

THE LINKAGE OF POLYDACTYLY WITH LEADEN  
IN THE HOUSE-MOUSE

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1. THE FACTOR *py*

THE existence of *polydactyly* as a recognisable Mendelian recessive in the house mouse was established by the work of S. B. Holt, who published decisive evidence in 1945 (1). In the following year (2) Holt and Wright were able to show that the same factor was present in the *fdget* stock in which polydactyly was observed by Grüneberg (5). It follows from Holt's work that in most of the occurrences of polydactyly studied in the literature, the situation has been much obscured by suppressors of varying intensity, so that no single-factor segregation has been observed, and that clear results will only be obtained by the use of stocks in which such suppressors have been largely eliminated. Somewhat more than 10 per cent. of suppression was, however, still present when Holt was obliged to relinquish this work.

Towards the end of 1948, I took over the care of the *polydactyly* stock (H) remaining in this department, which was at that time breeding about five in six polydactylous. The stock responded easily to selection, and from the following year I have had a closed stock in which polydactyly has invariably been manifest, as shown by over 500 mice bred in ten generations. The original stock H was, therefore, segregating in not many, perhaps only one suppressor. Outcrosses to other stocks have almost invariably shown evidence of one or more suppressors, sometimes capable of suppressing manifestation in as many as two-thirds of the mice recessive for the polydactyly factor (*py*) though usually less effective than this. The evidence for linkage between *py* and *ln* was thus somewhat obscured in the first matings in which it appeared, but by the end of 1949 it was possible (3) to report unmistakable linkage with recombination fraction of 20-30 per cent. in males. To the new linkage group so formed the number XIII was provisionally assigned. In reply to my information, Dr Snell at Bar Harbor informed me that his department had found *ln* to be weakly linked with *fuzzy*, *fz*, and strongly to *Splotch*, *Sp*, which he thought at that time to be linked with *Sd* (in Linkage Group V). It is now agreed that *Splotch* and *fuzzy* also belong to Linkage-Group XIII.

2. LINKAGE DATA

Stocks segregating in the factors of Linkage-Group XIII have now been established in this department. Since misconceptions appear still to be current as to the simplicity of the inheritance of

polydactyly in suitably prepared stocks (*e.g.* (4) Chase, 1951), it may be timely to put on record some of the linkage tests giving two-factor data for *polydactyly* and *leaden*.

The first mating giving clear single-factor segregation, with good though not perfect manifestation was put up in 1949, using a male doubly heterozygous in coupling, and gave 92 mice, which were classified in four classes as follows :—

TABLE 1  
*Males in coupling*

	+	<i>poly</i>	<i>leaden</i>	<i>poly leaden</i>	Total
P 225	34	10	15	33	92

The crossover classes are about 27 per cent., and very significantly less than one-half. Two other matings of the same male later gave concordant results, as follows :—

P 325	15	5	12	15	47
P 326	13	4	4	13	34
Total	62	19	31	61	173

In each case the double recessive was of the Élite polydactylous stock ; none the less it will be seen that the two crossover classes are sufficiently unequal to suggest either lower viability, or imperfect manifestation of polydactylous mice in these matings. Six confirmatory matings were made with males in coupling derived from the matings set out above ; these were :—

TABLE 1 (*concluded*)

	+	<i>poly</i>	<i>leaden</i>	<i>poly leaden</i>	Total
P 289	25	6	8	22	61
P 332	29	5	9	27	70
P 342	21	8	7	9	45
P 343	9	4	6	13	32
P 344	26	4	8	20	58
P 345	4	1	1	1	7
All C♂	176	47	70	153	446

I have plenty of evidence of occasional failure of manifestation, and little of any difference in viability. On the supposition of imperfect manifestation the simplest mode of calculation proceeds as follows :—

	Variance
$47/(176+47) = 21.076$ per cent.	$7.459$ (per cent.) <sup>2</sup>
$153/(153+70) = 68.610$ „	$9.658$ ( „ ) <sup>2</sup>
Manifestation $89.686$ „	$17.127$ ( „ ) <sup>2</sup>
Recombination $21.076/89.686 = 23.500$ per cent.	
Sampling variance	$6.090$ (per cent.) <sup>2</sup>

giving estimates of 89.7 per cent. manifestation, and 23.500 per cent. recombination. With these values the data are exceedingly closely

fitted, with  $\chi^2$  actually zero, thus giving no indication of disturbance due to unequal viability. The method of estimation used above was given by Bailey (7) in 1950. I have, however, modified his estimates of sampling variance.

