = 1$, and $w_{22} = 0.8$, and the equilibrium frequency of the *A* allele, $\hat{p}$, is 0.667. (B) Average fitness $\bar{w}$ against p for the same example. Note that $\bar{w}$ is a maximum at equilibrium.



$$\Delta p = p\left(\overline{w}_1 - \overline{w}\right)/\overline{w}$$

FIGURE 5.6 The change in allele frequency Δp plotted as a function of allele frequency p for a case of overdominance in which $w_{11} = 0.6$, $w_{12} = 1$, and $w_{22} = 0.2$. Starting with an allele frequency p_0 smaller than the equilibrium value, the positive value of Δp_0 indicates that the allele frequency in the next generation, p_1, will be greater than p_0 because $p_1 = p_0 + \Delta p_0$. At an allele frequency of p_1, the value of Δp_1 is also positive, and so p_2 is greater than p_1 because $p_2 = p_1 + \Delta p_1$. The steady increase continues until the population arrives at the equilibrium point $\hat{p}$. The same logic shows that, starting with an initial allele frequency greater than $\hat{p}$, the allele frequency decreases in each succeeding generation and ultimately converges to the equilibrium from the other side.

Incomplete dominance

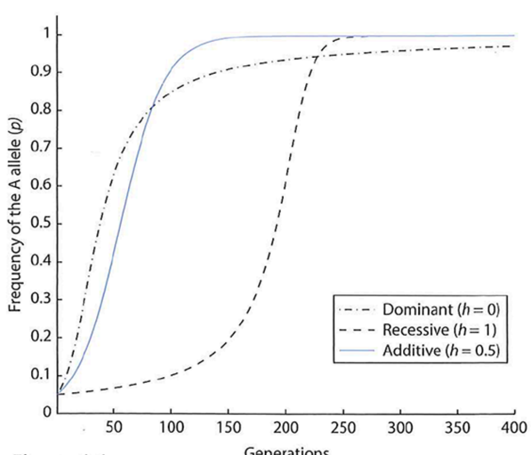


Figure 6.6

$$W_{AA} = 1$$
$$W_{Aa} = 1 - hs$$
$$W_{aa} = 1 - s$$

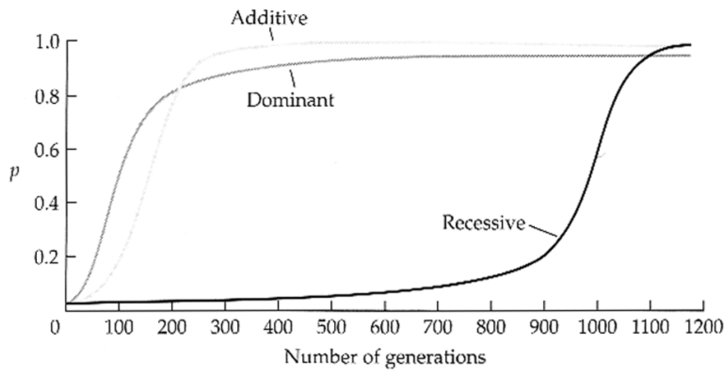


FIGURE 5.3 The change in frequency *p* of a favorable allele that is either dominant, additive, or recessive in its effect on fitness. The frequency of a favored dominant allele changes most slowly when the allele is common, and the frequency of a favored recessive allele changes most slowly when the allele is rare. In all three examples, the difference in relative fitness between the homozygous *AA* and *aa* genotypes is assumed to be 5%.

Heterozygote disadvantage

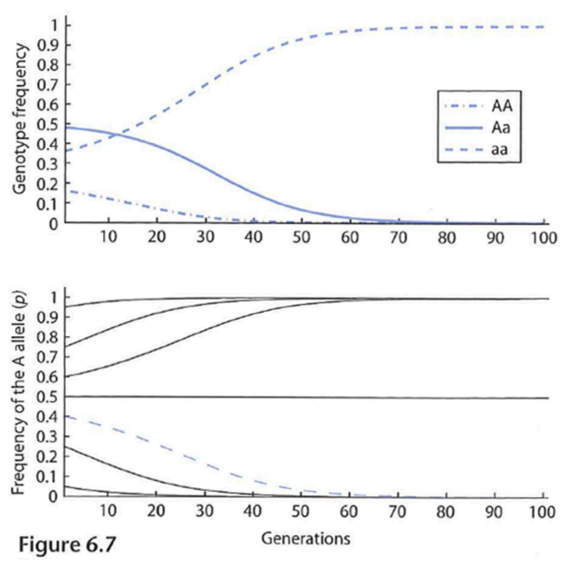


Figure 6.7

Heterozygote disadvantage

- $w_{11} > w_{12} < w_{22}$
- the same three equilibria as for overdominance, but stability is reversed
  - p = 0 and p = 1 are stable equilibria
  - an unstable equilibrium occurs at:

