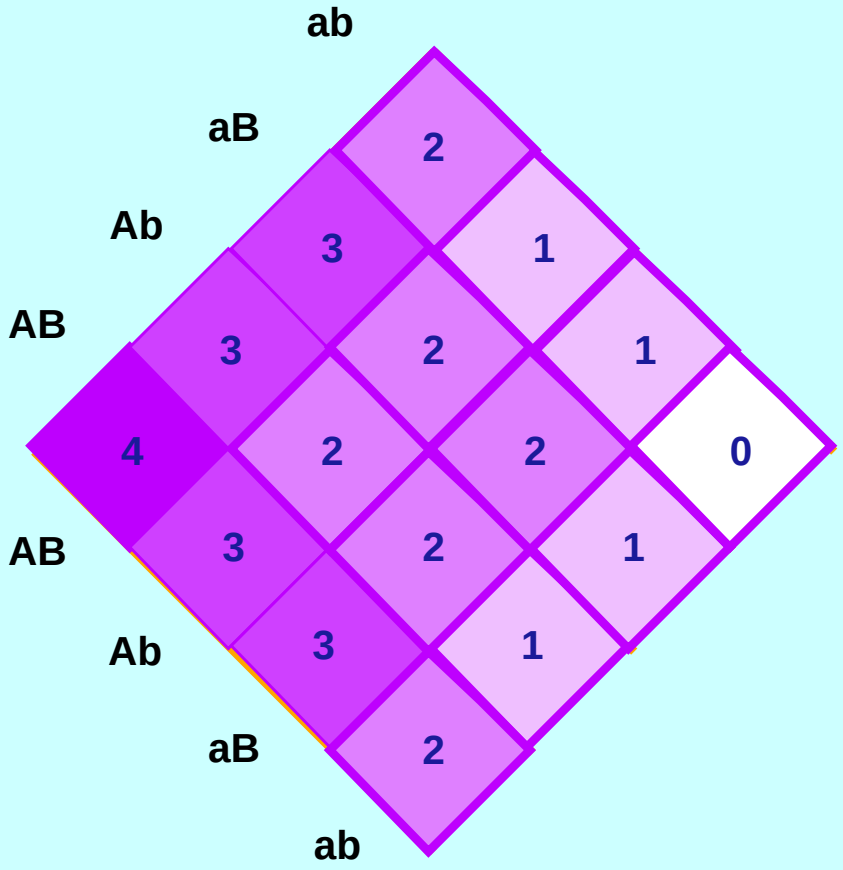
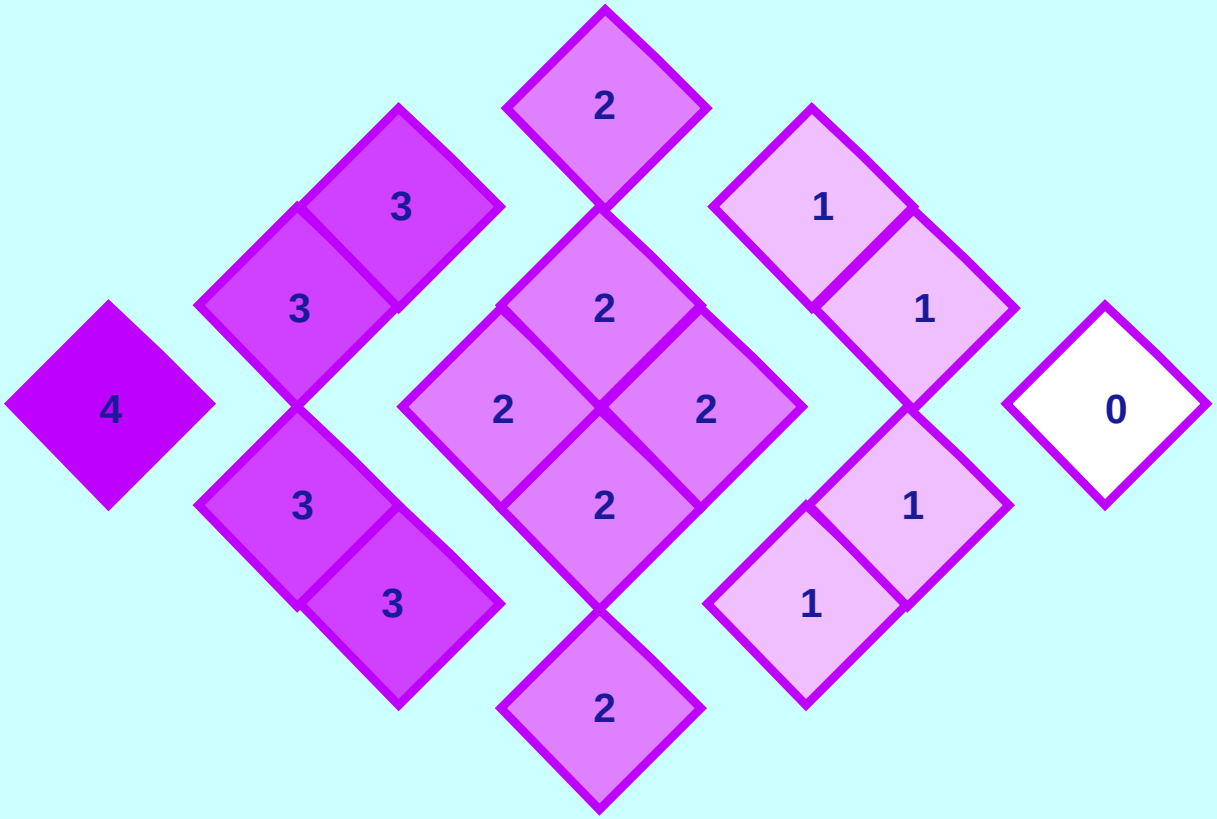
Quantitative characters

Joe Felsenstein

GENOME 453, Autumn 2013

A random−mating population with two genes having 2 alleles each, at equal frequencies, symmetrically affecting a quantitative character

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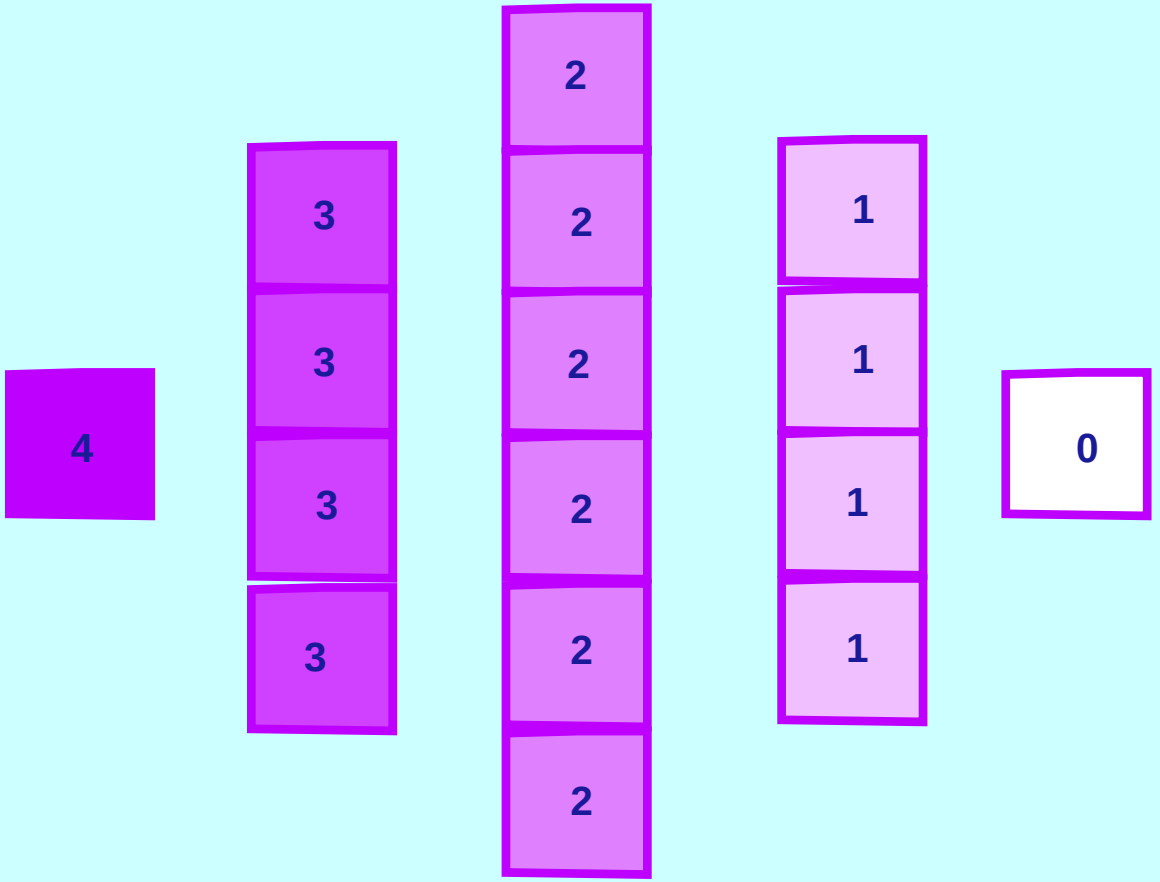
4
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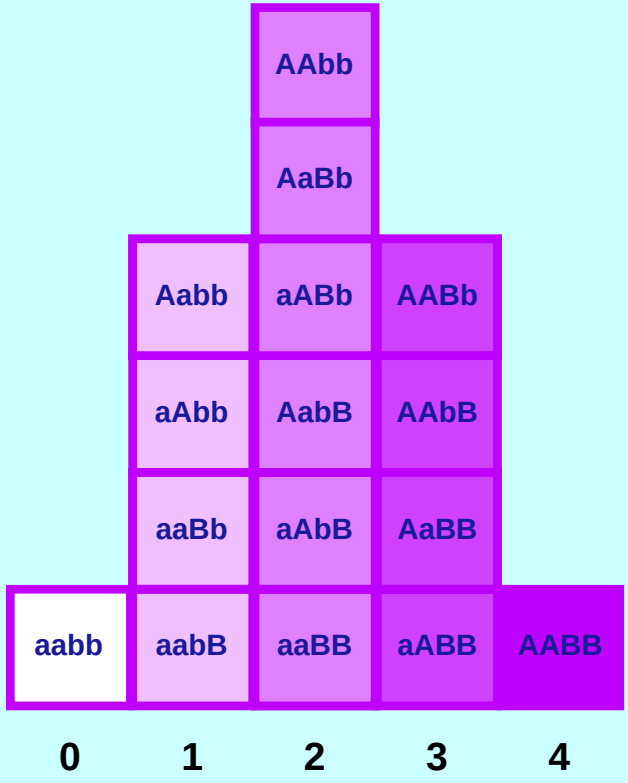
The distribution of the genotypes and the quantitative character before artificial selection



An imaginary quantitative character with 4 loci

The character is a sum of effects including interaction and environmental effects:

starting value

two loci that add up

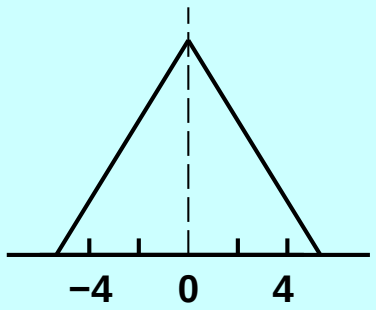
$$12 + \left\{\begin{array}{ll} AA & -1 \\ Aa & 2 \\ aa & 3 \end{array}\right\} + \left\{\begin{array}{ll} CC & -2 \\ Cc & 0 \\ cc & 3 \end{array}\right\}$$

$$+$$

	DD	Dd	dd
BB	5.24	0.8	−4.0
Bb	3.28	0.1	−3.08
bb	0.56	−1.0	−2.2

plus two that interact

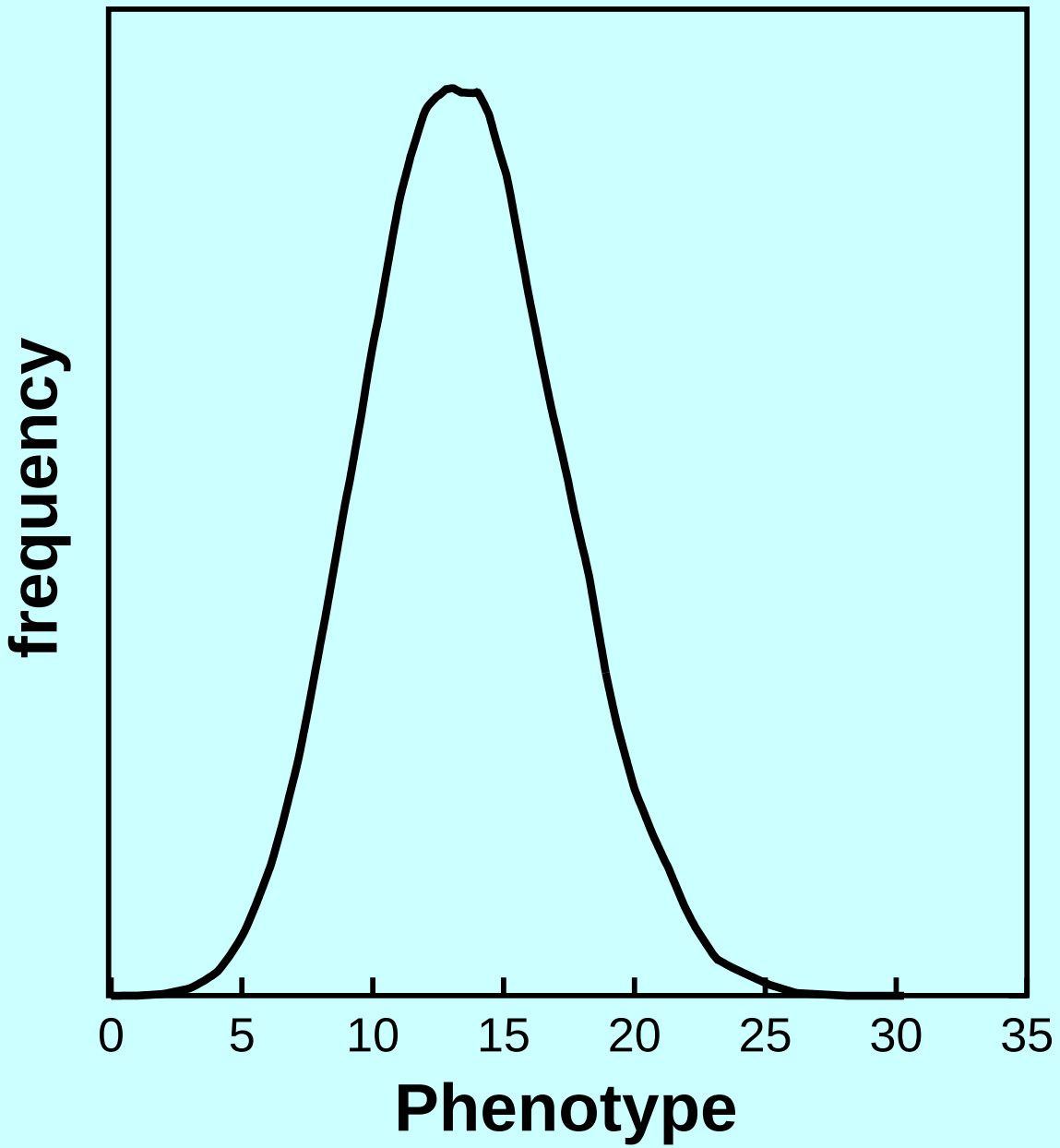
+



plus an environmental effect

What kind of distribution will this lead to when gene frequencies at the four loci are $p_A = 0.4$, $p_B = 0.5$, $p_C = 0.3$, and $p_D = 0.6$?

