

AN EXPERIMENTAL STUDY ON XENIA
IN THE DOMESTIC FOWL.

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(With Three Text-figures.)

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INTRODUCTION.

WE call animal xenia the change of colour of birds' eggs, which is said to take place when mating females with males of a breed characterised by eggs of a different tint. We are therefore dealing here with direct changes of egg-colour of the females examined, i.e. of the P generation, and not with the colour of eggs from F_1 hens. Such changes have been mentioned by v. Nathusius (11, 12), Kutter (9) and Seidlitz (15), who noticed that hens with white eggs began to lay more or less yellowish eggs a few days after having been mated with a Cochin cock. An analogous phenomenon, although in an opposite direction, was later described by Holdefleiss (5), who observed that the eggs of Plymouth Rocks (i.e. of a breed having brown eggs) become lighter in tint when the hens are mated with a cock of Italian breed characterised by white eggs. The best known are undoubtedly the researches undertaken in this direction by A. v. Tschermak. In his first papers (16, 17) this physiologist emphasises the changes which he states that he noticed in the eggs of *Fringilla canaria* mated with *F. spinus*, *F. cannabina*, *F. serinus*, *F. carduelis* and *Pyrrhula rubicilla*; in the last (18) he describes the phenomenon of xenia in several crosses of fowls. An analogous phenomenon in fowls has also been noticed, at least in one case, by

Walther(20). Goldschmidt(3) observed that a duck of Cayuga breed with dark eggs crossed with a drake of Pekin breed (having white eggs) laid white eggs. This author does not however attribute any essential importance to this case, as the duck examined was genetically of a mixed character, and he recommends a continual control of the material. I also observed occasionally during my experiments on the inheritance of egg-colour in fowls that the Polish Greenlegs mated with a cock of the same breed laid cream eggs characteristic of this variety, whereas the next year, after having been crossed with a Leghorn cock, they produced distinctly lighter eggs. I supposed that this phenomenon may possibly be brought about by xenia, but I emphasised that, owing to lack of exact knowledge of the natural, periodical variability of egg-colour in fowls, all that has been described in this direction "only *points* very distinctly to the phenomenon of xenia of eggs *without proving* it methodically" (Kopeć(6), p. 338).

In respect to natural colour variability of birds' eggs it ought to be emphasised that v. Tschermak (18), p. 51) appears to take it into consideration. As an instance of such changes the author describes a lightening of the eggs laid by hybrids of Minorca hen mated with a Cochin cock, where "die Eifarbe blasse binnen $1\frac{1}{2}$ Monaten in der Beobachtungszeit vom 5. ii. bis 25. iv. 1914 von dem ursprünglichen hellgelbbraun, allmählich fortschreitend, ab bis zu einem weiterhin recht stabil bleibenden schwach bräunlichem Weiss." v. Tschermak believes, it is true, that a "hyperkritischer Beurteiler" may reduce the phenomena he relates as xenia to such "spontan erfolgende 'Altersveränderung' der Pigmentierung," and in spite of the above observations he categorically opposes such an interpretation. It would be, according to his opinion, astonishing if "eine spontane Altersveränderung bei den weisseigen Rassen in einer Zunahme der Pigmentierung, bei den brauneigen Rassen gerade umgekehrt in einer Abnahme der Pigmentierung gelegen wäre." In respect of this argument of v. Tschermak the following remark should be made. A xenial darkening of the eggs was obtained by this author in three crosses, viz. ♀ White Italian × ♂ Langshan, ♀ Partridge Italian × ♂ Plymouth Rock and ♀ White Minorca × ♂ Cochin, and an analogous lightening in the three reciprocal crosses, but only *one* hen in each experiment was used¹. Each hen was kept alter-

¹ v. Tschermak's paper is considered by him as a report of the first series of experiments, to be succeeded by further researches on a reduced number of breeds and an increased number of specimens. So far as it is known to me the results of these investigations have not hitherto been published.

nately with a cock of the same breed (periods of pure culture) or with a cock of a different breed (periods of hybridisation). As the material of v. Tschermak consisted of only six experimental specimens, no control material being taken into consideration, the author can compare the eggs from the period of hybridisation with those of the same hen from the preceding period of pure culture, but he is unable to say how eggs from fowls which have never in their life been mated with a cock of a foreign breed with differently tinted eggs would behave during the same life or year period. On this account the increase of the range of variability of egg-colour during the periods of hybridisation is not a valid argument. Consequently v. Tschermak's opinion, that it would be strange if directly opposite changes in white and brown eggs were observed during one and the same period of hybridisation, is seemingly true, but requires an impartial confirmation on adequate control material of eggs from the breeds concerned. As v. Tschermak had no such control birds throughout the whole time of his experiments to give him standard eggs for comparison during every period of the life of the experimental hens, the problem of a specific "telegonical" character of certain other changes described by this author remains, according to my opinion, not satisfactorily solved (cf. also the general discussion below).