$$\hat{p} = \frac{w_{12} - w_{22}}{2w_{12} - w_{11} - w_{22}}$$

  - outcome depends on starting point
    - population may end up at a local equilibrium with relatively low fitness

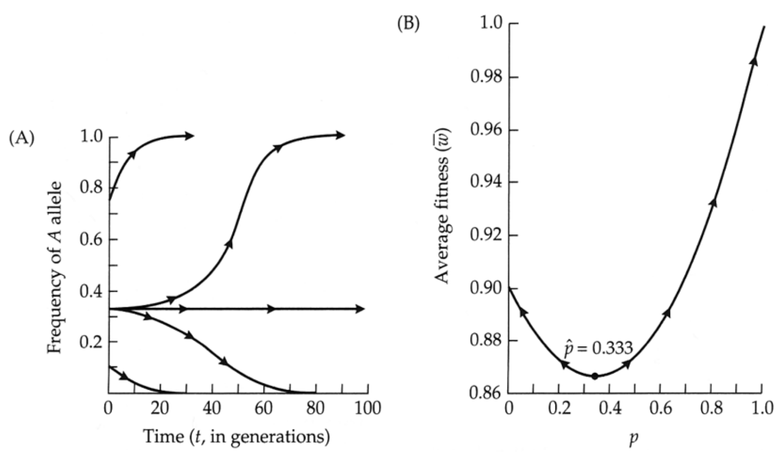


FIGURE 5.7 Selection when there is heterozygote inferiority. (A) The allele frequency goes to 0 or 1 depending on the initial frequency. In this example, $w_{11} = 1$, $w_{12} = 0.8$, and $w_{22} = 0.9$, and there is an unstable equilibrium when the frequency of the A allele is $\hat{p} = \frac{1}{3}$. An infinite population with $p = \frac{1}{3}$ maintains this frequency, but any slight upward change in the frequency of A results in eventual fixation, and any slight downward change in the frequency of A results in ultimate loss. (B) Average fitness $\overline{w}$ against p for the same example. The unstable equilibrium represents the minimum of $\overline{w}$.

pg. 195

The process of natural selection has the special quality that the genotype frequencies reached at equilibrium are always the same as long as the starting frequencies and relative fitness values are constant. Processes that always lead to the same outcome from a given set of initial conditions are called **deterministic** because the end state is completely determined by the initial state. Similar patterns of genotype frequencies in independent populations are therefore evidence that the process of natural selection is operating. In contrast, the stochastic process of genetic drift would result in random outcomes in each independent population. This also means that there is no need to view replicate outcomes of natural selection for the same set of initial conditions.

Strength of selection

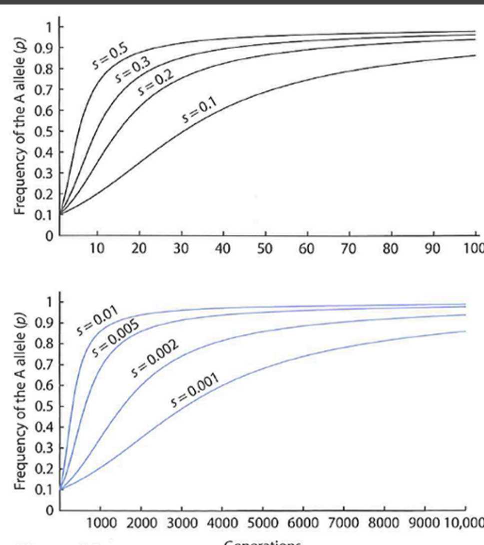
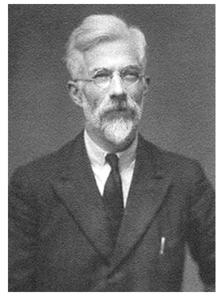