In parallel with these nine matings of males doubly heterozygous in coupling, eleven such matings were made with females. These are given in table 2 :—

TABLE 2  
*Females in coupling*

	+	<i>poly</i>	<i>leaden</i>	<i>poly leaden</i>	Total
P 301 .	22	11	13	10	56
P 306 .	30	10	15	20	75
P 322 .	12	9	7	19	47
P 323 .	28	13	13	17	71
P 347 .	5	5	4	11	25
P 388 .	7	4	4	4	19
P 389 .	7	3	5	6	21
P 390 .	7	2	10	10	29
P 392 .	11	7	4	8	30
P 399 .	10	5	7	7	29
P 400 .	10	3	10	6	29
All C♀ .	149	72	92	118	431

With the same calculations as for table 1, we find

		Variance
72/221	= 32.579 per cent.	9.939 (per cent.) <sup>2</sup>
118/210	= 56.190 „	11.722 ( „ ) <sup>2</sup>
Manifestation	88.769 „	21.661 ( „ ) <sup>2</sup>
Recombination	36.701 per cent.	
Sampling variance	7.055 (per cent.) <sup>2</sup>	

The fitting is again close, with  $\chi^2 = 0.272$  for one degree of freedom. The recombination fraction for females is remarkably larger than that for males, a circumstance which gives special interest to the verification of the values by matings in repulsion. The percentage manifestation is nearly the same, as might have been expected using males and females of the same parentage.

Eight matings using males in repulsion were obtained soon after the coupling series, but it is only recently that I have had results from females in repulsion. These two batches, therefore, are less closely related than those in coupling. It will be observed that the most recent lot has apparently perfect manifestation, as must occur sooner or later, save on the view that the gene *P $\gamma$*  is not an ordinary normal allelomorph. There has never been any evidence in favour of this possibility. In spite of all suggestions to the contrary, the gene *p $\gamma$*  seems to be quite simply recessive.

The male repulsion series is shown in table 3 :—

TABLE 3  
*Males in repulsion*

	+	<i>poly</i>	<i>leaden</i>	<i>poly leaden</i>	Total
P 364 .	8	8	22	6	44
P 382 .	12	8	11	5	36
P 383 .	4	16	23	4	47
P 384 .	11	23	21	6	61
P 385 .	19	24	28	2	73
P 461 .	2	0	2	0	4
P 462 .	1	4	2	0	7
P 463 .	1	6	7	1	15
All R♂	58	89	116	24	287

Variance

89/147	= 60.544 per cent.	16.251 (per cent.) <sup>2</sup>
24/140	= 17.143 „	10.146 ( „ ) <sup>2</sup>
Manifestation	77.687 „	26.397 ( „ ) <sup>2</sup>
Recombination	22.067 per cent.	
Sampling variance	11.522 (per cent.) <sup>2</sup>	

The manifestation is here the worst of the series, which accounts partly for the larger variance. The difference in males between coupling and repulsion is 1.433 per cent. with a standard error about 4.2. There is thus full agreement between coupling and repulsion.

The repulsion series for females is given in table 4.

TABLE 4  
*Females in repulsion*

	+	<i>poly</i>	<i>leaden</i>	<i>poly leaden</i>	Total
P 363 .	8	19	12	6	45
P 539 .	17	19	22	19	77
P 586 .	14	21	20	14	69
P 639, 791 .	11	13	13	14	51
P 653 .	20	17	14	12	63
P 665 .	11	18	14	9	52
P 672 .	17	25	20	16	78
All R♀	98	132	115	90	435

Variance

132/230	= 57.391 per cent.	10.632 (per cent.) <sup>2</sup>
90/205	= 43.902 „	12.014 ( „ ) <sup>2</sup>
Manifestation	101.293 „	22.646 ( „ ) <sup>2</sup>
Recombination	43.218 per cent.	
Sampling variance	5.641 (per cent.) <sup>2</sup>	

The difference between coupling and repulsion in females is 5.274 per cent., with a standard error 3.87 per cent. Like the difference for males it is not significant, though that for females exceeds its standard error.

## 3. SUMMARY

The four tests are summarised in table 5 :—

TABLE 5  
Summary of two-point linkage tests with *py* and *ln*

Sex	Phase	Number of mice	Manifestation per cent.	Recombination fraction per cent.	Standard Error
♀♀	Coupling . . .	431	89	36.7	2.60
	Repulsion . . .	435	100	43.2	2.38
♂♂	Coupling . . .	446	90	23.5	2.47
	Repulsion . . .	287	78	22.1	3.39
		1599			

In view of the agreement between coupling and repulsion data in each sex, we may calculate weighted means for the recombination fractions, namely

$$\begin{array}{l} \text{Females} \quad . \quad . \quad 40.3 \text{ per cent } \pm 1.77 \\ \text{Males} \quad . \quad . \quad 23.0 \quad \text{,,} \quad \pm 2.00 \end{array}$$

Using Kosambi's relationship the map distance in females is estimated to be 55.8 cM, while that for males is only 24.9 cM. There would seem to be about half a chiasma difference between the two sexes in this portion of the strand alone.

It has taken some time to obtain four-point data in this chromosome with equally clear segregation. However, I hope soon to be able to set out the position more fully. The loose linkage between *fz* and *ln* has been fully confirmed, both sexes giving near to 40 per cent., with no very striking sex difference. *Leaden* and *Spotch* lie between *fuzzy* and *polydactyly*. The order given by Grüneberg (1952, (6), p. 479) namely *ln-Sp-fz-py* seems to be based on guesswork.

The four markers available in the thirteenth chromosome serve to map a greater map distance than is yet available in any other linkage group.

## 4. REFERENCES

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