Moreover I believe that the experiments hitherto made on xenia in fowls can hardly be considered as conclusive on account of further methodical inaccuracies. First of all, as to the number of eggs disposed of by separate investigators, we are either not informed at all (v. Tschermak(18)), or we see that the material was scanty, as in the research of Holdefleiss(5) where the number of eggs from the two hens examined was only 92. Walther's(20) observations are based, it is true, on 630 eggs from 13 hens, but he introduces as many as six breeds, therefore considerably reducing the number of hens and eggs in each cross.

The method of estimation of the egg-colours by mere inspection, adopted by separate authors, in spite of a considerable range of variability of egg-tint emphasised by them in certain cases, does not seem to me to allow critical analysis of the observations. The authors either discriminate only a few colours, e.g. "weiss," "braun" and "mittel," or content themselves with a cursory report of a certain darkening or lightening of the hue. Especially in the experiments of Holdefleiss it ought to be remarked that from the 92 eggs examined by him only three chickens hatched at all, while in numerous other eggs no trace of development was observable. It is therefore doubtful whether the hens

he examined were permanently fecundated by a cock of a different breed, i.e. whether foreign sperm was really present in their sexual ducts. The deductions which may be drawn by a sceptical reader from material not scrutinised in this respect are well understood by Walther, who therefore first of all bases his research on the eggs from which chickens did hatch. v. Tschermak on the contrary does not seem to pay attention to this methodically important circumstance. And here it should be remarked that, as a rule, the above-mentioned authors have not recorded the colour of the eggs laid by the F_1 hens, although only by the examination of the egg-colour of this generation can we check the results obtained on xenia. I believe that, without ascertaining the intermediate character of the egg-colour in F_1 hens, the positive results on xenia may easily be reduced to secondary tint variations, having no connection with the phenomenon under examination; and *vice versa* no inferences ought to be drawn from negative results, if the colour of the eggs laid by F_1 hens exhibits complete dominance of either parental egg-hue, because it is obvious that in the latter case the experiments were made with unsuitable material¹.

As I have never bred canaries, I can discuss the papers of v. Tschermak (16, 17) on xenia in these birds only from a theoretical point of view. Normal, fecundated eggs of this form had "unscharfe, hellbraune, polygonale bis rundliche Flecken" on a bluish-green ground. On the other hand, the eggs of greenfinches, goldfinches and other wild forms which were used in crosses, showed, apart from analogous light brown spots, "eine ganz charakteristische schwarzbraune Zeichnung," i.e. dots, spots, commas and lines on a yellowish-white or somewhat greenish ground. On the eggs of canary-birds mated with the above-mentioned wild species the appearance of this black-brown marking (absent in normal canaries' eggs) was ascertained by v. Tschermak and considered as an unquestionable proof of appearance of xenia. v. Tschermak remarks, it is true, that the black photographs of his paper are not sufficient to produce conviction as to the truth of his observations, but I do not suppose that anybody would call in question these assertions. My criticisms do not refer to the facts, but to the decisive conclusions of v. Tschermak as to the indubitable character of xenia of this phenomenon. It is very characteristic that the tint of the ground,

¹ I am not able to report the methods of the earlier observations by v. Nathusius, Kutter and Seidlitz, as they were inaccessible to me. I do not believe, however, that v. Tschermak, who seems to know the original papers, would consciously degrade his methods as compared with the proceeding of his precursors.

supposedly the most liable to changes, remains unaltered in all crosses. On the other hand, it is striking that, as it is noticed by v. Tschermak in pure-bred canary-birds also, "ganz selten kommen völlig vereinzelt schwarzbraune Pünktchen auf der Stumpfpolhälfte vor" (v. Tschermak (17), p. 373). I do not know whether and to what degree variability of egg-colour throughout their whole life has been examined in canaries. From v. Tschermak's paper (17), p. 387 we learn however that, according to Paessler (13) and Wickmann (21), "die meisten Raubvögel, welche sonst weisse Eier legen, mitunter gefleckte produzieren und umgekehrt." (Cf. here also the great variability of egg-colour noticed in *Corvus corax* L. by Krause (10) and in *C. frugilegus* L. by Tur (19).) I want to remark, moreover, that the "xenial-eggs" of canary-birds were compared by v. Tschermak with eggs from greenfinches, goldfinches and other wild forms, derived, it is true, from known sources, but laid by apparently totally foreign females, not genetically connected with the males used in the crosses.

Consequently I do not consider the appearance of xenia either in fowls or in canary-birds as proved. From the fundamental research of Punnett and Bailey (14) on heredity of egg-colour in poultry it is clear that these authors did not succeed in observing such phenomena, and P. Hertwig (4) has also called into question the phenomenon of xenia in fowls.

MATERIAL AND METHODS.

