

THE LINKAGE RELATIONS OF SEX FACTORS TO TWO
ADJACENT MUTANT FACTORSRaymond J. Greb and Magnhild T. Greb
Huron College

Sex determination in the parasitic wasp *Habrobracon juglandis* (Ashmead) is as yet a problem requiring further investigation.

In a report to the Academy last year a brief summary of the work accomplished was presented¹.

It is important to recall that in addition to normal diploid females and haploid males, if parents are related, anomalous diploid males occur.

The first satisfactory explanation for sex determination in this wasp was suggested by Whiting² who advanced the hypothesis that females are heterozygous for an allelic pair of sex factors, haploid males have either member of the pair of alleles while biparental males are homozygous for either.

More recently a scheme of multiple alleles has been suggested by Whiting³ with femaleness still depending on heterozygosity, diploid maleness on homozygosity at the sex loci. Therefore, inbreeding has been carried on throughout this experiment in order to limit the number of kinds of sex alleles. Presence of biparental males is taken to indicate degree of inbreeding in this respect. Eye color was their indicator. Black-eyed males from orange-eyed mothers mated by black-eyed males would be biparental males.

The locus for fused (*fu*) antennae was the first found to be linked to the sex-determining factor. Several other genes are known to be linked to fused. Glass (*gl*) eye is closely linked to fused and shows 46% cross over with stubby (*sb*) antennae.

¹Greb, Magnhild T. and Raymond J., 1939. Linkage on the Sex Chromosome of *Habrobracon*. Proc. S. Dak. Academy of Sci. 19:92-95.

²Whiting, P. W., 1933, Sex Determination in Hymenoptera. The Collecting Net, Woods Hole 8:113-121, 122.

³Whiting, P. W., 1939, Sex Determination and Reproductive Economy in *Aabrobracon* (abstract). Genetics, 24:110-111.

This report is a preliminary record of work being done to determine the location of stubby with respect to fused and the sex locus. Two stubby females were mated to the same

$$\text{fu Sb } \text{O}$$

orange fused male and the daughters (———— —) were bred

$$\text{Fu sb } \text{o}$$

as virgins. A summary of the offspring produced is given in Table I. In this count stubby and fused showed 21.3% cross-overs, the relationship gotten from a count of males of non-inbred material.

Among the first offspring of the above females orange stubby sons were selected and mated to the mother. Thereafter, among other females, some that were homozygous for both orange and stubby were produced. These were selected and mated to a closely related orange fused male. Thus, orange-eyed females heterozygous for stubby and fused—with these factors on opposite sex chromosomes—were obtained.

Twenty of these females were mated to one closely related type male. Two hundred eighty-seven daughters were, in most cases, selected as virgins and bred out to determine the composition of each. Four types were expected and obtained—those carrying sb and fu, sb alone, fu alone or neither. It was necessary to examine at least 15 sons from each in order to have data that would be statistically reliable. In most cases many more than 15 sons were counted.

In Table II the data have been summarized with respect to derivation of the test female as to mother and on the basis of the composition of the daughter. As will be seen, 58 daughters carried no recessive genes, 33 carried both fu and sb, 69 carried only sb and 127 carried fu alone. The first two classes listed involved recombinations between sb and fu—that is 31.7% showed crossing-over had taken place between sb and fu during oogenesis of the eggs which produced them.

Mothers 5, 10, 14 and 19 each produced biparental sons as well as the daughters tested. Therefore, it may be assumed there would have been only two sex alleles present in

these cases. Summarizing data from these alone we find that there were 3 females carrying no recessives, 20 carrying both fu and sb, 5 carrying only sb and 41 carrying fu. Exactly one third or 33 $\frac{1}{3}$ % of this group showed recombination had taken place between fu and sb.

We also note that there were 5 females carrying sb alone while 41 carried fu alone. Ordinarily, this ratio should have been one to one. No doubt the presence of the sex locus between these two factors accounts for the seeming discrepancy. Since only one type male was used as the father, he, apparently, carried the same sex allelomorph as was carried on the sb chromosome. The union of these two chromosomes would produce a biparental male instead of a female. The 5 females showing sb present would have come then, as a result of a cross-over between the sex locus and sb, thereby linking sb with the other sex allelomorph and giving, when fertilized, an individual heterozygous for sex—a female. The same assumption would explain the fact that there were only 3 females carrying no recessives while 20 carried both fu and sb. The recombination between sb and fu apparently is more frequent between sb and the sex locus than between fu and the sex locus. Therefore, there are more females carrying fu sb than there are females with neither recessive present. This would place the sex locus closest to fu, as previous data have shown it to be. However, more data are needed to make any calculations possible—especially data of reciprocal nature.

Work is being done to obtain reciprocal data for sb and fu and incidentally for the sex locus as well. Some of the orange-eyed females heterozygous for fu and sb were mated to one orange-eyed male. The daughters were bred as virgins to find those that were carrying fu and sb. Three such females were selected and mated to a closely related type male. Daughters from this cross were bred to determine their composition. So far, only a few results have been obtained. In this case sb alone and fu alone would be the recombination varieties. There were six females with fu, none with sb. Of the non-cross-over classes, four carried no recessives while 8 carried both. Again there are exactly 33 $\frac{1}{3}$ % recombinations

between fu and sb and again sb appears less frequently than expected if the sex locus did not interfere.

On the basis of these incomplete data the conclusion is that fu and sb show thirty-three and one third per cent recombinations when females are used for the counts. It also appears that the sex locus is between sb and fu and is nearer fu. These data also support the conclusion that sex in *Habrobracon* is determined by multiple allelomorphs and that biparental males are produced when there is homozygosity at the sex locus.

TABLE I
Sons obtained from fu + o
+ sb + females

Straights		Recombinations	
Kind	Number	Kind	Number
sb	136	type	37
o sb	112	o	37
fu	111	sb fu	20
o fu	111	o sb fu	33
Total	470	Total	127

TABLE II
Mother and composition of test female

Daughters	Mothers																				Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
+	5	6	3		1	5	10	5	4	1	1	7	5	1		4					58
sb	5	2	2	4	1	14	6	6	2	3	7	11	2	1	1			1			69
fu	5	5	4	2	15	8	10	4	4	2	2	12	8	12	2	7	1	2	2		127
fu sb		1	1	1	7	2	1	1	2	4		2	1	5	1			4			33