The resulting distribution



Distributions of quantitative characters

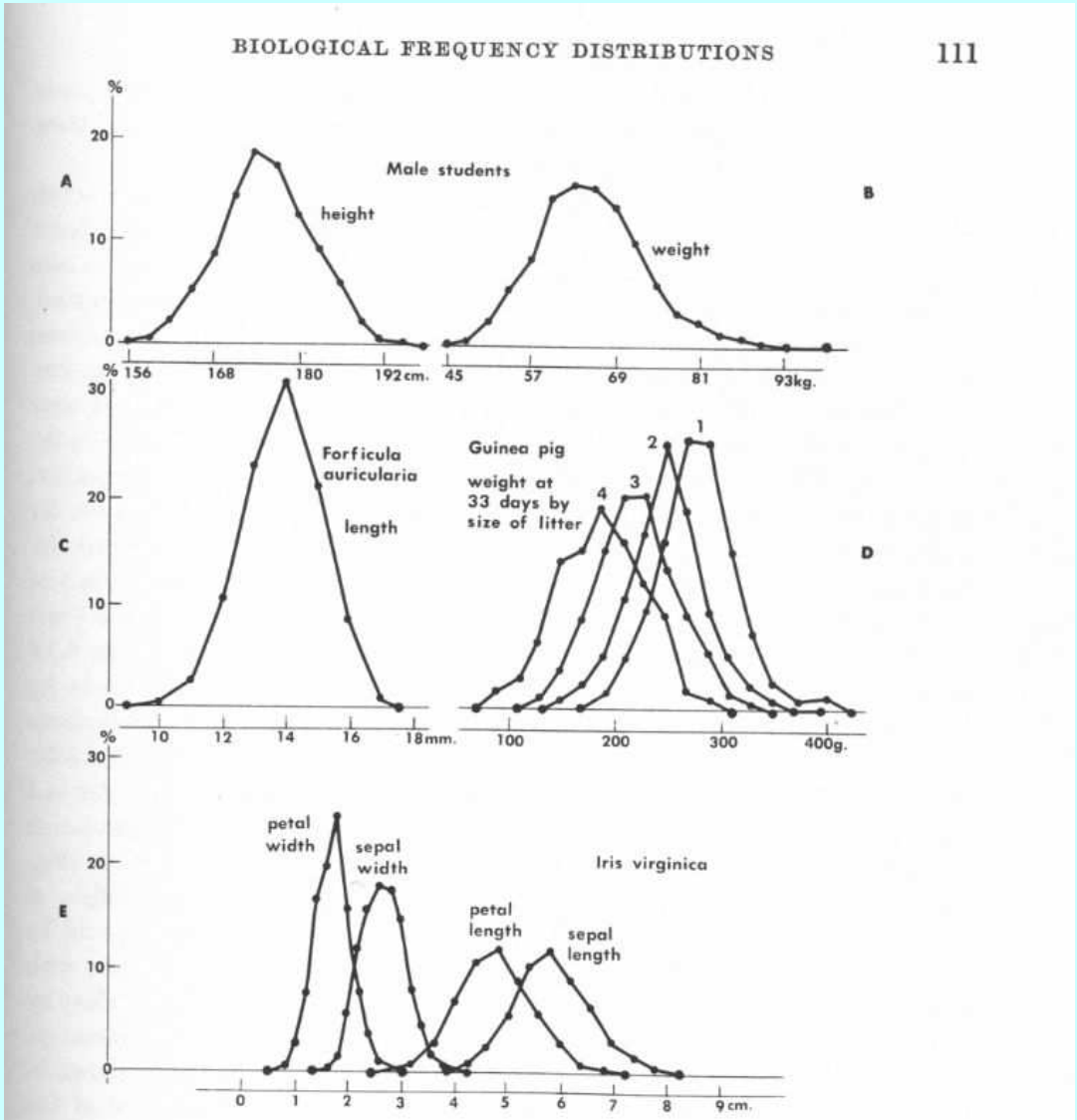


FIG. 6.2. Some unimodal distributions of sizes. Numbers of individuals. *A*, *B* 1,000 male students; *C*, 1,519 *Forficula*; *D*, 80, 382, 530, and 205 guinea pigs in litters of 4, 3, 2 and 1 respectively; *E*, 1,584 ± flowers of *Iris virginica*. (From data: *A* and *B*, Castle 1916*a*; *C*, Diakonov 1925; *D*, Wright and Eaton 1929; *E*, Anderson 1928.)

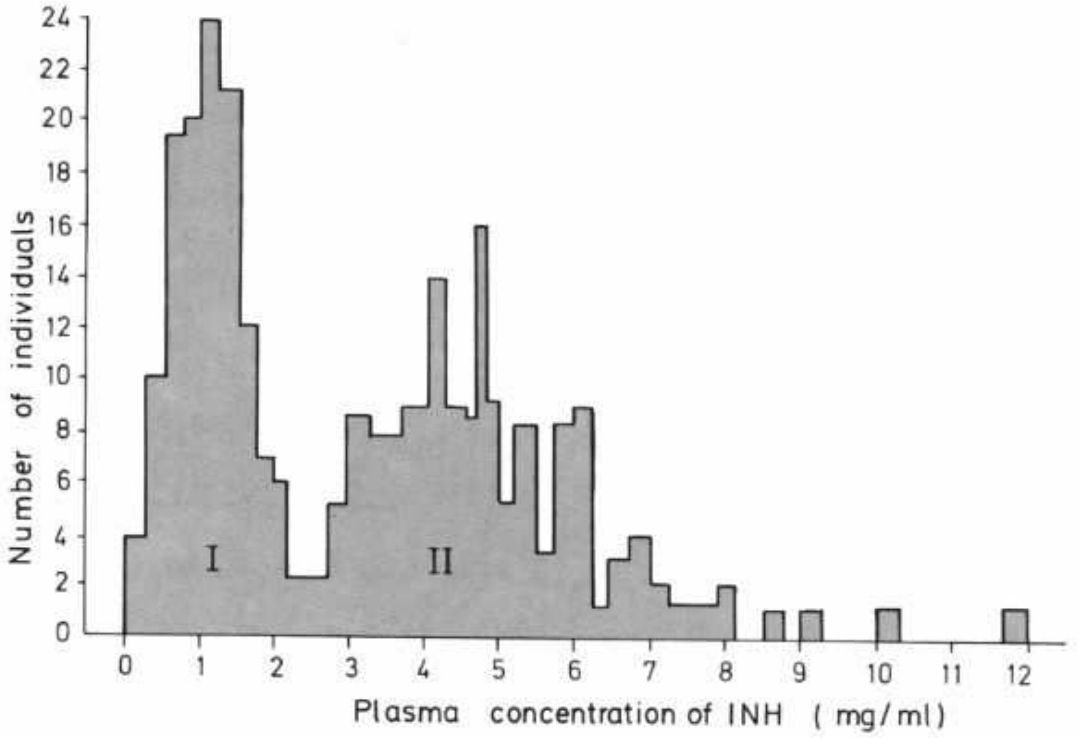


Fig. 3.49. Plasma concentration of isoniazid (*INH*) in 267 members of 53 families; bimodal distribution. The antimode is between 2–3 mg% (adapted from: Evans et al., 1960 [117])

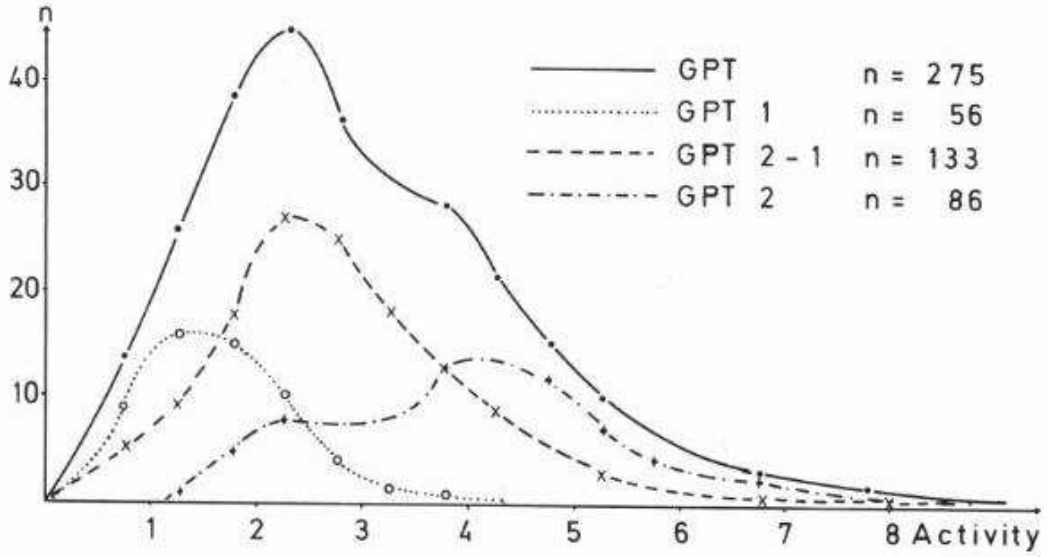


Fig. 3.51. Distribution of enzyme activities for three GPT genotypes, almost combining to a somewhat skewed normal distribution (data from Becker, P.E. (ed.), 1976 [6])

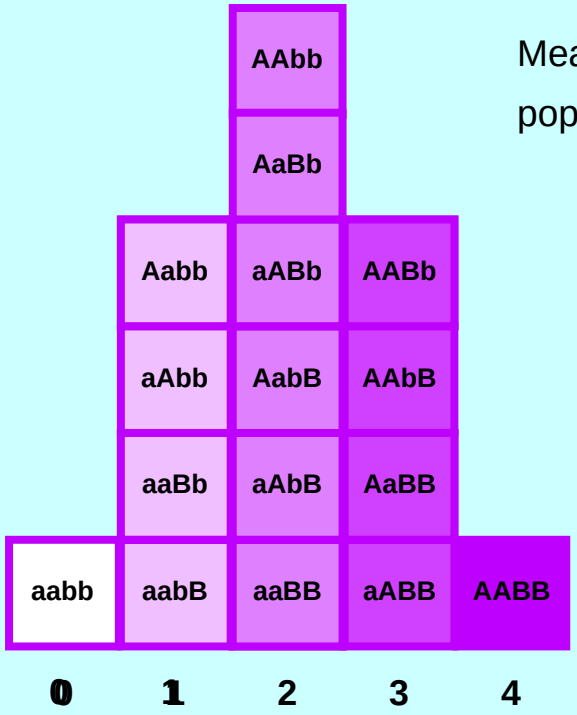
Recall this distribution

The distribution of the genotypes and the quantitative character before artificial selection

Before selection

frequency of A = 0.5

frequency of B = 0.5



Mean phenotype of population = 2.0

Truncation selection

The distributions after artificial selection which saves only those individuals at or above 2