My research on xenia in fowls was partly published elsewhere¹. The present paper contains more detailed materials and observations. The experiments were performed on two breeds: on two years old White Leghorns which lay as a rule chalk white eggs, and on Buff Orpingtons of the same age, with more or less brown eggs. A darkening of the eggs from Leghorn fowls kept with an Orpington cock, or a lightening of the eggs from Orpingtons bred with a Leghorn cock would prove the existence of xenia. Thus the investigations were restricted to a single reciprocal cross, and the basis of this one experiment could be quantitatively enlarged. In order to obtain a suitable standard material of eggs for comparison, some fowls of the same age, both Leghorns and Orpingtons, were bred throughout the whole time of the investigations separately without a cock. The eggs from these hens served as a permanent control of the natural periodical variability of egg-colour

¹ Cf. *Mém. de l'Institut Nat. Polonais d'Économie rurale à Pulawy*, VI, 1925, presented November 2nd, 1924.

in fowls. My object was to examine whether the phenomena of xenia noticed by the foregoing authors might not be reduced to purely physiological variability.

I attempted also to test the phenomenon of xenia by further direct experiments. For this purpose Leghorn hens were injected with testicles from Orpington cocks and Orpington hens with the sexual glands from Leghorn males. The injections were made six times, i.e. on May 12th, 17th and 26th and on June 4th, 12th and 19th, 1923. The cocks were quickly killed and the aseptically removed testicles were ground in a sterilised mortar with the addition of from 20 to 30 c.c. of physiological salt solution. The thick fluid obtained was introduced directly into the abdominal cavity of the hen by means of a Prawatz syringe with a blunt needle. Each Leghorn fowl was every time injected with 0.5, each Orpington with 0.4 of a foreign testicle. The fowls were carried over again to their hen-houses, no symptoms whatsoever of disease being observed. If the investigations which refer the shell pigments to the blood or to its decomposition products are right¹, it might have been supposed that in my experiments, where during five weeks as much as three complete Orpington testicles had been introduced directly into the abdominal cavity of each Leghorn fowl, and 2.4 Leghorn testicles into each Orpington hen, a much greater influence on egg-colour ought to be observable than during normal crosses with a properly chosen cock.

All the hens examined from either race were sisters derived from the same hatching in 1921. They began to lay in the spring of 1922. All fowls were from thorough-bred material kept by the author for several years. The specimens belonging to either breed and to each series of experiments were kept in separate hen-houses provided with running yards of the same dimensions, enclosed with wire nets. The food was the same for all hens during the whole time of observation. The eggs were checked in trap-nests. The egg production was in general scanty, undoubtedly partly owing to the small running yards. During the period from November 1st till January 1st in 1923 only the Orpington hens laid some eggs.

For the determination of egg-colour I used a graduated set of tints arranged *ad hoc* by means of thoroughly blown shells of all the 13 tints which have been discriminated, from the lightest hue of the Leghorn eggs to the darkest colour observed in Orpingtons. All the eggs which have been laid were examined, not one being rejected. Owing to changes of egg-colour which occur with time the tint of the egg was determined

¹ For references see the paper of Giersberg (2).

on the day on which the egg was laid. The shells which constituted the set of colour standards were kept in a dry and dark room. When the tint of any shell of this set underwent any change it was replaced by a fresh one.

The observations lasted from April 1st, 1923, till July 1st, 1925, and they were divided as a rule into periods of two months. The average egg-colour in degrees of the standard scale was determined for each period separately. As the changes of egg-colour, which might have been noticed during the observations, were identical in separate fowls of one material, the general average intensities were also denoted for all eggs of one period from all hens of one material together. In 1923 as well as in 1924 many eggs from hens kept with a cock of different breed were incubated during different seasons, and the eggs proved fertile. The plumage colour of the F_1 generation was more or less distinctly that of hybrids. Several hens, one year old, of this generation were examined in regard to the colour of their eggs. The hens Nos. 1, 20 and 33 died before the observations were finished. The total material consisted of 3577 eggs from 38 hens, viz. 487 eggs derived from five Leghorn hens bred with an Orpington cock, 448 from four Leghorns injected with Orpington testicles and 240 from two control Leghorns, 308 eggs from two Orpington hens bred with a Leghorn cock, 591 from five Orpingtons injected with Leghorn testicles and 428 from two control Orpingtons, finally 218 eggs from eight F_1 hens *ex* ♀ Orpington × ♂ Leghorn and 857 from ten F_1 hens *ex* ♀ Leghorn × ♂ Orpington.

DESCRIPTION OF THE OBSERVATIONS.

The account of the present observations is based on the curves in Figs. 1 and 2, representing the general averages of colour intensity of eggs from all hens of each material. The results obtained in this way should be compared by the reader with the individual averages for separate hens, plotted in Tables I and II. From these it will become evident that the general results cannot be reduced or cancelled by certain fluctuations of the individual averages. The first average intensities of colour are computed for eggs laid by the hens of separate material from April 1st till May 12th, 1923, i.e. till the day on which testicles from a cock of a different breed were injected into fowls of one series of experiments. The following average data refer to the period from May 12th till July 1st, 1923, the remaining being always calculated for full two month periods. In my materials *xenia* would consist in the darkening of the white eggs from Leghorns kept with an Orpington cock

and in the lightening of the brown eggs from Orpingtons mated with a Leghorn male.

