ON THE TOPOGRAPHY OF THE SEX-CHROMOSOME IN FOWLS[1].

By A. S. SEREBROVSKY and E. T. WASSINA.

At the Anikowo Genetical Station is carried on the study of the sex-chromosome in fowls, and the phenomena of crossing-over between sex-linked characters in fowls[2] had already been observed in 1922.

Later on, by a set of special matings and an exact record of all cases of cross-over, we endeavoured to find the relative distribution of these genes in their chromosome, and to determine the distance between them, having in view the construction of a map of the sex-chromosome of fowls.

We studied the following genes (in the order of their location) *Trage*, *Trufege*, *Tuge*, *Suke*.

(1) *Trage*-gene (Tg; its absence tg = *atrage*), causing the well-known pattern of Plymouth Rock colouring. This character is easily determined at the early age of 1–2 days in the Plymouth Rock colouring, that is to say in the presence of *Tifa* (melanism). In most other combinations *Trage* appears at an older age, *i.e.* at $1\frac{1}{2}$–2 months. And some forms of *Trage* are so difficult to establish, that to decide whether it is present or absent is only possible after having observed the progeny of the doubtful bird. Such difficulties, as we have pointed out, do not always allow the use of the whole of our material.

(2) *Trufege* (Tfg; its absence tfg = *atrufege*), the gene of yellow legs characteristic of some races of fowl: Indian game, Orloffs and others.

Unfortunately, till now, we have not always succeeded in establishing the presence of this gene with complete certainty.

First of all the colour of the legs is definitely determined at about three months old, at which age, if not earlier, a considerable number of chickens perish. Moreover the presence of certain colour characters ("buff," *Tofa*-gene) (melanism, *Tifa*-gene) and the presence of negro-pigment (*Trule*-gene), influence the leg-colouring, hindering the normal manifestation of the *Trufege* gene.

(3) *Tuge* (Tu; its absence tu = *atuge*), silver (white) colouring or marks, well-known in fowls; often described in English literature (Haldane, Davenport, Sturtevant, Punnett), called "silver" (S). Unfortunately it is very difficult to establish the presence of "silver" when

[1] From the Anikowo Genetical Station, Director Prof. N. K. Koltzoff.

[2] Serebrovsky, A. S., *The American Naturalist*, LII. Nov.–Dec. 1922.

the *Tifa*-gene (melanism) is present. In such cases it is most convenient to observe *Trage*.

(4) *Suke* (S; its absence s = *asuke*), the inhibitor of the rate of feathering in chicks, a very convenient character thanks to its appearance at an early age and the ease with which it is determined[1].

Suke chicks, when one month old, still have the wings little developed and very short tails. The *Suke* chickens on the tenth day of their birth differ most sharply from the *asuke*. Hence this gene can be recorded at this age, thus affording the possibility of making use of nearly the whole material.

As we have said, it is hardly possible to observe simultaneously the heredity of all four genes. It is easy to observe the pairs *Trage-Suke*, more difficult *Tuge-Suke*, much more difficult *Trage-Trufege*, *Trage-Tuge*, and even more so to study three simultaneously. Later on it will be necessary to create forms with such combinations of genes, as to enable us to establish at an early age the presence or absence of all the genes studied.

In the present report we have made use only of chickens, in which the presence or absence of the genes under consideration was definitely established.

To determine all the types of crossing-over, there have been carried out investigations on pairs of the genes studied.

(1) *Trage-Trufege.*

The gene of yellow legs is, evidently, located close to the gene of the cross-barring pattern *Trage*-gene. Hitherto we have not noticed a single case in which these two characters broke apart.

Out of 69 chicks in this test, only two cases are marked as crossovers with a note of interrogation. One of these *trage-atrufege*, and the other *atrage-trufege*. In both cases the colouring of the legs is doubtful. Both chickens perished, therefore we did not succeed in determining exactly this colouring (Table I).

TABLE I.

Crossing-over between Trage *and* Trufege.