Before selection

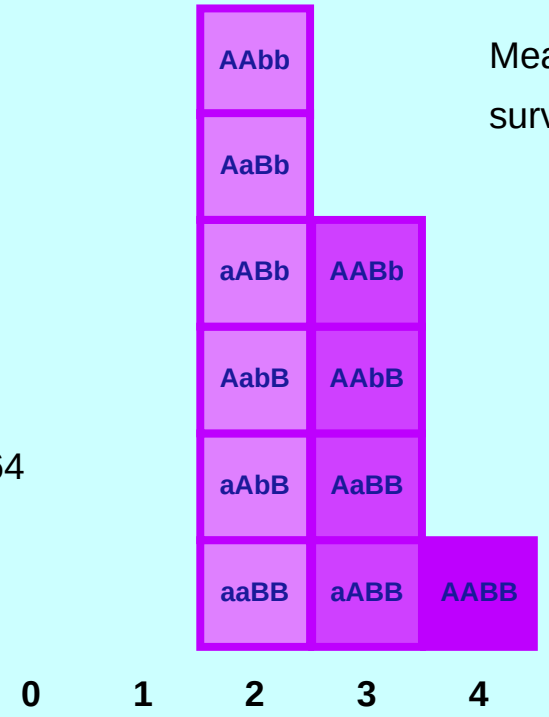
frequency of A = 0.5

frequency of B = 0.5

After selection:

frequency of A = 14/22 = 0.6364

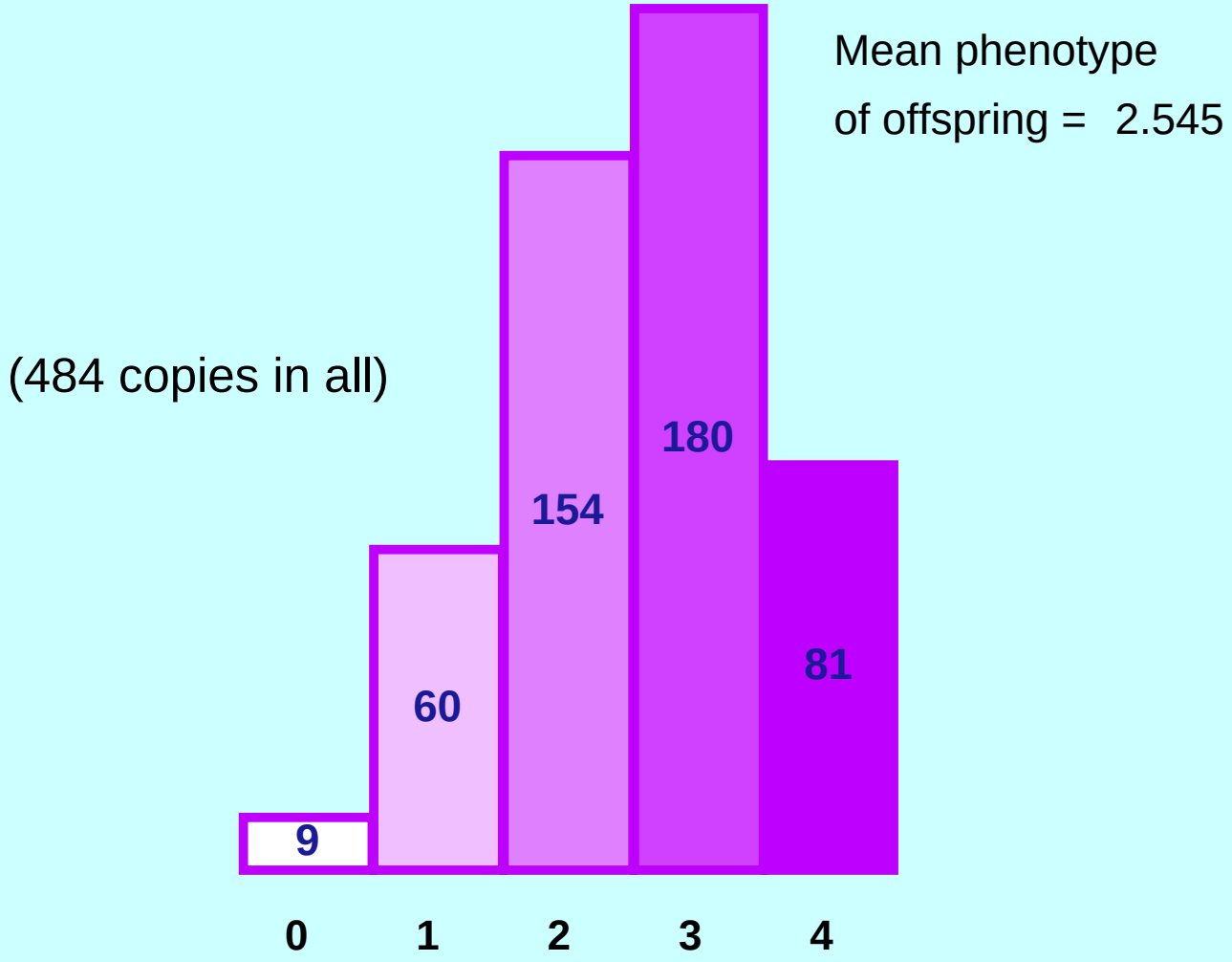
frequency of B = 14/22 = 0.6364



Mean phenotype of survivors = 2.545

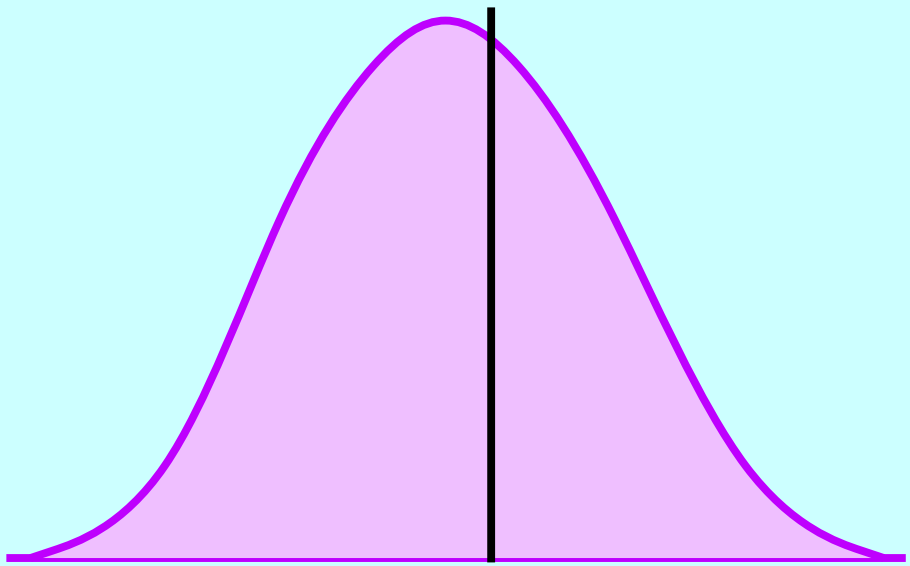
Offspring of truncation selection

In fact, the offspring will have this distribution:



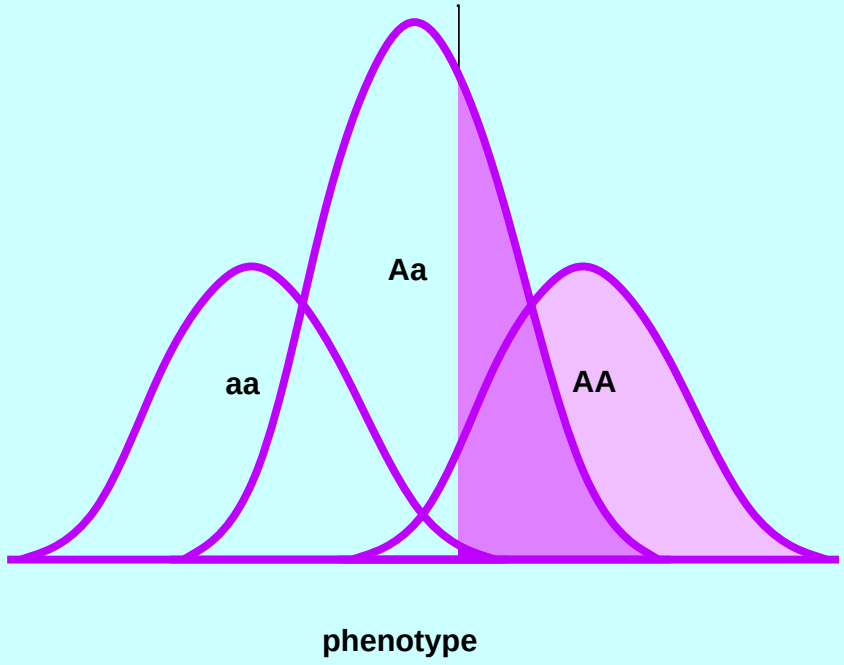
Effect of truncation selection on one locus

With a larger number of loci, focusing just on one locus



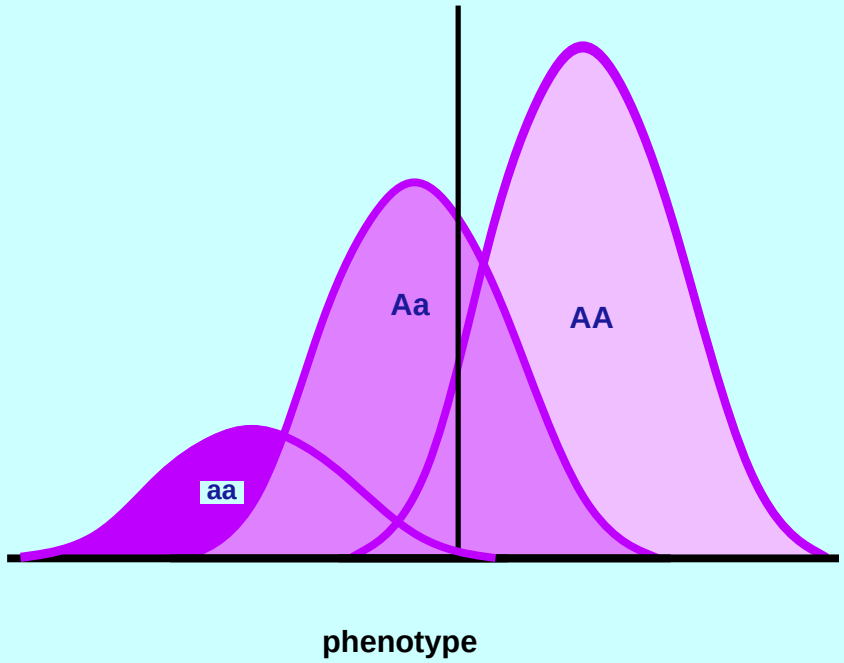
Effect of truncation selection on one locus

With a larger number of loci, focusing just on one locus

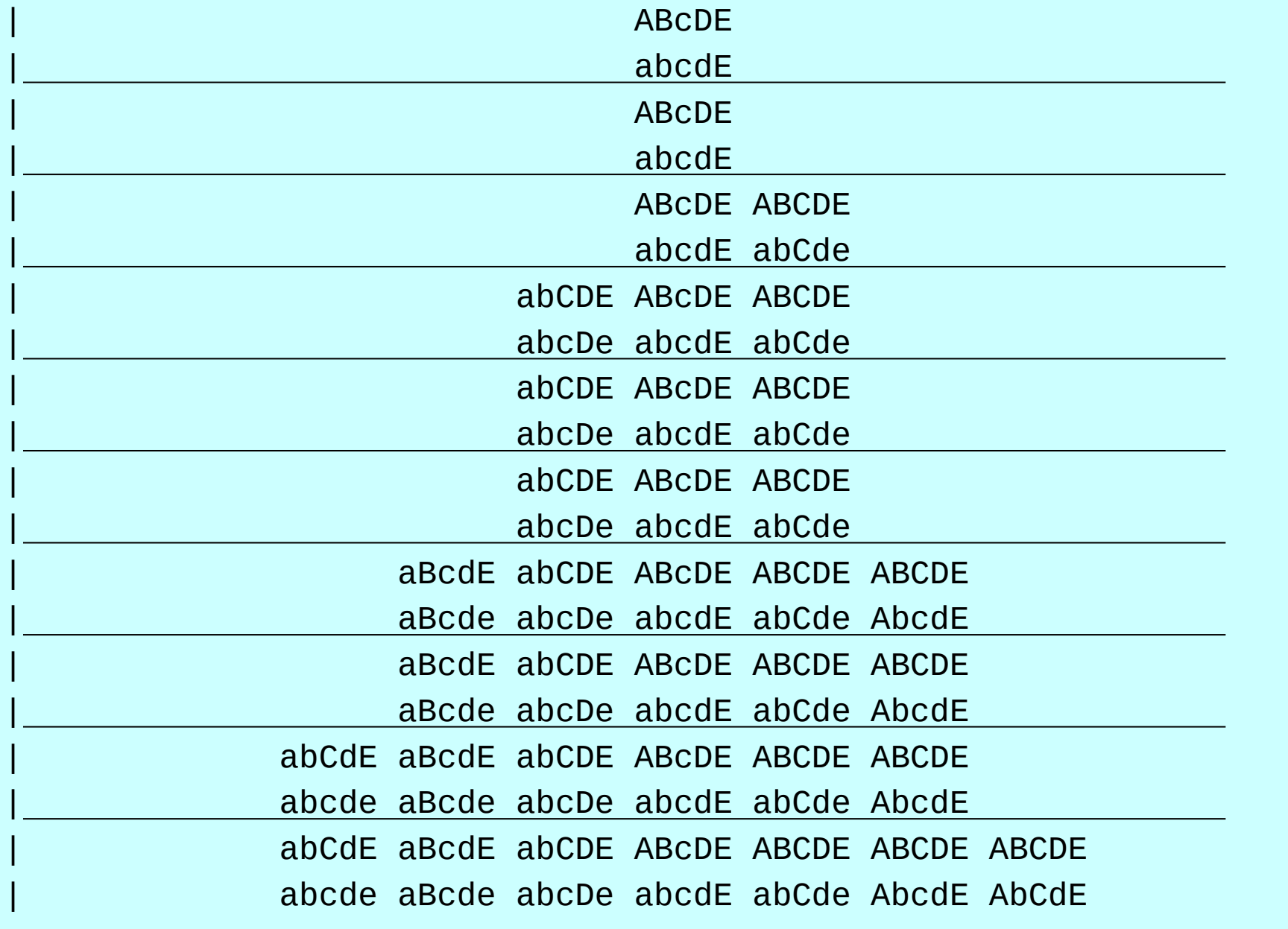


Effect of truncation selection on one locus

The distribution of offspring at this locus



Effect of truncation selection with 5 loci - before

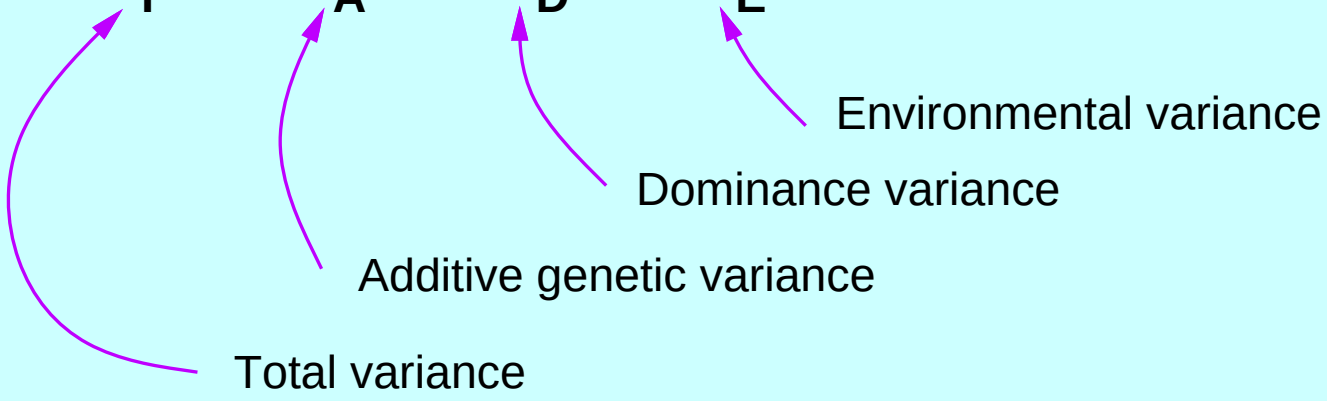


Heritability

(assuming genes are additive and environments are independent)

Variance of a character = V_T

$$V_T = V_A + V_D + V_E$$



$$\text{heritability} = h^2 = \frac{V_A}{V_T}$$

heritability in effect measures the fraction of variations that are passed on to the next generation, undisrupted by Mendelian segregation

Heritabilities in a real-life example

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Angus National Cattle Evaluation Fall 2011

Angus Trait Heritabilities and Genetic Correlations

Trait	CED	BW	WW	PG	RADG	YH	SC	Doc	HP	CEM	Milk	MW	MH
Calving ease direct (CED)	**.20**[1]	-.69											
Birth wt direct(BW)		**.42**											
Weaning direct (WW)			**.20**	.15[2]									
Postweaning gain (PG)				**.20**		.54[3]	.29[3]						
Residual Average Daily Gain (RADG)					**.31**[4]								
Yearling ht (YH)						**.45**							
Scrotal circumference (SC)							**.43**						
Docility (Doc)								**.37**					
Heifer Pregnancy (HP)									**.13**				
Calving ease maternal (CEM)										**.12**[5]			
Maternal milk											**.14**		
Mature wt (MW)												**.55**	.80
Mature ht (MH)													**.82**

[1]Heritability estimates are on the diagonal.