A. Observations on Leghorns.

From the curves in Fig. 1 it is evident that in Leghorn fowls permanently bred with an Orpington cock the variations of egg-colour, throughout the period of the observations (cf. Fig. 1, interrupted line) in general exactly correspond not only with those found in the egg-colour of similar hens injected with testicles of a different breed (dotted line), but also to those of the control specimens kept without any cock at all (continuous line). In all three cases the average colour intensities decreased from spring to autumn 1923 and (after a certain interval in the laying period) underwent a very remarkable increase in winter, i.e. from January 1st till March 1st, 1924. Shortly after this increase the colour intensity underwent a marked decrease in all three groups simultaneously, i.e. from March 1st till May 1st, 1924. After this period no large changes in the egg-colour were noticed until the winter of 1924-25. The increase of colour intensity during the winter and the decrease during the spring of 1925 were again very distinct in all three groups.

Certain small inevitable differences in the course of these tint variations between the three groups of Leghorn fowls do not offer evidence of any regularity in the different groups, whether experimental or control. The average colour intensity was, it is true, lower in the control eggs than in the experimental material during the period between July 1st and September 1st, 1923; but from September 1st till November 1st, 1923, and during the periods from January 1st till March 1st and from May 1st till July 1st, 1924, as well as from January 1st till March 1st, 1925, the eggs from control hens averaged a rather darker tint. In the remaining periods the colour of the control eggs was intermediate.

On surveying the seriations of the egg-colour intensity I remarked that the darkest egg, denoted by the 13th, i.e. the highest degree of the scale, was laid during the period between January 1st and March 1st, 1924, by one of the fowls which had been injected the preceding year with Orpington testicles. In the material of Leghorn fowls mated with an Orpington cock as well as in that of the control there was not one instance of such extreme winter darkening of egg-colour. This might, of course, suggest the supposition that we have to do here with the phenomenon of xenia. But, apart from this exceptionally dark egg, the same injected fowls contained two eggs of the first and second degree of