	♂♂ $\frac{Tg\ Tfg}{tg\ tfg}$ × ♀♀ $\frac{tg\ tfg}{—}$		Total
Trage Trufege	29	67 non-crossovers	67 non-crossovers
atrage atrufege	38		
Trage atrufege	1	2 crossovers (?)	2 crossovers (?)
atrage Trufege	1		

[1] See Warren, *Journal of Heredity*, 1925.

All the ♂♂ investigated had the structure $\frac{\text{Tg Tfg}}{\text{tg tfg}}$, and fowls mated with them had the structure $\frac{\text{tg tfg}}{—}$ and some $\frac{\text{tg Tfg}}{—}$. Of the offspring of the latter only the ♀♀ were counted.

(2) *Trage-Tuge.*

The breaking apart of these two characters was observed rather often. Out of 77 chicks recorded we got 33 cases of crossing-over, *i.e.* 43 per cent. ± 5·60 per cent.[1]

There were investigated both couplings between Tg and Tu in structure $\frac{\text{Tg Tu}}{\text{tg tu}}$ and also repulsion in structure $\frac{\text{Tg tu}}{\text{tg Tu}}$. But repulsion between Tg and Tu, all cases of their reunion and *vice versa* of the simultaneous absence of both in their progeny are cases of crossing-over (Table II).

TABLE II.

Crossing-over between Trage *and* Tuge.

	♂♂ $\frac{\text{Tg Tu}}{\text{tg tu}}$ × ♀♀ $\frac{\text{tg tu}}{—}$		♂ $\frac{\text{Tg tu}}{\text{tg Tu}}$ × ♀♀ $\frac{\text{tg tu}}{—}$		Total
Trage Tuge	21	35 non-crossovers	4	8 crossovers	44 non-crossovers
atrage atuge	14		4		
Trage atuge	13	25 crossovers	6	9 non-crossovers	33 crossovers
atrage Tuge	12		3		43 % ± 5·60 %

The linkage between "silver" and "cross-barring" of the Plymouth Rock pattern was studied by Haldane[2]. In 1921 he described 35 per cent. of crossing-overs as having appeared in his experiments. Agar[3] recorded 35·7 per cent. crossing-overs in Wyandotte × Plymouth Rock matings and 46·4 per cent. in Rhode-Island matings.

(3) *Trage-Suke.*

Suke is located from *Trage* at about the same distance as *Tuge*. Out of 189 chickens, crossing-over occurred in 83 cases; *i.e.* 44·0 per cent. ± 3·6 per cent. of crossing-overs (Table III).

[1] The error has been calculated according to formula $m = \frac{\sqrt{p\,\%\,q\,\%}}{n}$.

[2] *Science*, Dec. 30, 1921.

[3] *Journal of Genetics*, XIV, 1924, p. 265.

TABLE III.

Crossing-over between Trage *and* Suke.

	♂♂ $\frac{\text{Tg S}}{\text{tg s}}$ × ♀♀ $\frac{\text{tg s}}{—}$		Total
Trage Suke	54	106 non-crossovers	44 % ± 3·6 %
atrage asuke	52		
Trage asuke	43	83 crossovers	,,
atrage Suke	40		

(4) *Trufege-Suke.*

The distance between *Trufege* and *Suke* is very great. Crossing-overs occurred in nearly half of the cases—49·0 per cent. ± 5·9 per cent. (Table IV).

TABLE IV.

Crossing-over between Trufege *and* Suke.

	♂♂ $\frac{\text{Tfg S}}{\text{tfg s}}$ × ♀♀ $\frac{\text{tfg s}}{—}$		Total
Trufege Suke	14	36 non-crossovers	49 % ± 5·9 %
atrufege asuke	22		
Trufege asuke	20	34 crossovers	,,
atrufege Suke	14		

(5) *Tuge-Suke.*

These two genes are in the following relation: out of 112 chickens, we recorded 21 cases of crossovers, which makes—19·0 per cent. ± 3·7 per cent. (Table V).

TABLE V.

Crossing-over between Tuge *and* Suke.