[2]Upper off-diagonals are genetic correlations.

[3]Genetic correlation between 365-d yearling weight and SC or YH.

[4]Feed intake heritability.

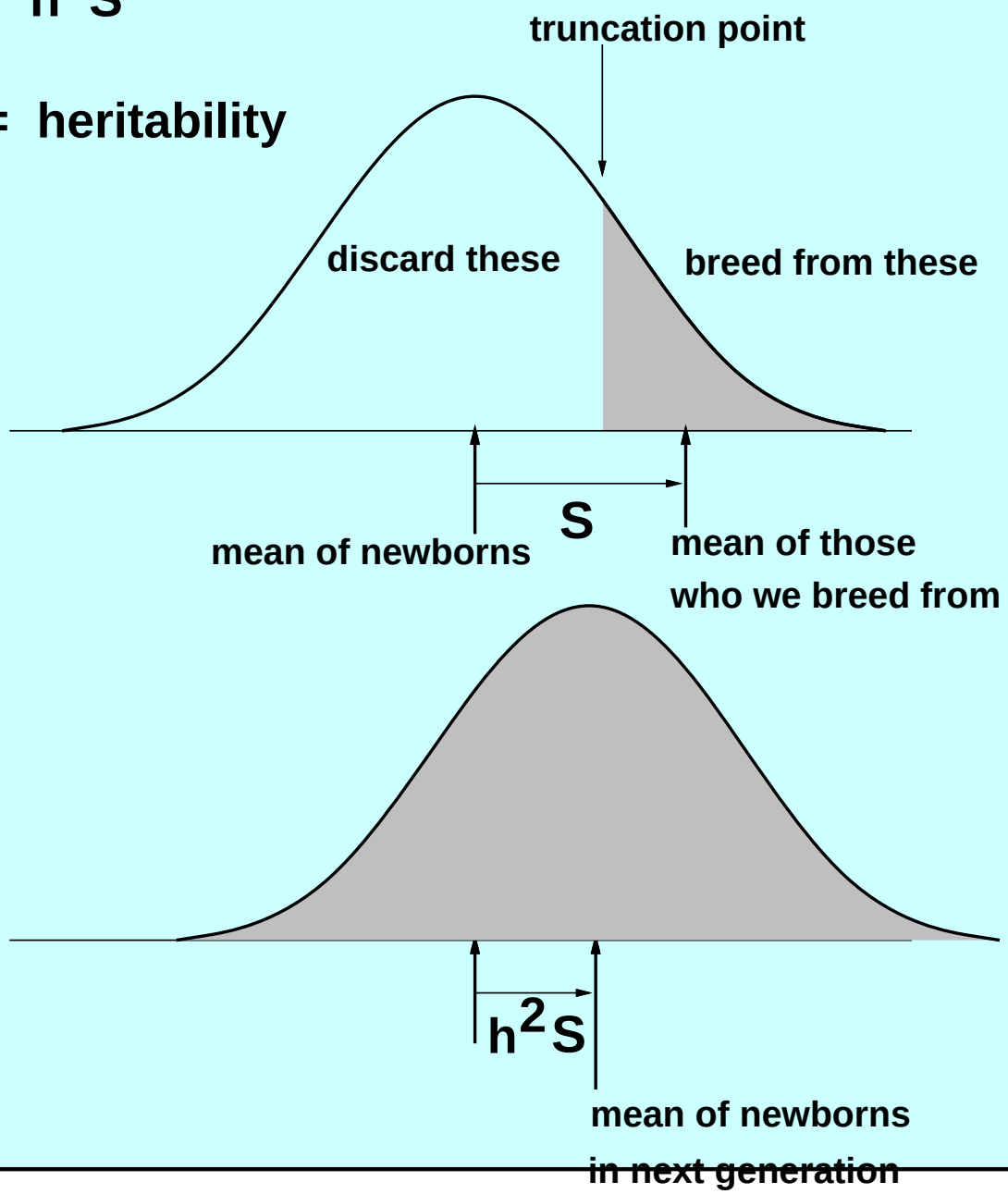
[5]Maternal component only.

Genetic parameters for carcass traits are published by the Journal of Animal Science at **http://jas.fass.org/**, MacNeil and Northcutt (2008).

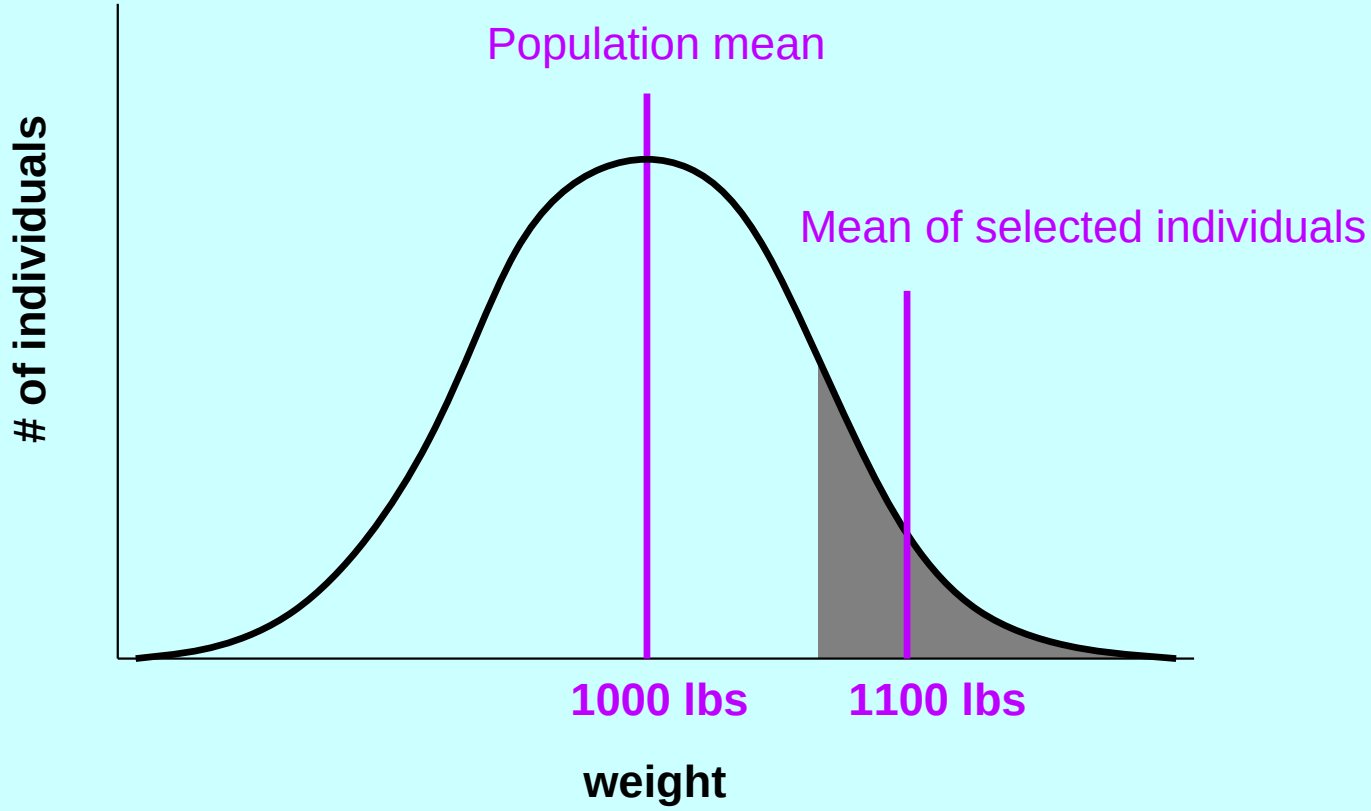
Response to artificial selection

$R = h^2 S$

h^2 = heritability



Response to artificial selection



If heritability = 0.4

S = selection differential

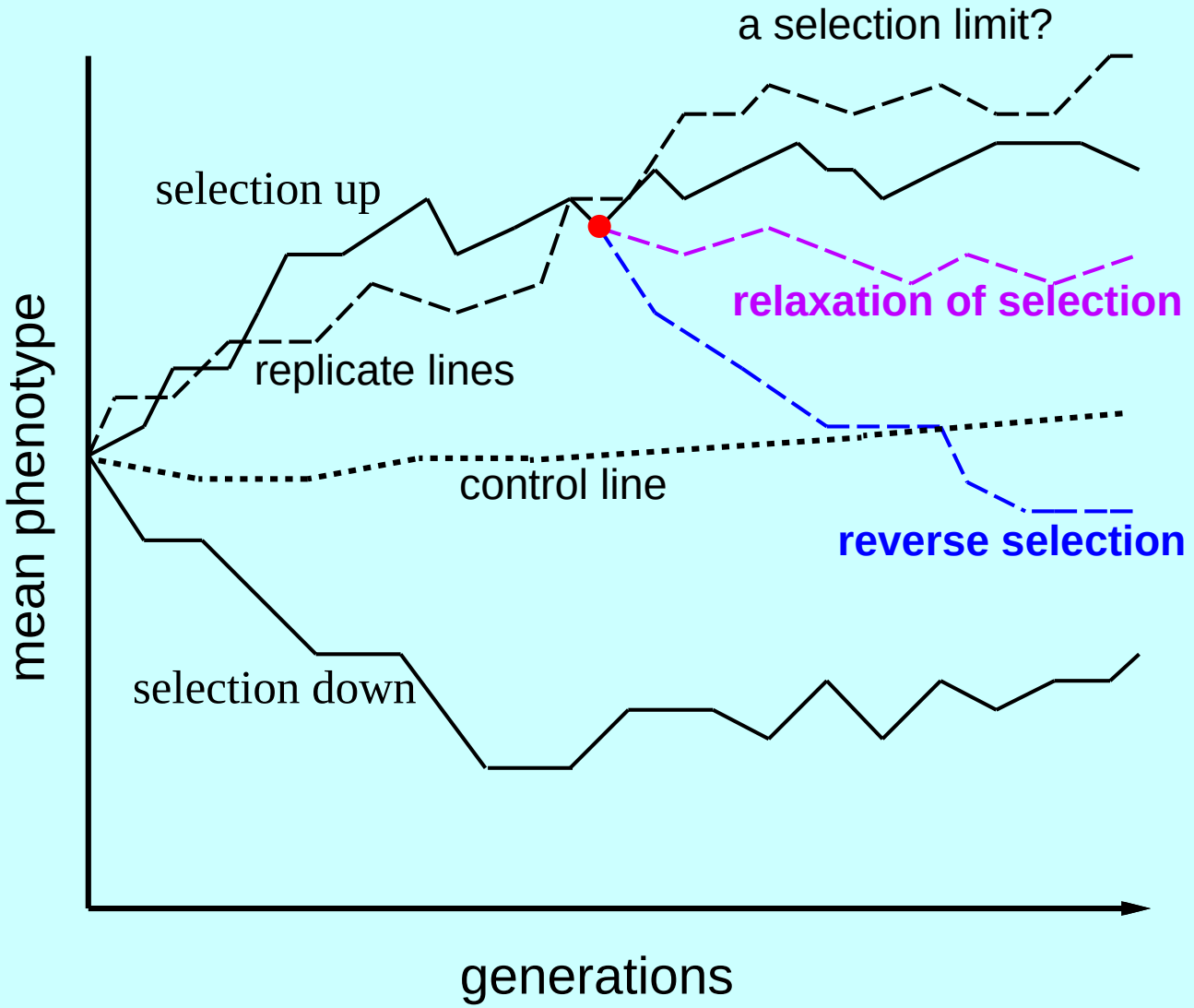
= mean of selected individuals − population mean = 100 lbs