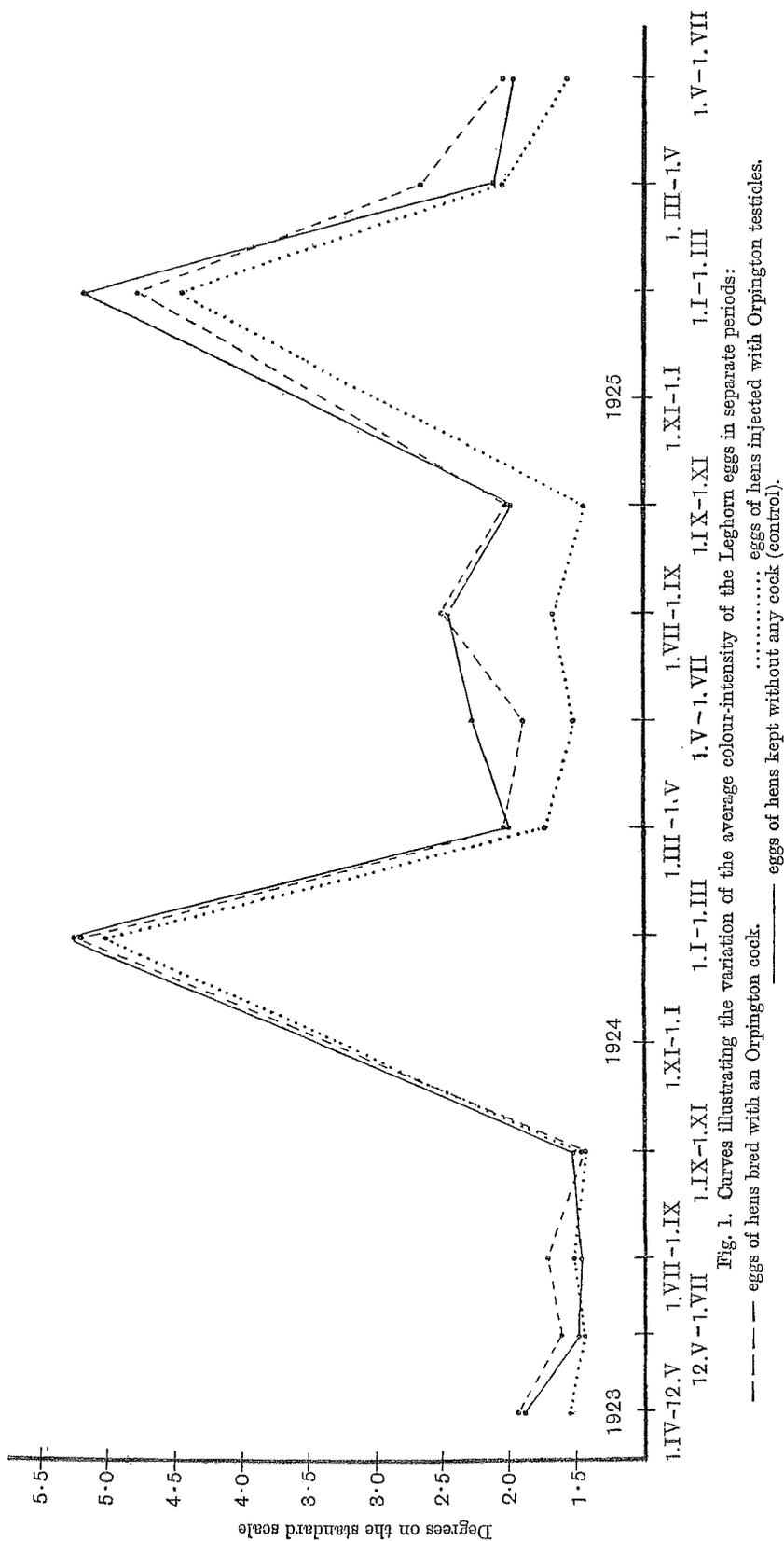


Fig. 1. Curves illustrating the variation of the average colour-intensity of the Leghorn eggs in separate periods:

— eggs of hens bred with an Orpington cock.

--- eggs of hens kept without any cock (control).

..... eggs of hens injected with Orpington testicles.

the set of colour, i.e. four eggs which were on the contrary lighter than any egg of both the remaining materials during the mentioned period. Moreover an analogous extreme colour deviation was observed in the control material and it amounted here to the eleventh degree of the scale, being therefore only two degrees lower than the darkest egg of the injected hens. (In the winter period of 1925 the darkest egg was, just the reverse, found in the control material.) This proves that no special character of xenia ought to be attributed to the exceptionally dark coloured egg of the injected hens, notwithstanding its most extreme

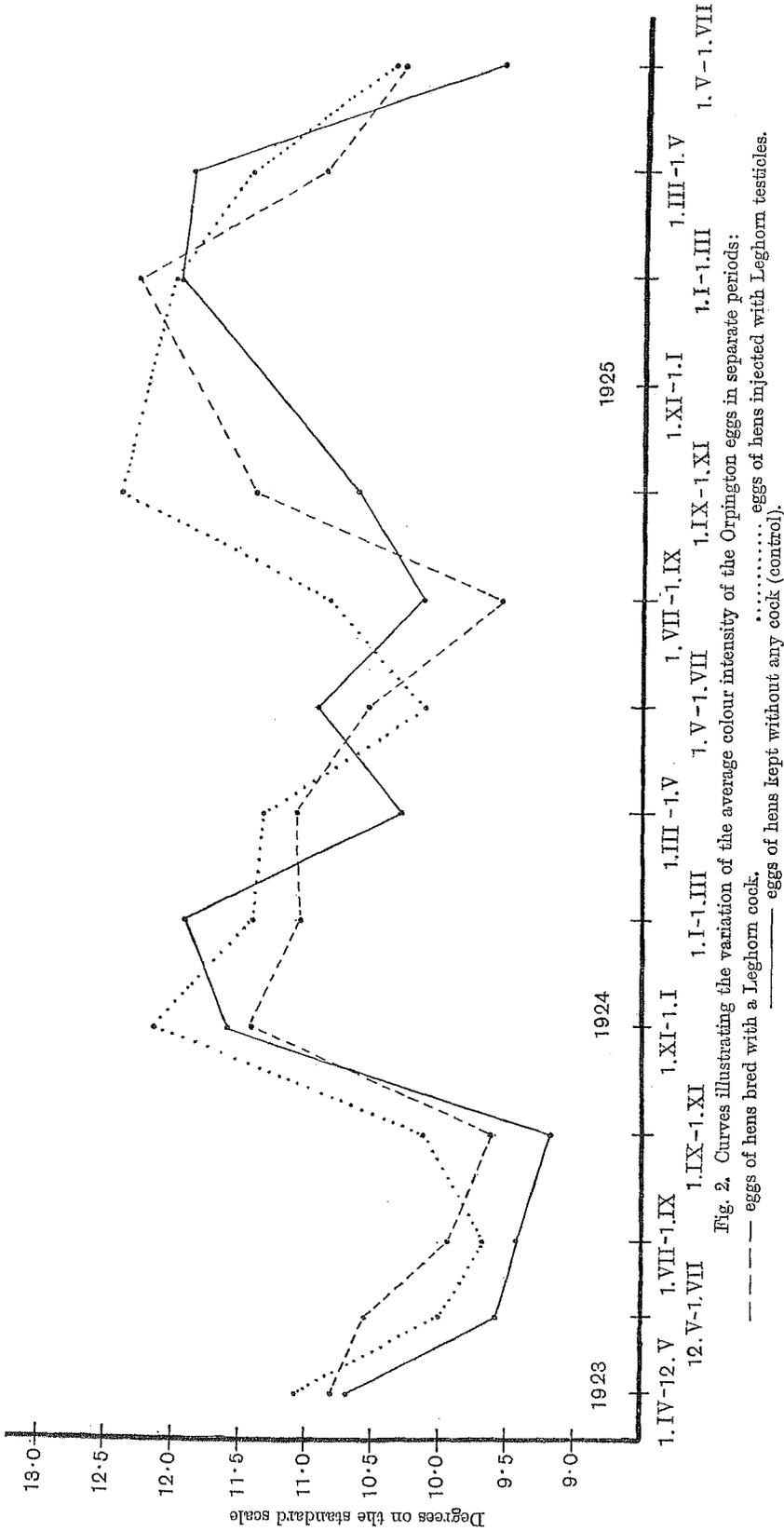
TABLE I.