	♂♂ $\frac{\text{Tu S}}{\text{tu s}}$ × ♀ $\frac{\text{tu s}}{—}$		♂♂ $\frac{\text{Tu s}}{\text{tu S}}$ × ♀♀ $\frac{\text{tu s}}{—}$		Total
Tuge Suke	44	72 non-crossovers	3	4 crossovers	91 non-crossovers
atuge asuke	28		1		
Tuge asuke	10	17 crossovers	10	19 non-crossovers	21 crossovers
uge Suke	7		9		19 % ± 3·7 %

From these data we can arrange the four genes in the following approximate order: *Trage* with *Trufege* located close to it at one end of the chromosome, and *Tuge* with *Suke* at the opposite one.

Since the percentage of crossing-overs shown by the pair *Trage-Suke* (44·0 per cent. ± 3·6 per cent.) and by the pair *Trage-Tuge* (43·0 per cent. ± 5·6 per cent.) is nearly the same, we cannot say which of

the two, *Tuge* or *Suke*, is the next to *Trage*. We suggest the order: Tg, Tfg, Tu, S, partly from our earlier data of a few years ago (see Serebrovsky, 1922), and partly on the basis of Haldane's data, who obtained between Tg and Tu 35 per cent. of crossing-overs. We must suppose that the distance between the two loci is great, for the real percentage of crossovers is greater than the observed owing to double crossing-overs which cannot always be detected. That the double crossing-over occurs is obvious from the cases where, between two genes, a third one is located, which gives a crossing-over with both extreme genes.

In our material we had two cases of double crossing-overs (see Tables VI and VII).

TABLE VI.

The double crossing-overs.

$$\male\male\ \frac{\text{Tg Tu S}}{\text{tg tu s}} \times \female\female\ \frac{\text{tg tu s}}{\text{—}}$$

Non-crossover		Crossover 1		Crossover 2		Crossover 1, 2		
Tg Tu S	tg tu s	Tg Tu s	tg tu S	Tg tu s	tg Tu S	tg Tu s	Tg tu S	
9	3	1	1	5	6	0	1	In the 26 cases 1 double cross-over

TABLE VII.

The double crossing-overs.

$$\male\ \frac{\text{Tg tu S}}{\text{tg Tu s}} \times \female\female\ \frac{\text{tg tu s}}{\text{—}}$$

Non-crossover		Crossover 1		Crossover 2		Crossover 1, 2		
Tg tu S	tg Tu s	tg Tu S	Tg tu s	tg tu S	Tg Tu s	Tg Tu S	tg tu s	
6	3	0	0	3	4	0	1	In the 17 cases 1 double cross-over

We hope to solve the problem before us, viz. the working-out of a map of the sex-chromosome—by further accumulation of material; but for this we must, however, find a new gene, located between Tg and Tu, to help us to determine the exact distance and order between the sex-linked genes. Such a gene may turn out to be *Trama*, described under symbol S (= Spangling) by Lefevre and Rucker[1], and now being studied at the Anikowo Genetical Station.

[1] *Genetics*, VIII, 1923 . 367.

The study of the sex-chromosome of fowls, apart from its theoretical importance, is of great economic interest, for Pearl and Surface have described an intensifier of egg-laying, located in the sex-chromosome.

Since work of this nature was started at the Anikowo Genetical Station, this question has formed part of our programme of investigation. In the progeny of a Pavloff cock, in which segregation occurs in relation to gene *Tuge*, were compared the egg-laying of *Tuge* and *atuge* sisters, but the recorded data are still difficult to interpret[1].

At the present time at the Anikowo Genetical Station are carried on further experiments on investigation of the rôle of different areas of sex-chromosome on transmission through inheritance of elements of egg-laying. A. N. Promptov studied 23 cocks of our flock to test the presence of lethal genes in the sex-chromosome. In spite of considerable variations in the sex-ratio in the offspring of some cocks, no lethal genes were found.

[1] See A. S. and R. I. Serebrovsky in "Genetics of Domestic Fowls," *Transact. of the Anikowo Genetical Station* (in the press).