R = gain

= $h^2 S$ = 40 lbs

This is the expected gain in one generation

Some features of artificial selection experiments



Body weight in mice

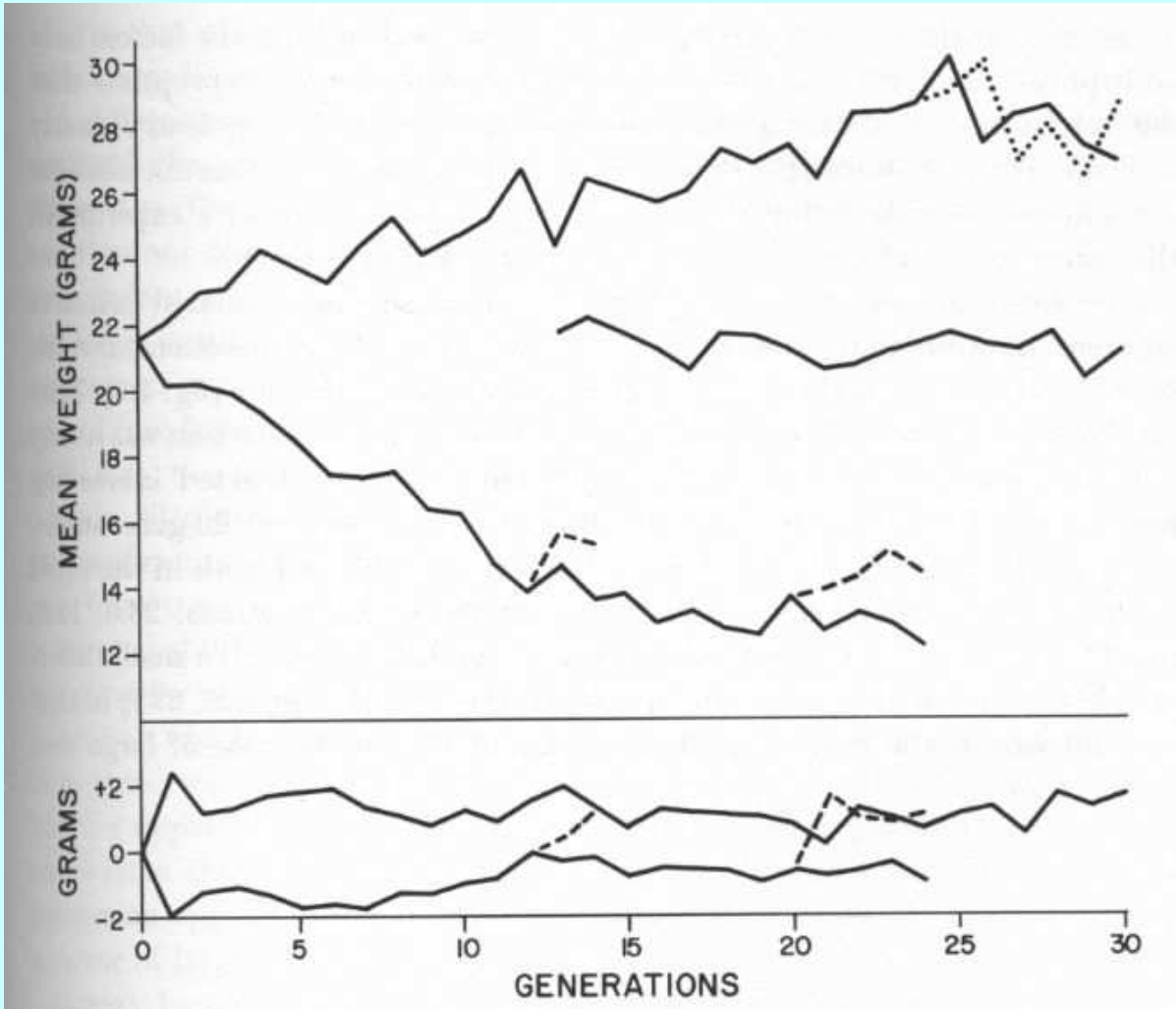


FIG. 7.5. Courses of selection of mice for high or low weight at six weeks in com parison with controls. Effects are shown of late relaxation (*dotted lines*) in th high line and of reverse selection (*broken lines*) at two times in the low line Standard deviations are shown below. Redrawn from Falconer (1955, fig. 1), © 1955 by Cold Spring Harbor Laboratory; used with permission.

Tooth decay in rats

frequencies in mice of Falconer and Bloom.

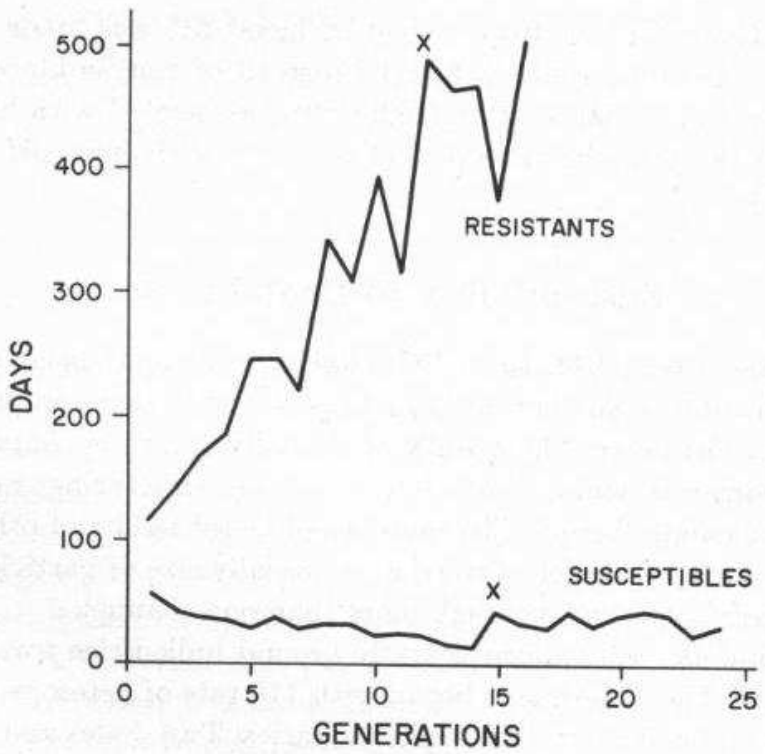


FIG. 7.11. Average number of days from exposure of rats to a cariogenic diet to recognition of caries, under selection for resistance or for susceptibility. The crosses indicate the time after change to a less cariogenic diet. Reprinted, by permission, from Hunt, Hoppert and Rosen (1955). © 1955 by the American Association for the Advancement of Science.

White blood cell counts

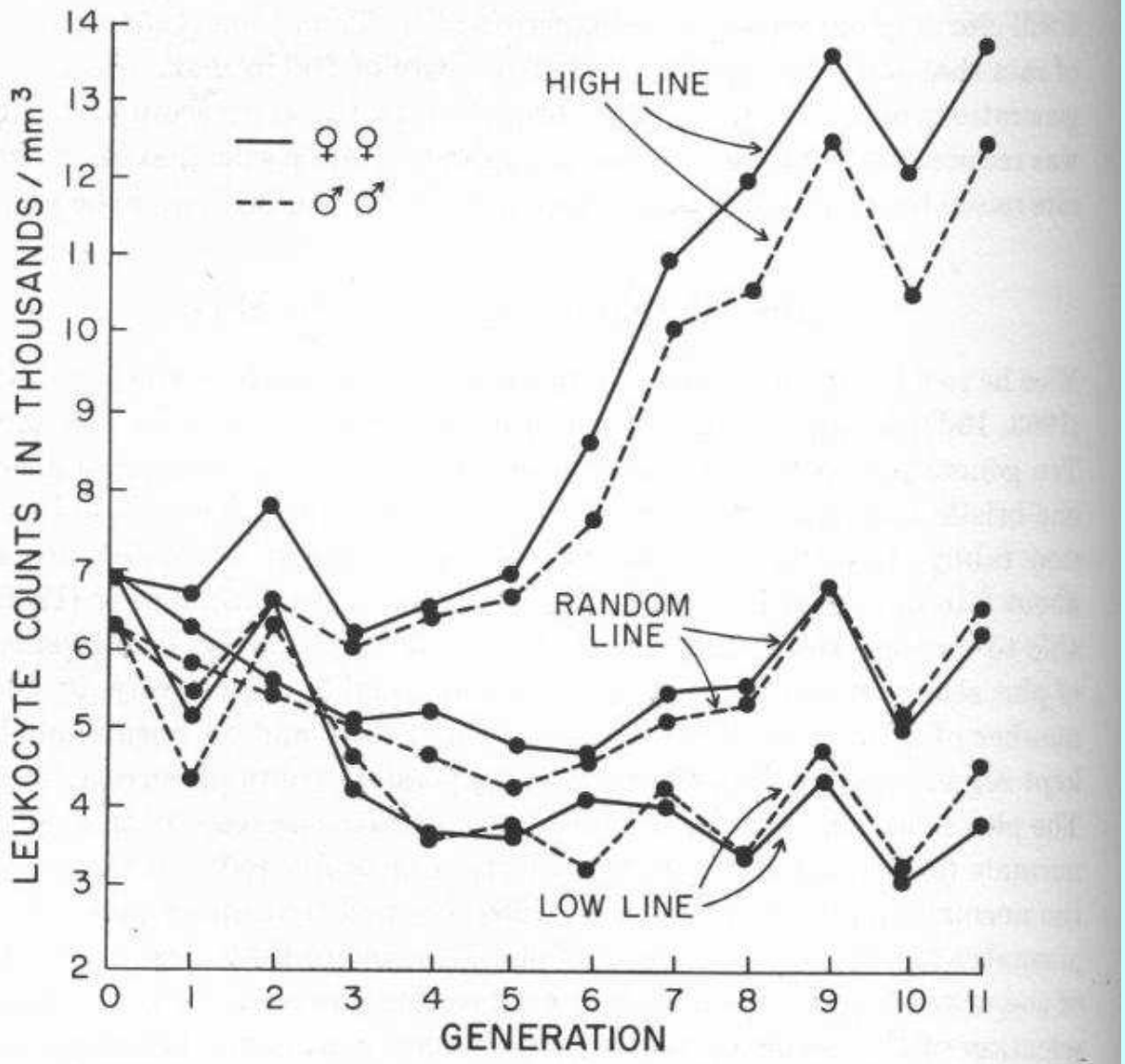


FIG. 7.12. Courses of change of leukocyte counts, in mice selected for resistance or for susceptibility, over 11 generations. From Chai (1966).

Chicken legs

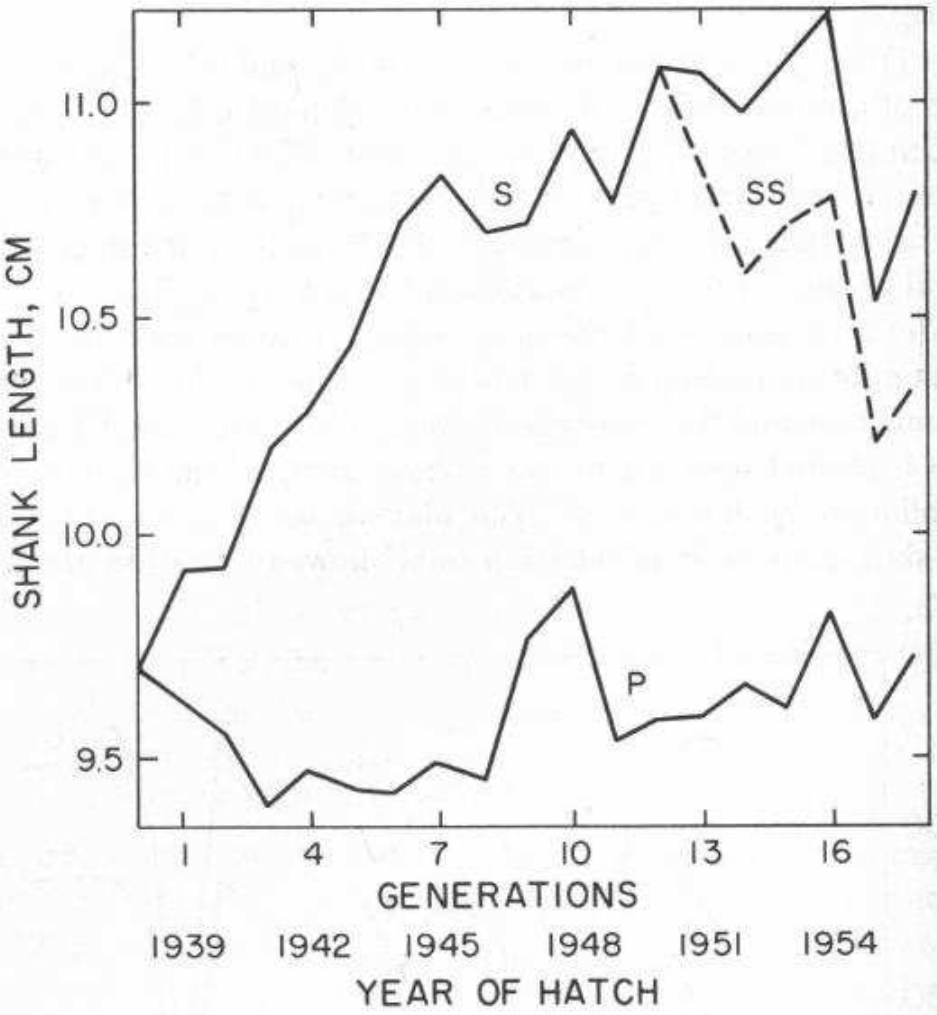


FIG. 7.15. Courses of selection (S) of White Leghorn fowls for increased shank length and suspension of selection (SS) in comparison with controls (P). Redrawn from Lerner (1958, fig. 4.10); used with permission.