Individual averages of colour intensity of the Leghorn eggs calculated for each hen separately, in degrees on the used scale.

Period	Hens bred with an Orpington cock. Number referring to each hen					Hens injected with Orpington testicles. Number referring to each hen				Hens kept with out any cock (control). No. referring to each hen	
	44	45	46	47	48	31	32	33	41	42	43
1. iv. -12. v. 1923	1.67	1.75	2.20	2.00	2.01	1.78	1.57	1.39	1.50	1.94	1.71
12. v. - 1. vii.	1.27	1.58	2.00	1.75	1.83	1.56	1.61	1.29	1.38	1.92	1.18
1. vii.- 1. ix.	2.00	1.85	1.65	1.31	1.86	1.57	1.35	1.64	1.56	1.38	1.50
1. ix. - 1. xi.	1.56	1.25	1.67	1.17	1.40	1.38	1.42	1.62	1.45	1.57	1.50
1. xi. - 1. i. 1924	—	—	—	—	—	—	—	—	—	—	—
1. i. - 1. iii.	4.33	—	6.50	—	—	4.50	—	8.25	3.00	5.57	4.80
1. iii. - 1. v.	2.58	1.92	1.69	2.63	2.00	1.73	2.00	1.00	3.00	2.29	1.94
1. v. - 1. vii.	2.13	2.27	1.50	1.00	1.75	1.27	1.72	—	1.43	2.28	2.36
1. vii.- 1. ix.	3.33	2.36	2.08	—	3.17	1.40	2.00	—	1.60	2.30	2.69
1. ix. - 1. xi.	1.50	1.50	3.83	1.00	1.50	1.00	1.75	—	—	2.00	2.00
1. xi. - 1. i. 1925	—	—	—	—	—	—	—	—	—	—	—
1. i. - 1. iii.	5.40	5.50	5.25	3.20	4.25	5.00	4.75	—	3.60	5.60	4.75
1. iii. - 1. v.	2.20	2.91	2.77	2.25	2.80	1.33	2.00	—	2.60	2.67	1.80
1. v. - 1. vii.	2.50	2.44	1.80	1.67	1.50	1.50	1.33	—	2.00	2.00	2.00

colour darkening¹. Stress must be laid on the fact that during the period from January 1st till March 1st, 1924, the average colour intensity of the eggs from injected hens was just the smallest, since it only amounted here to the fifth degree, being in Leghorn fowls bred with an Orpington cock 5.20, and in the control hens 5.25. On reviewing the individual averages (Table I) we see, it is true, that the highest winter intensity of

¹ As to the especially dark eggs of Leghorns it must be remarked that their deep tint was caused by the fact that they were laid after an interval of from two to three months. All my Leghorns (which have been imported from England) did not lay eggs at all during long periods in winter. On the other hand, the eggs of Leghorns, although being chalk white, as a rule, show from time to time a certain yellowish nuance (cf. table of colour in Benjamin's paper (1)). I believe the pigment became accumulated in such quantities during the long period when the hens laid no eggs that it caused the especially dark pigmentation of the eggs which were first laid after the long winter interval.



egg-colour (8.25) appeared in a hen with injected Orpington testicles (hen No. 33), but at the same time, from January 1st to March 1st, 1924, another hen of the same experimental material laid, on the contrary, the lightest eggs (hen No. 41 with an average egg-colour intensity = 3.00).

From the above it results that no such regular changes of egg-colour appeared in any of the experimental material, as might be attributed to the phenomenon of xenia.

B. *Observations on Orpingtons.*

Analogous observations were made on the Orpington eggs, viz. in all the three groups the egg-colour becomes lighter during the period between April 1st till November 1st, 1923, whereas in winter from November 1st, 1923, till January 1st, 1924, a considerable darkening was ascertained in hens mated with a Leghorn sire (cf. Fig. 2, interrupted line), as well as in hens injected with Leghorn testicles (dotted line) and in the control birds (continuous line). In the succeeding period of 1924 the pigmentation became gradually lighter (irrespective of certain fluctuations), whereas during the next winter, 1924-5, it became darker again. Here also the course of all these changes does not indicate the appearance of xenia, i.e. of an especial decrease of colour intensity in the experimental eggs, notwithstanding certain differences between the separate groups. And, although the tint of the control eggs was the darkest from January 1st to March 1st, from May

TABLE II.

Individual averages of colour intensity of the Orpington eggs calculated for each hen separately, in degrees on the used scale.

