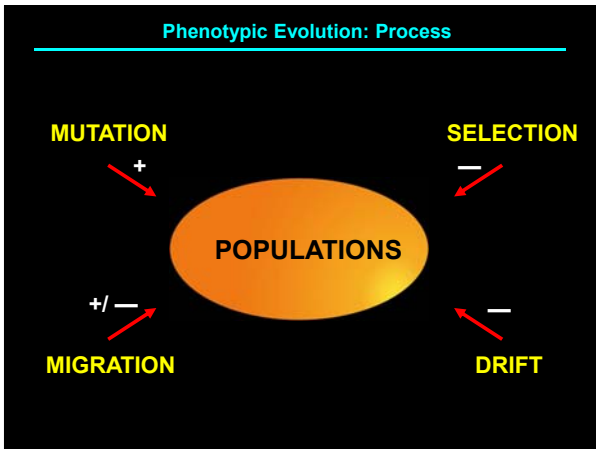


HOW DOES MUTATION CHANGE ALLELE FREQUENCIES?

- Assume: a single autosomal locus with 2 alleles.

  Frequency (**A**) = p
  Frequency (**a**) = q

- Suppose that **A** mutates to **a** at rate *u*: **A** ⟶ **a** = *u*
- And **a** mutates to **A** at a rate *v*: **a** ⟶ **A** =*v*

Change in p by mutation from generation t → t + 1:

$$p_{t+1} = p_t (1-u) + q_t (v)$$

A alleles remaining as A

a alleles mutating to A

Since p + q = 1, q = 1 - p we can substitute (1-p) for q:

$$p_{t+1} = p_t (1-u) + (1-p_t) (v)$$

- **Example:**

If p and q = 0.5,

And u = 0.0001 and v = 0.00001

$$p_{t+1} = p_t (1-u) + (1-p_t) (v)$$

$$p_{t+1} = 0.5 (1 - 0.0001) + (1 - 0.5) (0.00001)$$

$$= 0.499955$$

At Equilibrium:

$$\hat{p} \times u = \hat{q} \times v,$$

And $\hat{p} = v / (u + v)$, $\hat{q} = u / (u + v)$

If u = 0.0001 and v = 0.00001,

$\hat{p}$ = 0.091 and $\hat{q}$ = 0.909

However, if p starts out at 1.0, it would take about **40,000** generations to reach $\hat{p}$ = 0.091!!!

THE THEORY OF NATURAL SELECTION

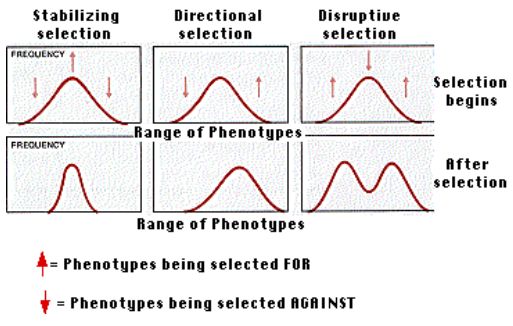
"That one look like bunny, and that one look like turtle, and that one look like pterodac ... Aaagghhhhh!"

DEFINITION OF SELECTION

- Any consistent difference in fitness among phenotypically different biological entities.

SOME IMPORTANT POINTS

1. Natural selection is not the same as evolution.
2. Natural selection is different from evolution by natural selection.
3. Natural selection has no effect unless different phenotypes also differ in genotype.
4. Natural selection is variation in average reproductive success (including survival) among phenotypes.



IMPORTANT PARAMETERS FOR STUDYING SELECTION IN MENDELIAN POPULATIONS

- Absolute Fitness (**W**) = Total number of offspring produced

= **(Probability of survival to maturity) x (mean number of successful gametes)**

- Relative Fitness = Absolute Fitness (W) / Mean Fitness ($\bar{W}$)

$$\bar{W} = p^2W_{AA} + 2p(1-p)W_{Aa} + (1-p)^2W_{aa}$$

- Selection Coefficient (**s**) = Fitness disadvantage to homozygous genotype: $W_{aa} = 1-s$
- Dominance Coefficient (**h**) = Proportion of s applied to the heterozygous genotype: $W_{Aa} = 1-hs$

NATURAL SELECTION OPERATING ON A SINGLE LOCUS

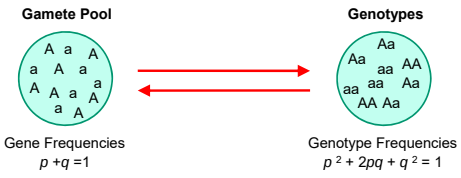
Assume: 1) Discrete generations
2) No evolutionary forces other than selection