Thorax bristles in Drosophila

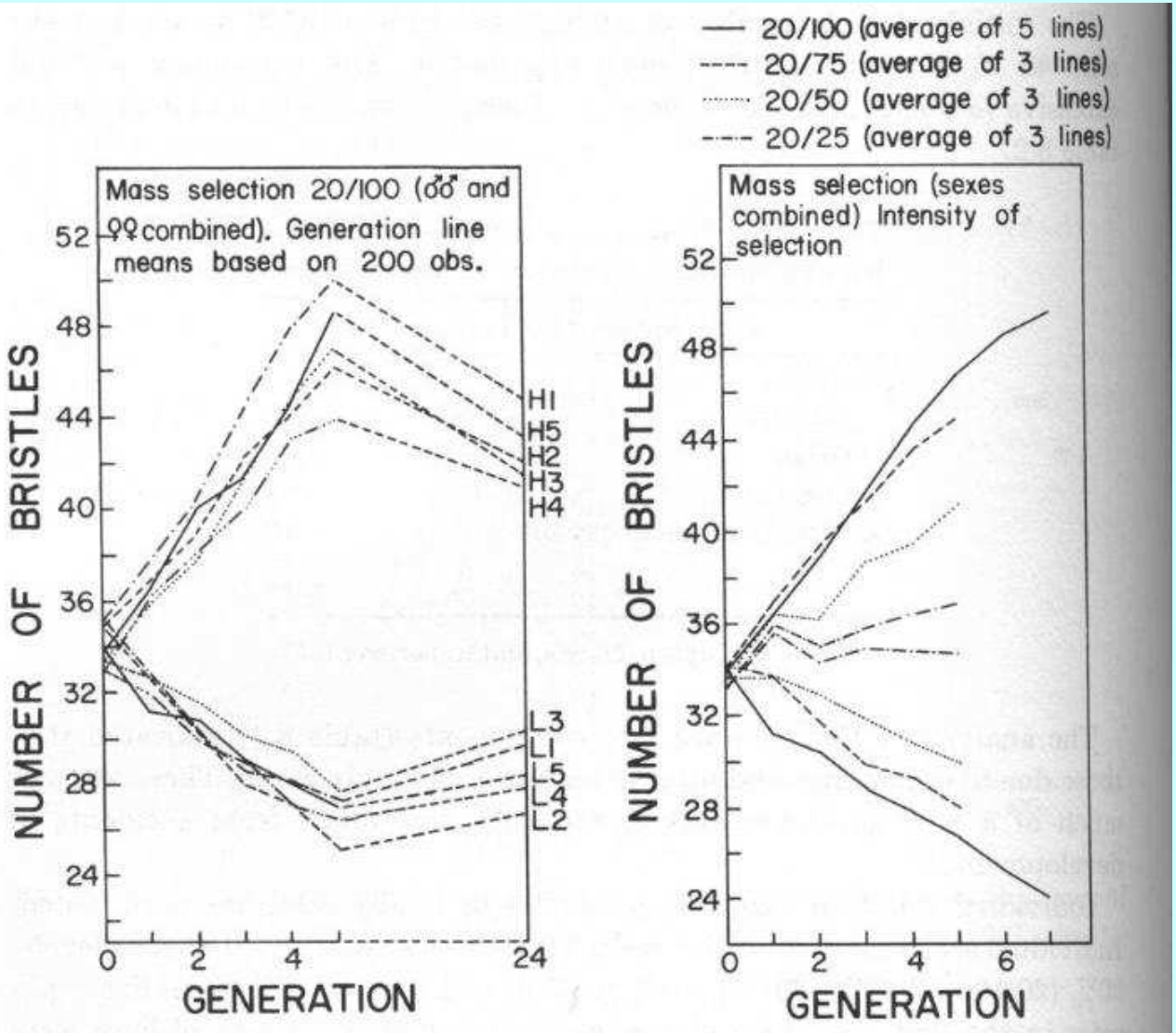


FIG. 8.4. Courses of selection for number of abdominal chaetae in five lines of *D. melanogaster*, in each direction, followed by 19 generations of relaxation (*left*). Courses of selection (high and low) at different intensities (*right*). Redrawn from Clayton, Morris, and Robertson (1957, figs. 1 and 3).

Abdominal bristles in Drisophila

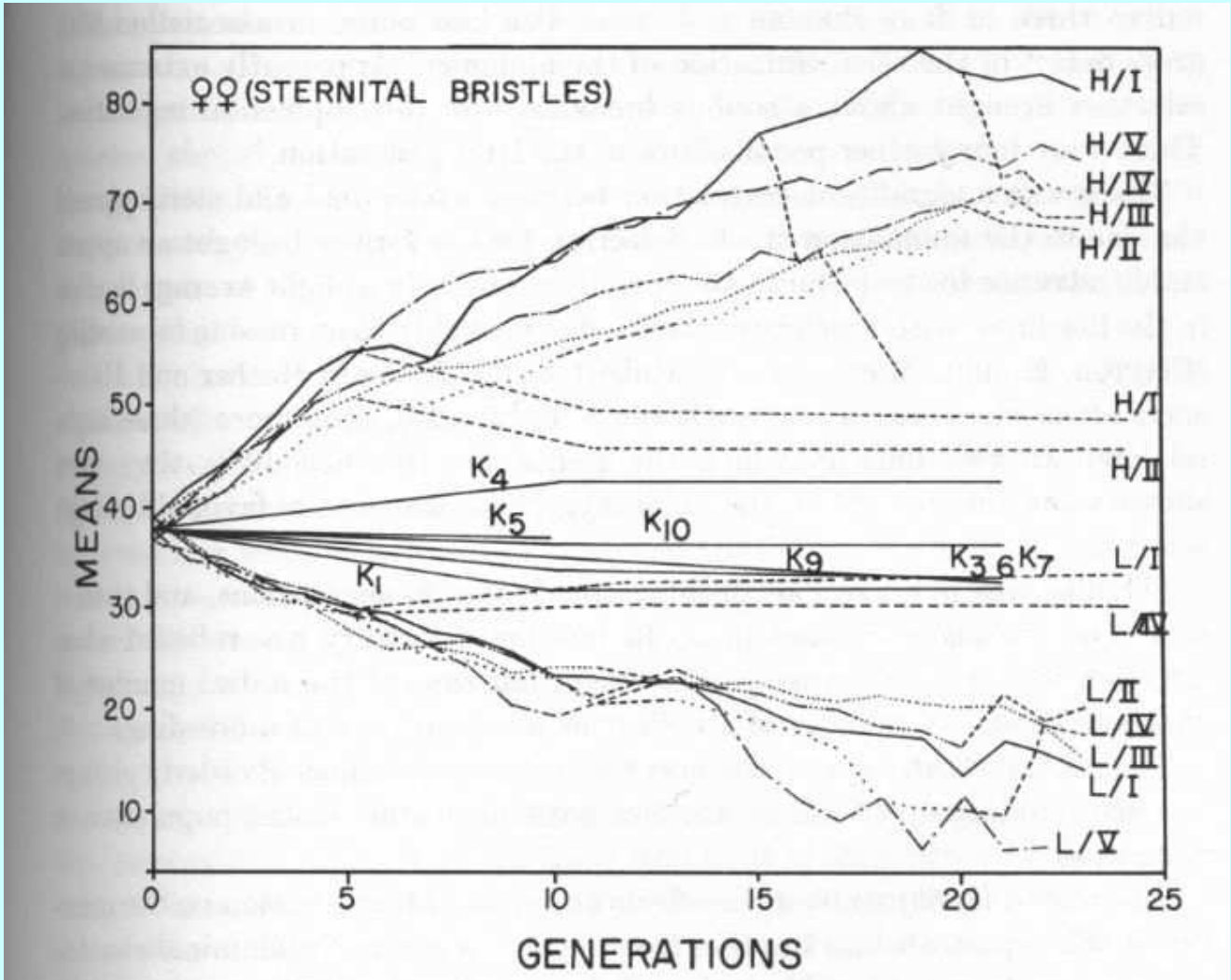
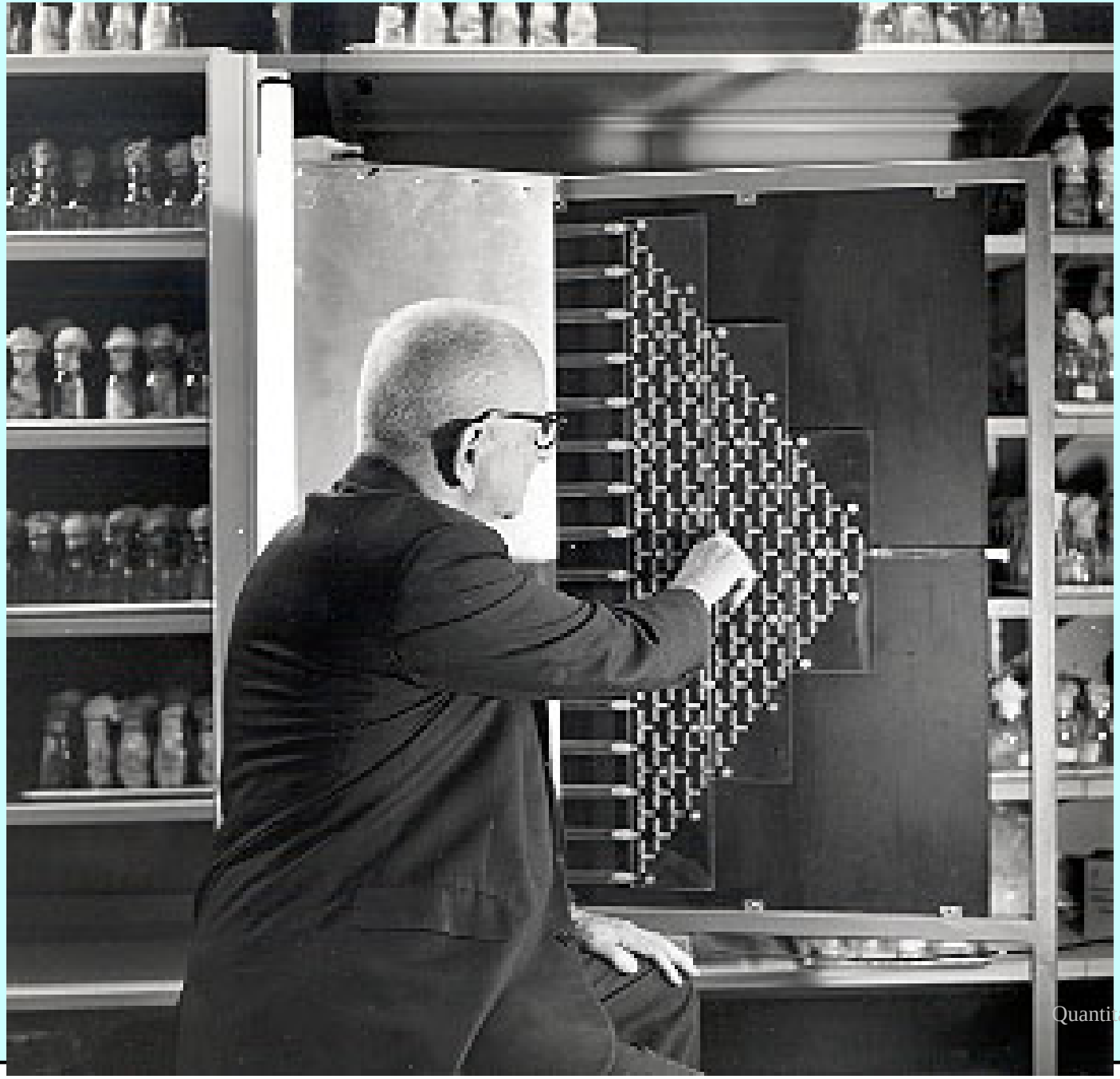


FIG. 8.6. Courses of selection, high, H; low, L; in five lines each, for number of abdominal chaetae (sternital bristles) in females of *D. melanogaster*, continuing the selection of figure 8.4. The effects of relaxation are shown by broken lines. The courses in a number of unselected lines, *K*, are also shown. Redrawn from Clayton, Morris, and Robertson (1953).

Dobzhansky's glass maze



Artificial selection on geotaxis

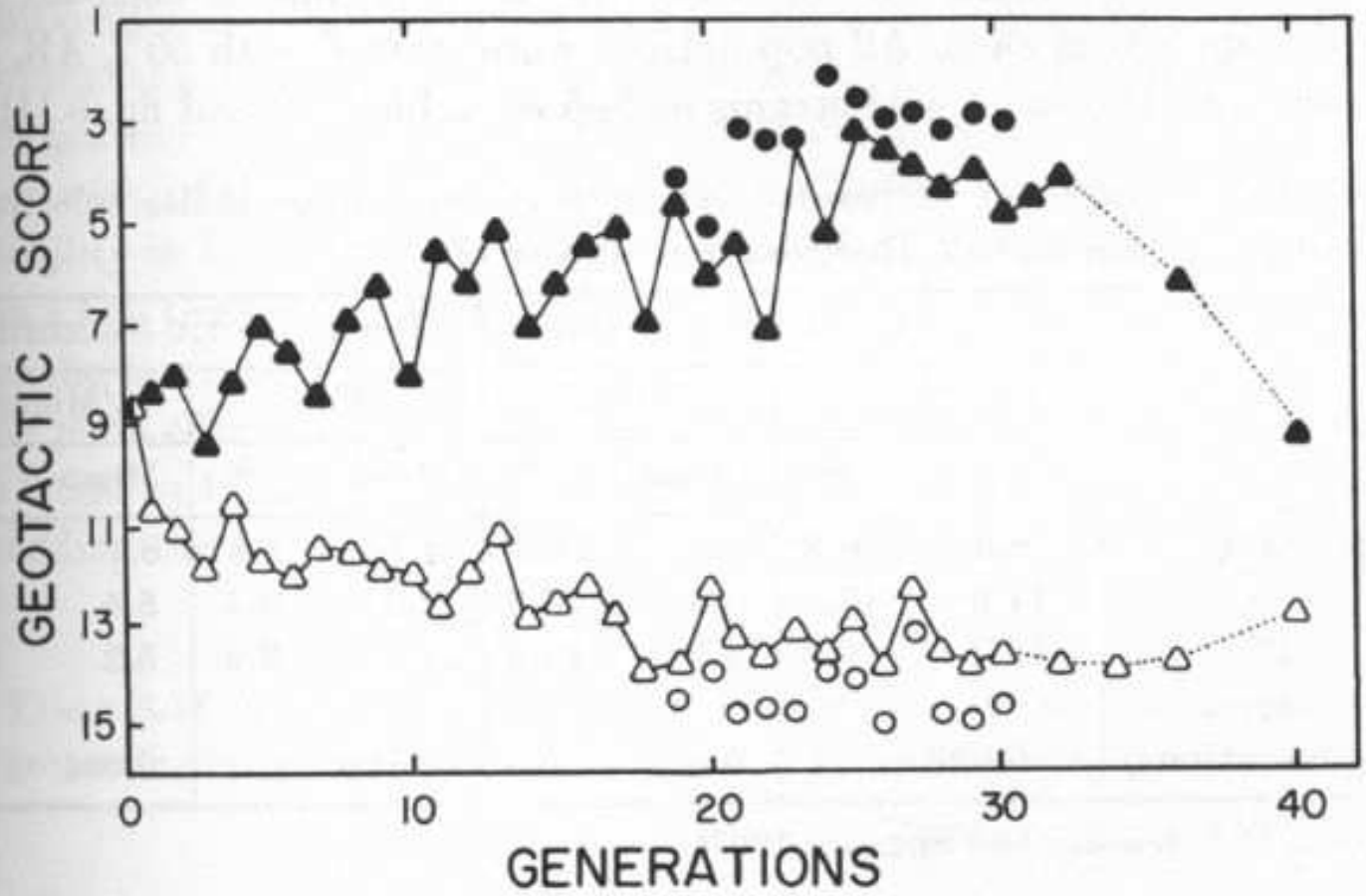


FIG. 8.10. Courses of selection in each direction for geotaxis in *D. pseudoobscura*. Mean scores of retests of 100 "best" flies (*solid circles*, minus; *open circles*, plus). Relaxation of selection, *dotted lines*. Reprinted, by permission, from Dobzhansky and Spassky (1969).