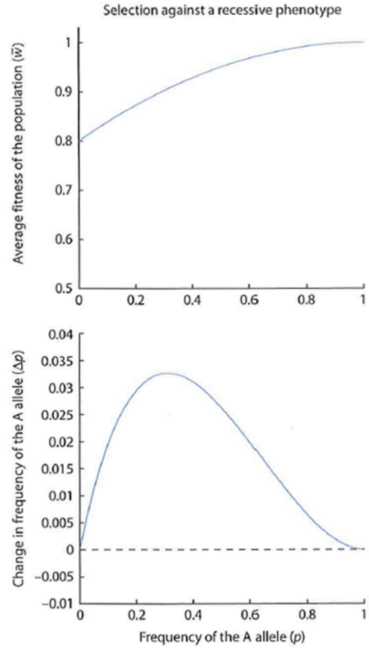
Figure 6.9

Fisher's Fundamental Theorem

- *"the rate of increase in fitness of any organism at any time is equal to its genetic variance in fitness at that time"*
- *with constant relative fitness values*, mean fitness is non-decreasing and reaches a maximum at equilibrium allele frequencies
- thus, natural selection generally increases the mean fitness of the population - adaptation!

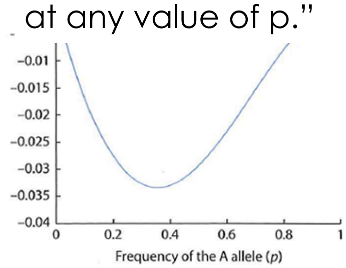


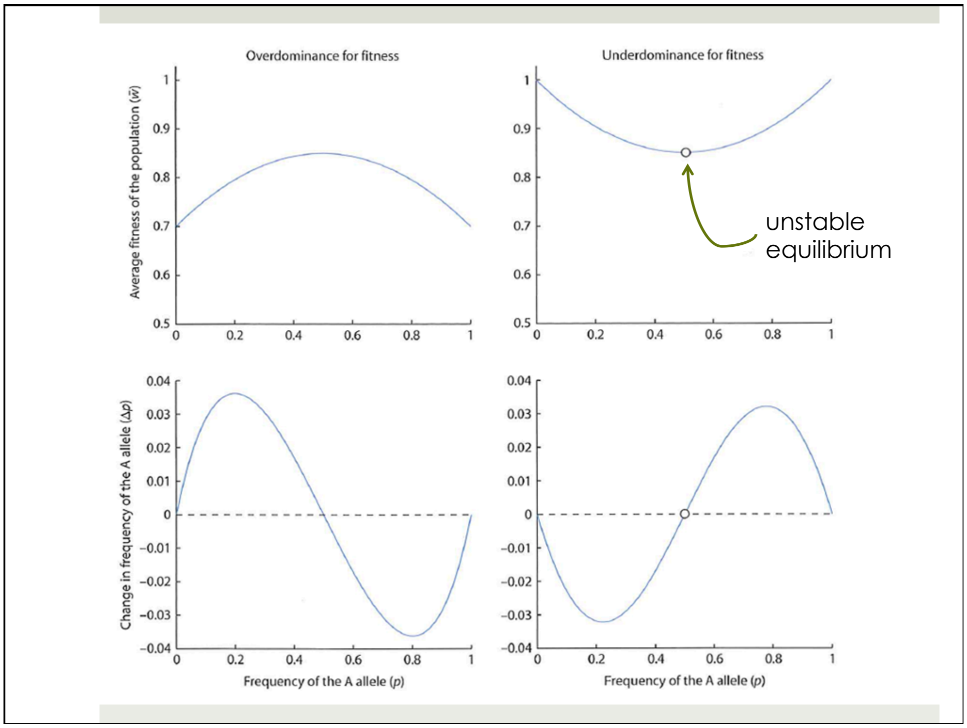
$$\Delta\bar{w} = \mathrm{var}(w)$$



Selection against a dominant phenotype

Pg. 202: "Also compare each plot of Δp against p to the corresponding plot of w against p. There is a striking relationship between Δp and w. Both the magnitude and sign of Δp correspond exactly to the slope of the w line at any value of p."




Overdominance for fitness
Underdominance for fitness
Average fitness of the population ($\bar{w}$)
Change in frequency of the A allele (Δp)
Frequency of the A allele (p)
Frequency of the A allele (p)
unstable
equilibrium