Genotype	AA	Aa	aa
Frequency before selection	p^2	$2p(1-p)$	$(1-p)^2$
Fitness	W_{AA}	W_{Aa}	W_{aa}
Frequency after selection	$p^2 W_{AA} / \bar{W}$	$2p(1-p) W_{Aa} / \bar{W}$	$(1-p)^2 W_{aa} / \bar{W}$

The new frequency of **A** allele after selection,

p' = freq(AA after selection) + ½freq(Aa after selection)

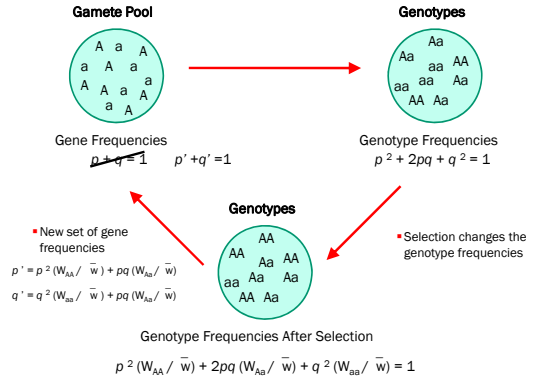
Box 6.5 in Z&E



Gene Frequencies
$p + q = 1$

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

- With random mating the genotype frequencies will be in H-W equilibrium, and the gene frequencies will stay the same from one generation to the next.



CHANGE IN ALLELE FREQUENCIES PER GENERATION

$$p' = \frac{p^2 w_{AA} + pq w_{Aa}}{\overline{w}}$$

$$\Delta p = p' - p$$

$$\Delta p = \frac{p^2 w_{AA} + pq w_{Aa}}{\overline{w}} - p = \frac{p(p w_{AA} + q w_{Aa}) - p\overline{w}}{\overline{w}}$$

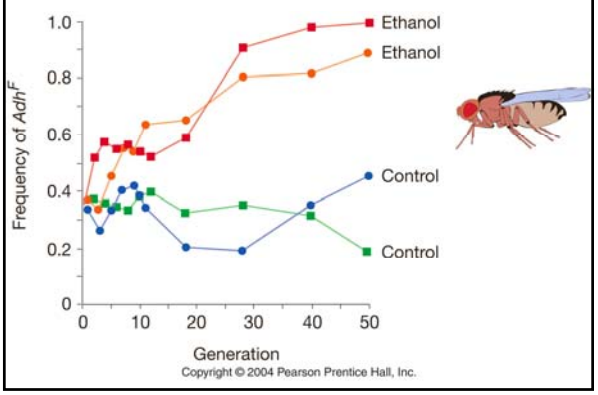
$\overline{w} = p^2 w_{AA} + 2p(1-p) w_{Aa} + (1-p)^2 w_{aa}$

AFTER SOME ALGEBRA…

$$\Delta p = \frac{pq[p(w_{AA} - w_{Aa}) + q(w_{Aa} - w_{aa})]}{\overline{w}}$$

- **We can see what happens with various types of selection by substituting explicit values for the allele frequencies and the fitnesses of the different genotypic classes.**

DIRECTIONAL SELECTION ON A SINGLE LOCUS



CASE 1: ADVANTAGEOUS ALLELE WITH DIFFERING DEGREES OF DOMINANCE

FITNESSES:

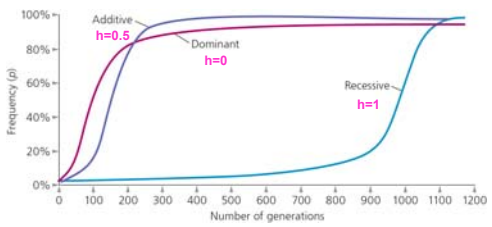
$W_{AA} = 1$ $W_{Aa} = 1 - hs$ $W_{aa} = 1 - s$

$$\Delta p = \frac{spq[h(1-2q)+q]}{1-2pqhs-sq^2}$$

THE RATE OF SPREAD OF A FAVORABLE ALLELE DEPENDS ON THE DEGREE OF DOMNINANCE

FITNESSES:

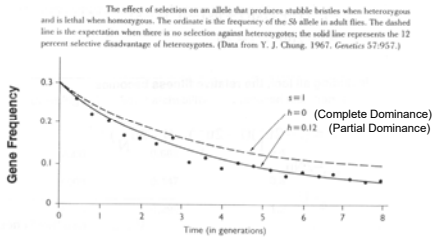
$W_{AA} = 1$ $W_{Aa} = 1 - hs$ $W_{aa} = 1 - s$