Artifical selection on phototaxis

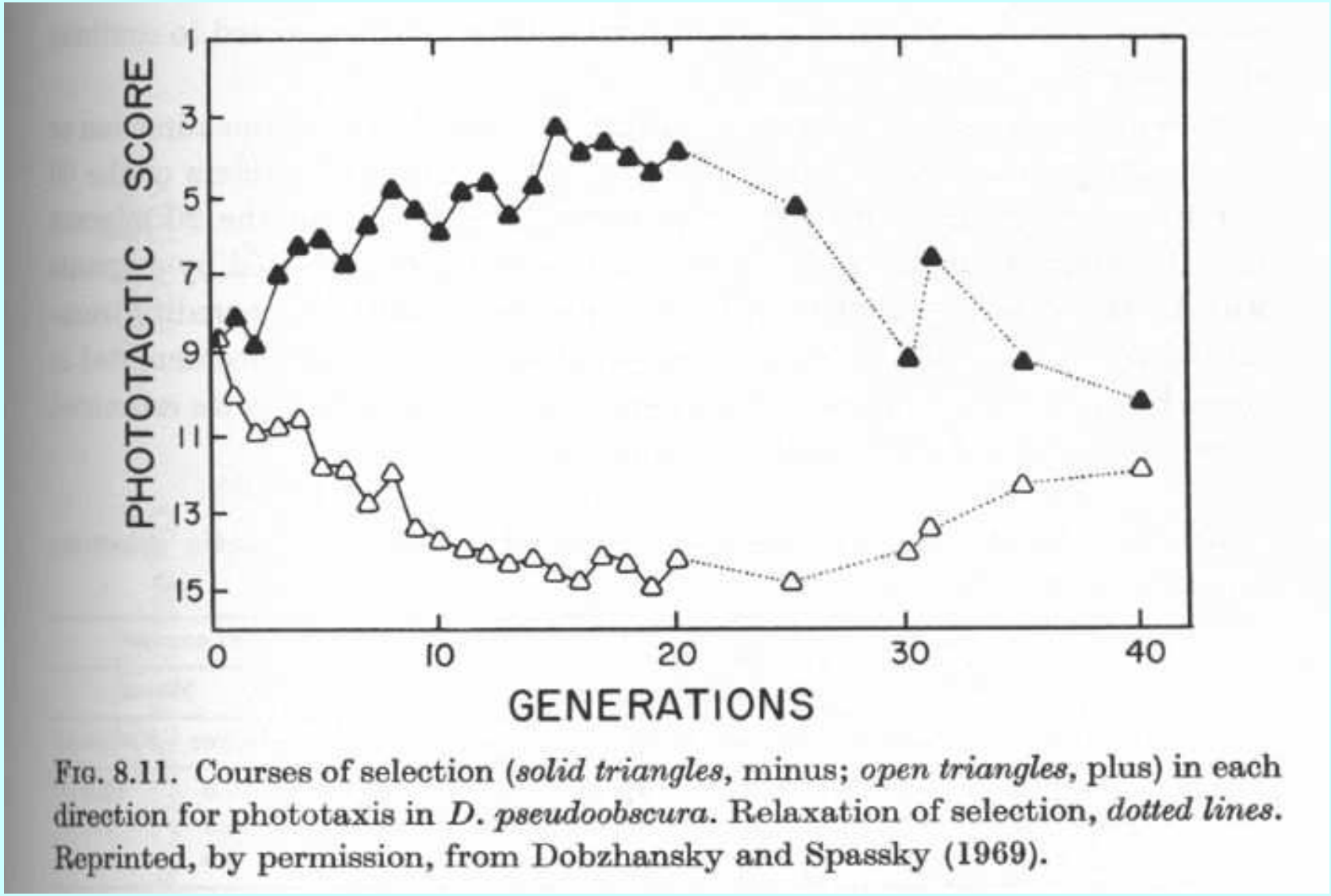
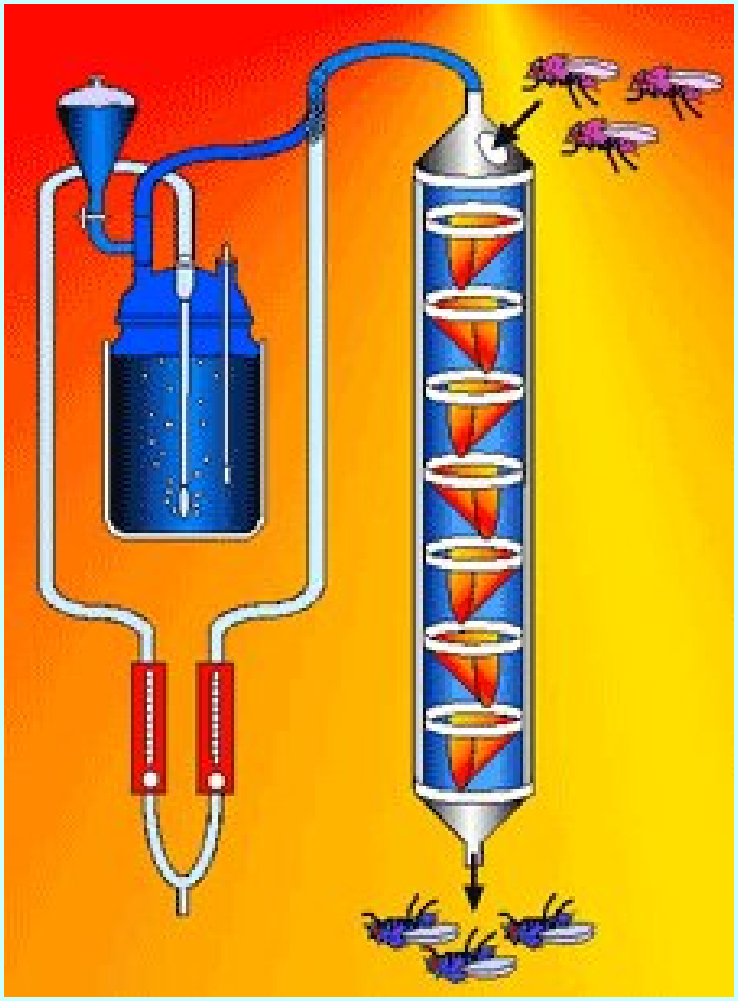
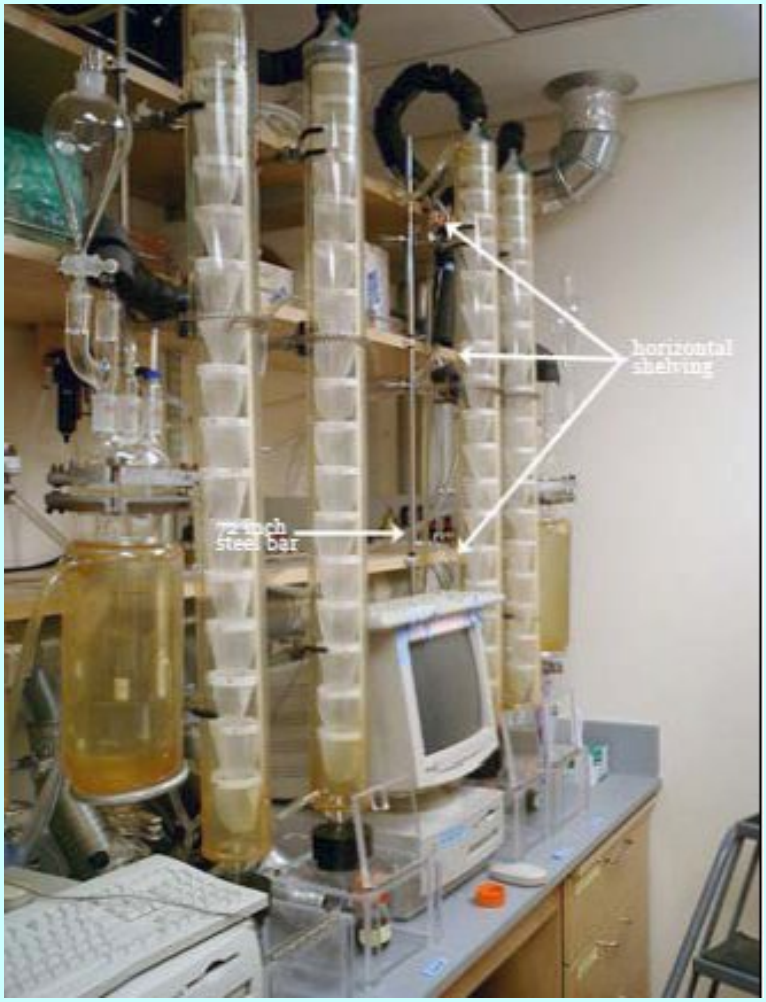


FIG. 8.11. Courses of selection (*solid triangles*, minus; *open triangles*, plus) in each direction for phototaxis in *D. pseudoobscura*. Relaxation of selection, *dotted lines*. Reprinted, by permission, from Dobzhansky and Spassky (1969).

Ken Weber's "inebriometer"



diagram



photograph

The Illinois corn selection experiment (oil content)

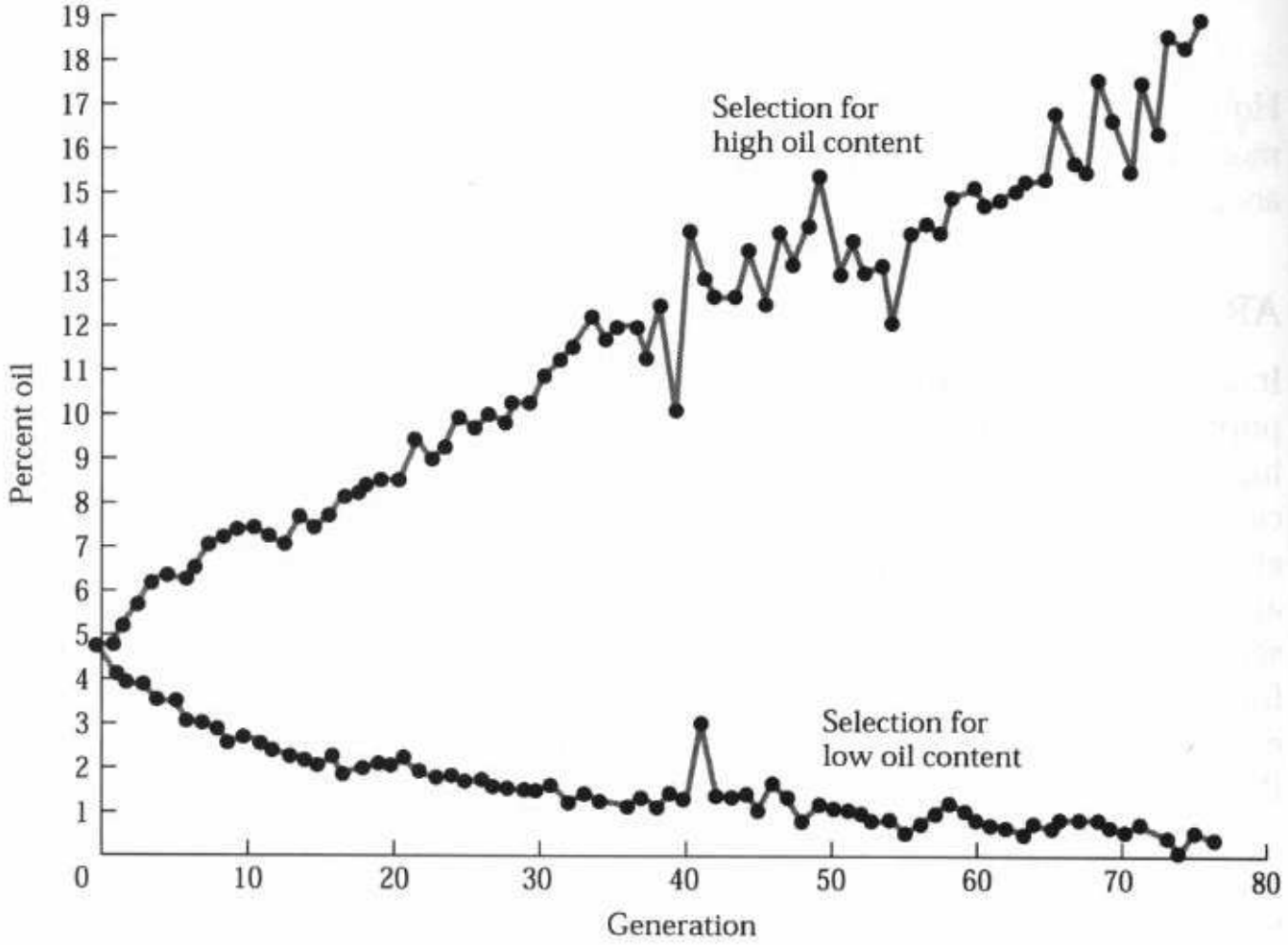
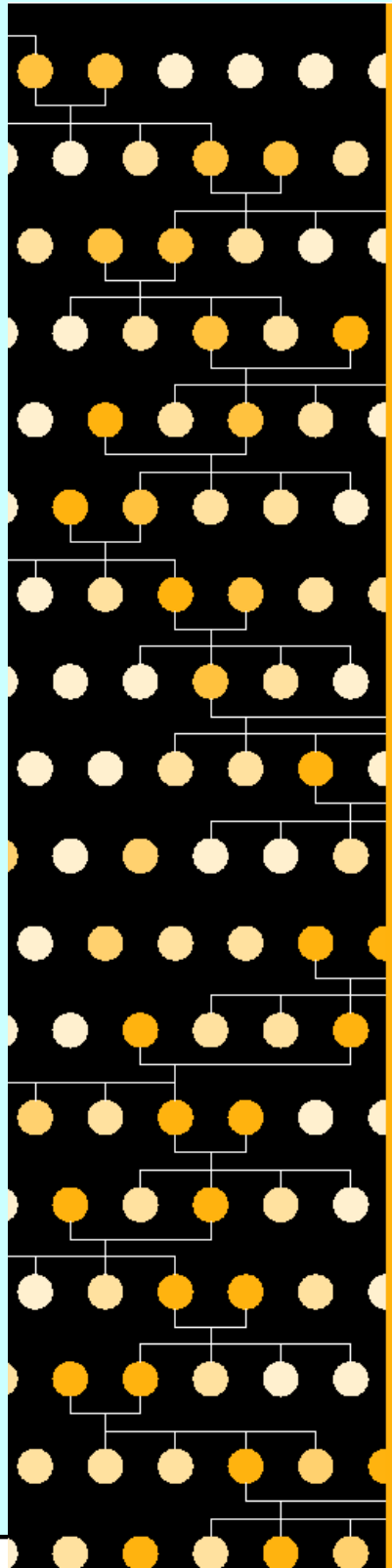


Figure 4.6 Results of a long-term experiment selecting for high and low oil content in corn seeds. Begun in 1896, the experiment has the longest duration of any on record and still continues at the University of Illinois. (After Dudley 1977.)