Period	Hens bred with a Leghorn cock. Number referring to each hen		Hens injected with Leghorn testicles. Number referring to each hen					Hens kept without any cock (control). Number referring to each hen	
	16	18	1	6	14	15	20	3	17
1. iv. -12. v. 1923	10.58	11.09	10.94	11.30	11.50	11.20	10.67	10.73	10.67
12. v. - 1. vii.	10.75	10.45	9.59	10.56	9.46	10.71	9.67	9.63	9.65
1. vii.- 1. ix.	10.42	9.50	8.76	10.12	9.50	10.73	10.00	9.50	9.32
4. ix. - 1. xi.	11.08	8.53	8.48	12.39	9.62	11.10	9.50	8.67	9.50
1. xi. - 1. i. 1924	—	11.40	13.00	11.88	—	12.73	11.92	11.67	11.50
1. i. - 1. iii.	12.00	10.63	10.00	11.80	11.00	11.83	10.50	12.80	11.29
1. iii. - 1. v.	12.23	9.31	9.88	12.10	10.50	11.65	8.50	10.12	10.40
1. v. - 1. vii.	10.88	9.91	9.07	11.64	9.00	11.50	—	10.83	10.95
1. vii.- 1. ix.	10.25	8.38	9.63	10.00	9.00	11.81	10.00	10.00	10.31
1. ix. - 1. xi.	11.33	11.50	—	12.57	—	12.17	—	12.25	9.94
1. xi. - 1. i. 1925	—	—	—	—	—	—	—	—	—
1. i. - 1. iii.	12.43	12.00	—	12.75	11.00	12.57	—	12.67	11.00
1. iii. - 1. v.	11.47	10.23	—	12.20	9.78	12.57	—	12.60	10.50
1. v. - 1. vii.	10.80	9.75	—	10.33	9.67	11.60	—	11.00	9.50

1st to July 1st, 1924, as well as from March 1st till May 1st, 1925, these eggs became the lightest tinted during other periods (e.g. from March 1st till May 1st, 1924, or from September 1st, 1924, till March 1st, 1925). Cf. here also the individual averages for each of the examined fowls separately, plotted in Table II.

C. *Observations on F_1 hens.*

The eggs of the F_1 generation of the cross between Leghorns and Orpingtons have a typical intermediate tint between the white and the brown colour of both parental breeds. In Leghorns run with an Orpington cock since 1923 the mode of the curve of variation for egg-colour

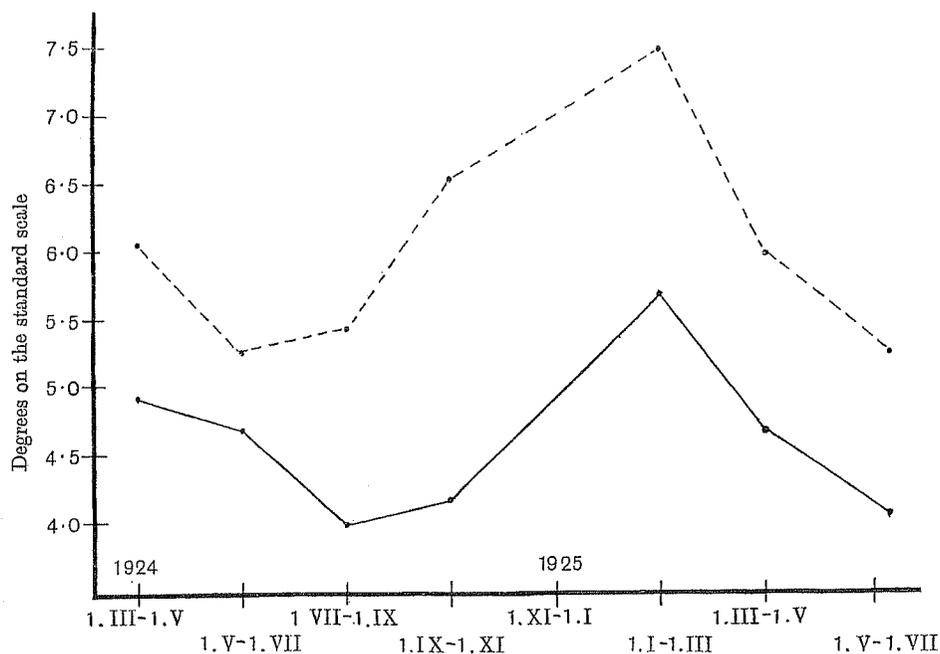


Fig. 3. Curves illustrating the variation of the average colour intensity of the F_1 hens in separate periods:

— eggs of hens from ♀ Orpington × ♂ Leghorn.
 - - - eggs of hens from ♀ Leghorn × ♂ Orpington.