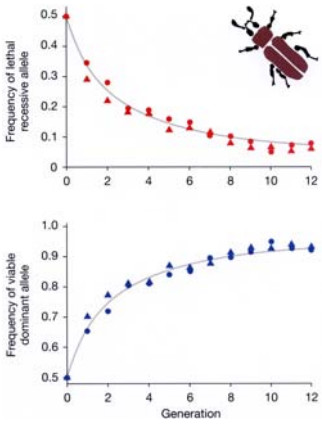


SELECTION AGAINST A PARTIALLY RECESSIVE LETHAL (s = 1)

FITNESSES:

$W_{AA} = 1$ $W_{Aa} = 1 - hs = 1 - h$ $W_{aa} = 1 - s = 0$



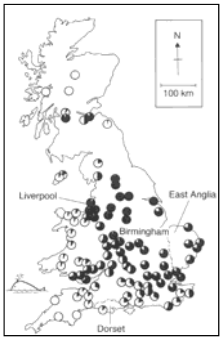


Decline in frequency of a lethal recessive allele

Corresponding increase in frequency of the dominant allele

Fig. 5.16 F & H

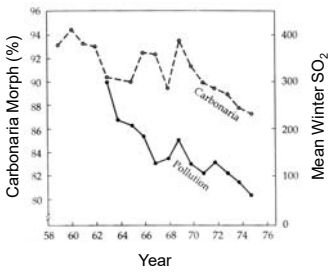
SINGLE LOCUS SELECTION
Case Study: Industrial Melanism



Biston betularia

- Frequencies of melanic and peppered forms of the moth in different parts of Britain. From Less (1971)

RESPONSE TO A CHANGE IN SELECTION:



FROM: Bishop & Cook 1980

ESTIMATING SELECTION: MARK – RECAPTURE EXPERIMENT

- Frequencies of three peppered moth forms in a sample from Birmingham. The observed numbers are the actual numbers *recaught*; the expected numbers are the numbers that would have been *recaught* if all forms survived equally. Data from Kettlewell (1973).

		Numbers Recaptured		
	Genotype	Observed	Expected	Survival Rate
typica	cc	18	35.97	0.5
insularia	Cc	8	8.57	0.93
carbonaria	CC	140	121.46	1.15

SELECTION AND DOMINANCE COEFFICIENTS

Genotype	Absolute fitness scaled to 1.0	
cc	0.43	W_{cc} = 1-s
Cc	0.81	W_{Cc} = 1-hs
CC	1.00	W_{CC} = 1

- Selection Coefficient (against homozygotes):

  s = 1 – 0.43 = 0.57

- Dominance Coefficient:

  hs = 1 - 0.81 = 0.19
  h = 0.19 / s = 0.19 / 0.57 = 0.33

RESISTANCE TO PESTICIDES IN HOUSEFLIES

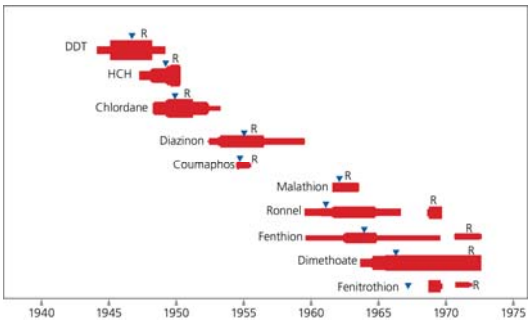


Fig. 8.24 Z&E

WEEDS QUICKLY EVOLVE RESISTANCE TO HERBICIDES

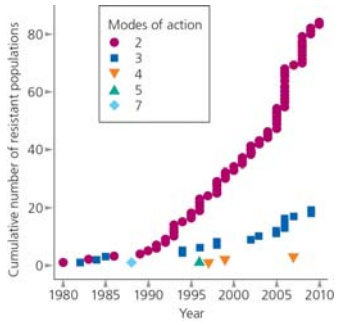
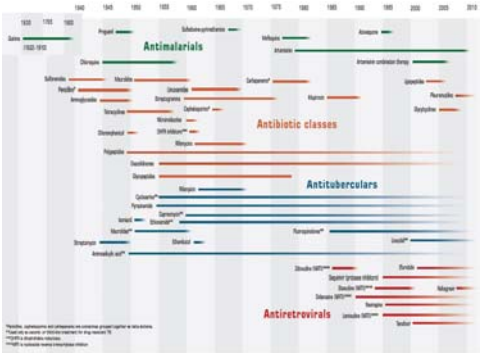


Fig. 8.25 Z&E

DRUG RESISTANCE



Source: Annex B of "The Race Against Drug Resistance"

NEW TOOLS – SAME PROBLEMS?