Long-Term Selection

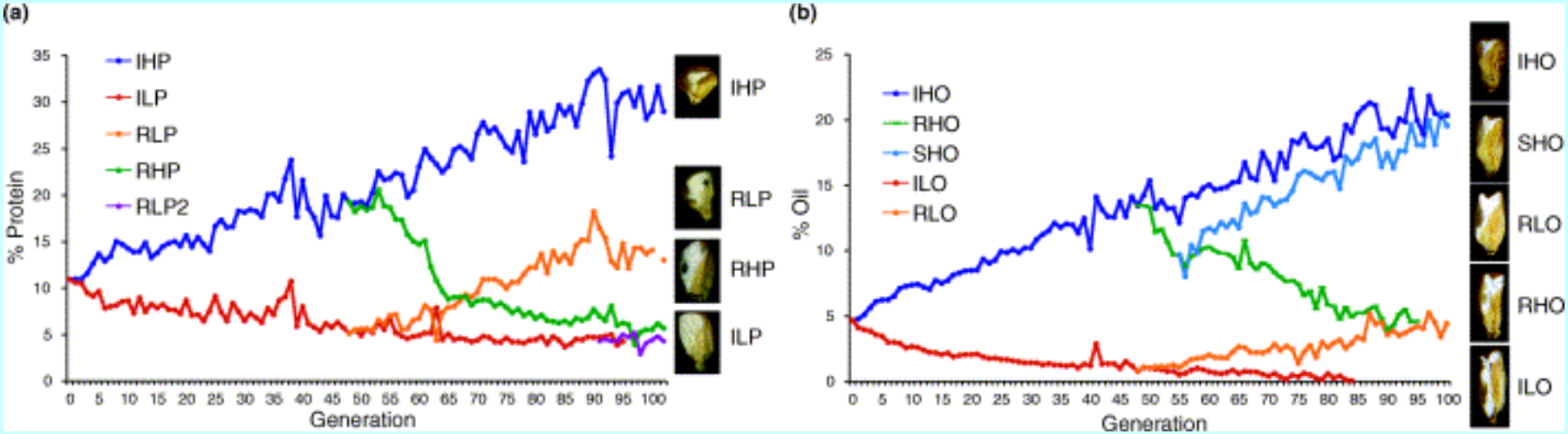
A celebration of 100 generations of selection for oil and protein in maize

June 17–19, 2002

Holiday Inn Hotel and Conference Center
1001 West Killarney
Urbana, Illinois
USA

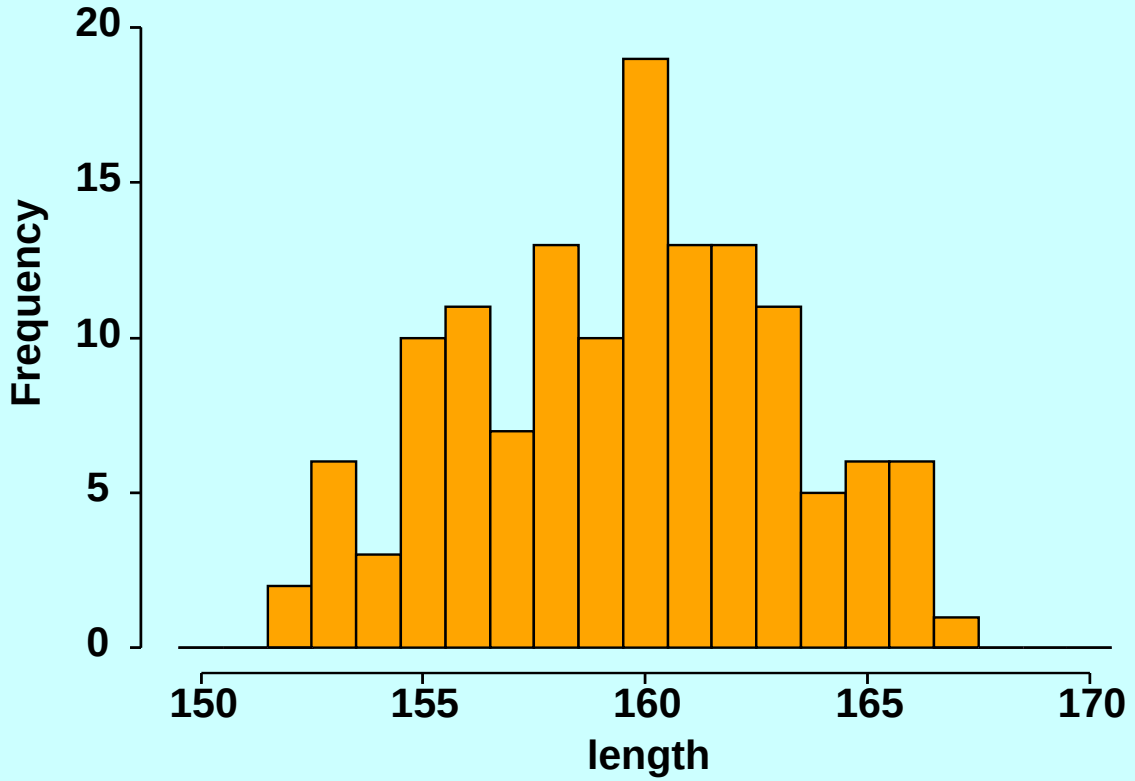
Office of Continuing Education
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

The Illinois corn selection experiment (protein, oil)



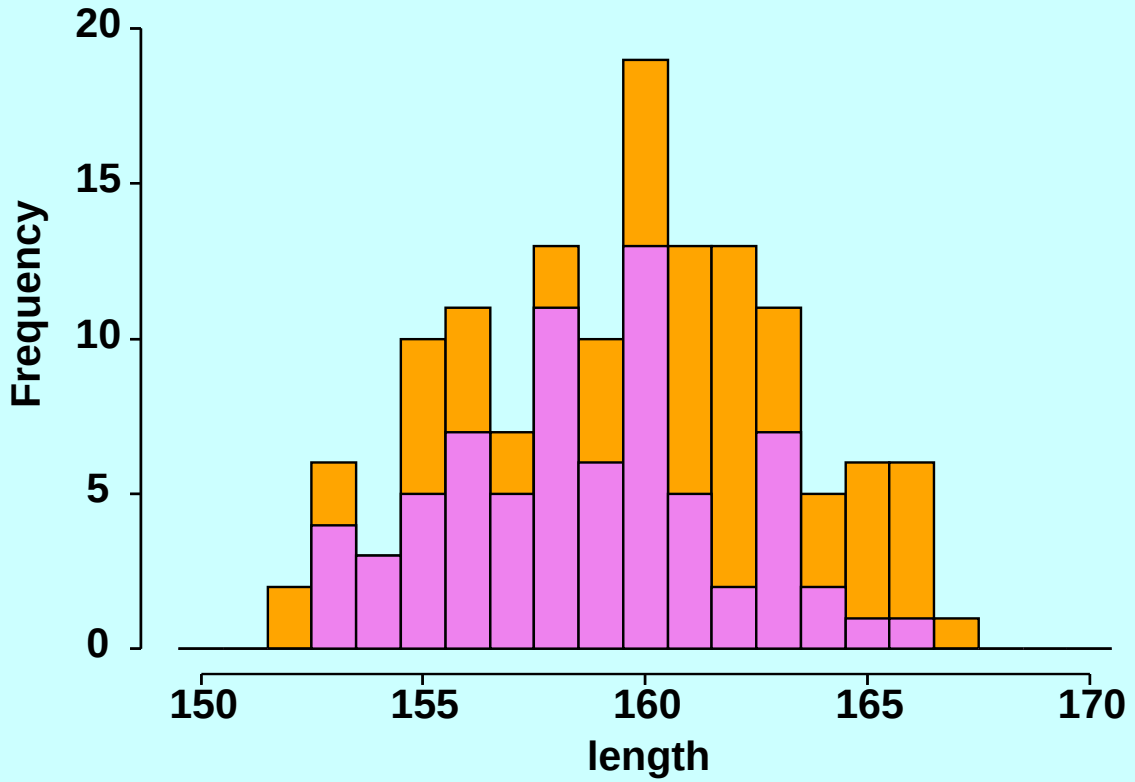
Stephen P. Moose, John W. Dudley and Torbert R. Rocheford . 2004. Maize selection passes the century mark: a unique resource for 21st century genomics. *Trends in Plant Science* **9 (7):** 358-364.

Hermon Bumpus's 1896 sparrows – lengths



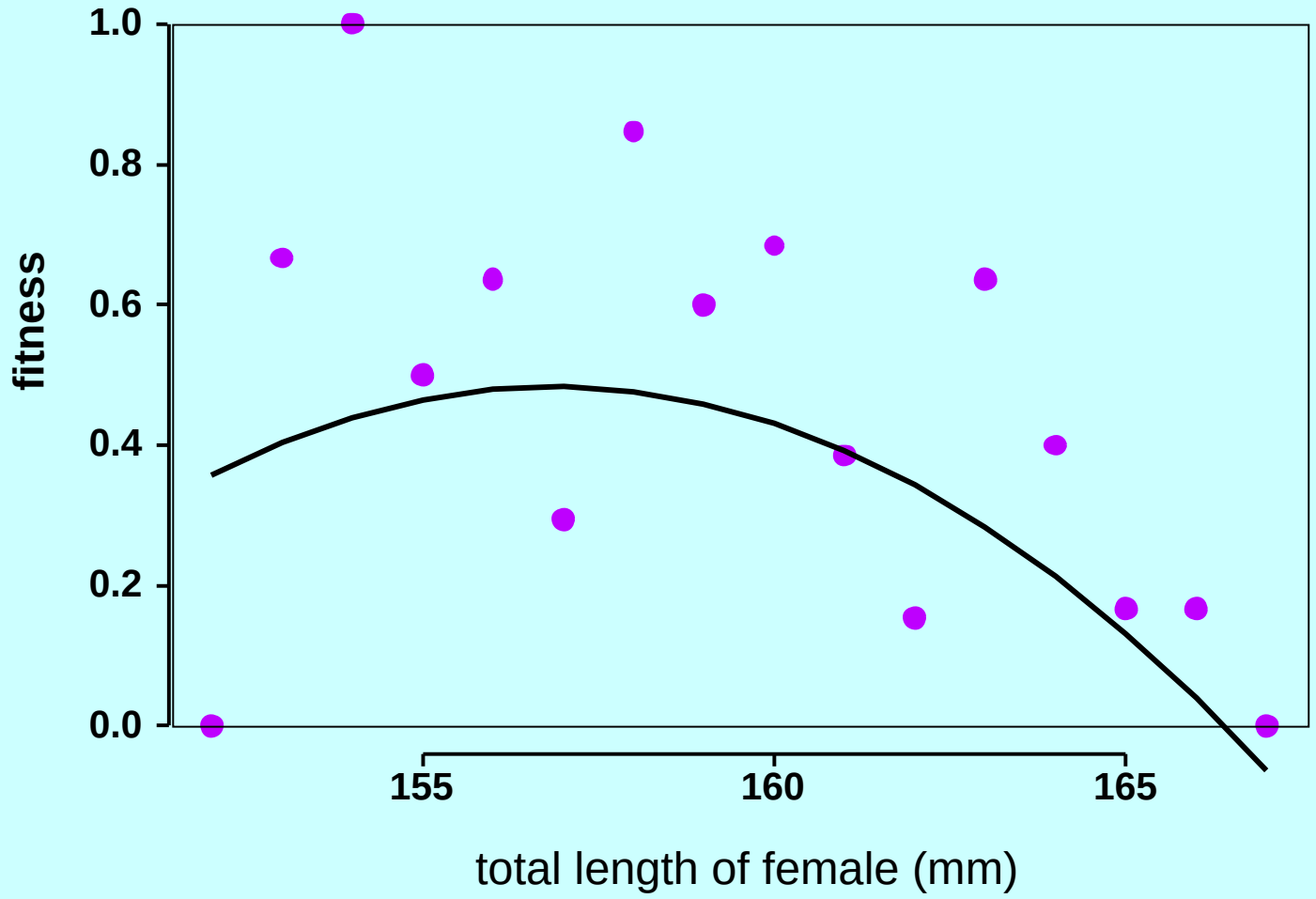
Histogram of female total lengths in millimeters

Sparrow survival data



Histogram of total lengths of females, and those that survived

Least squares fit of estimated fitnesses



Fraction of surviving females, and estimate of (quadratic) fitness curve