falls on the first or second degree of our standard scale, according to the period of the year in which the observations were made. Similarly in Orpingtons run with a Leghorn cock the position of the mode varies between the 10th and 13th degrees, according to the season. In F_1 birds *ex* ♀ Orpington × ♂ Leghorn the mode varies between third and sixth

degrees and in F_1 birds *ex* ♀ Leghorn \times ♂ Orpington between the fourth and seventh degrees. And while the general average colour intensity ranged in Leghorns between the 1.43 and the 5.20 degree on our scale, in Orpingtons between 9.63 and 12.33, the intensity in the first cross ranged from 3.97 to 5.69, in the second from 5.25 to 7.48, being therefore in both cases more or less intermediate. The individual fluctuations of the average tints of F_1 eggs from separate F_1 fowls were not large enough to cancel the intermediate character of the colour of eggs of this generation. The F_1 hens were one year old at the beginning of the observations, while those of both P breeds were already two years. As, according to Benjamin⁽¹⁾, the tint of eggs in fowls undergoes certain changes with age of the birds, I want to remark that in my material these changes are not distinct enough to have any influence on our general conclusion as to the average tint of eggs from hybrids. More detailed data are given in another paper on the inheritance of egg-colour in these crosses (Kopeć^(8a)).

Stress must be laid on the fact that during the winter period (from September 1st, 1924, till March 1st, 1925) a considerable increase of average colour intensity appeared also in the eggs from F_1 hens of both crosses, which was succeeded by a marked decrease in spring (cf. Fig. 3).

GENERAL DISCUSSION AND SUMMARY.

From the above it follows that the changes of egg-colour observed among Leghorn fowls kept with an Orpington cock, or among Leghorns injected with Orpington testicles, are definitely parallel to those which take place in eggs from control hens, to which foreign sperm had not been introduced either by copulation or by injections. The same is true of the egg-colour variability in the experimental and in the control material of Orpingtons. In both breeds it is quite evident that a decrease of egg-tint occurs in all hens without exception from spring till autumn, and a succeeding increase during winter. We have seen that analogous changes are observable also among the eggs of the F_1 generation of the two crosses between Leghorns and Orpingtons. Such behaviour of the eggs from hybrids confirms the opinion that the changes noticed in the experimental material are always brought about by natural, physiological periodical variation. This result is in agreement with the extensive investigations of Benjamin⁽¹⁾, who ascertained on numerous White Leghorns that in these fowls there is yearly "a tendency for the eggs produced to gradually become whiter during the first five or six months of production, and then to become more tinted again toward the end of the production season." Indeed,

my curves on the whole conform with those of Benjamin's White Leghorns (Benjamin⁽¹⁾, Figs. from 36 to 39). Punnett and Bailey⁽¹⁴⁾ also noticed that eggs laid in March are sometimes several degrees darker in colour than those laid in July.

If we consider that no other or more distinct changes, than those characterising normal variability, appeared in hens mated with a cock of a different breed, nor in those injected with testicles from a foreign race, we must deny any possible influence to xenia. It could, of course, be supposed that the poultry material chosen for my research was not adapted to induce xenia. It was not *a priori* excluded that the brown egg-colour of my Orpingtons, as well as the specific white pigment of eggs from Leghorns, which according to Wickmann's⁽²¹⁾ research is characteristic of white eggs, could, owing to purely chemical causes, be unable to undergo such mutual changes. The typically intermediate egg-tint in hybrids proves, however, that the colours of these eggs may exert an influence on each other by means of genetical mingling.

Consequently I am inclined to look upon the previously described xenia in fowls as based upon a misunderstanding due to insufficient consideration of natural variability of egg-colour intensity. I believe that v. Tschermak's⁽¹⁸⁾ well-known work may also be explained by this variation. It may be objected by the adherents of xenia that, while in my observations on natural variability the brown as well as the white egg-colour undergo the same changes (i.e. simultaneous increase or simultaneous decrease of intensity) during the same seasons, the contrary is true of the experiments of v. Tschermak: during one and the same period of observations white eggs from certain breeds become darker and the brown eggs from other breeds lighter. I would remark, however, that v. Tschermak's results are unfortunately recorded in too general a manner to allow of an exact analysis. It must be emphasised that such results as those obtained by v. Tschermak may have been fortuitous. First of all it is remarked by this author that in two of the six cases he describes a change was hardly visible, i.e. distinct changes took place only in four hens belonging to various breeds. It is evident from my Tables I and II that the individual fluctuations of egg-colour intensity are often very distinct, and that in one and the same groups of fowls the increase of the colour intensity during autumn and winter and the decrease during spring and summer begin earlier in one specimen and later in another, lasting differently in separate fowls. It is also possible that in v. Tschermak's case the opposite changes of egg-tint during the long period of hybridisation, lasting nearly a year, were

influenced not only by the ages of the individual hens, in respect to which no data are given, but also by the very different frequency of egg laying in different birds. This is the more probable because, as my own inquiries show, egg-colour intensity seems in some degree to depend on the more or less frequent function of the sexual tracts, i.e. to their greater or smaller widening during separate laying periods (Kopeć(8)). It is probable that a division of v. Tschermak's series of observations into shorter periods would to a considerable degree efface the opposite changes he describes. v. Tschermak emphasises moreover a distinct increase of colour variability, observed as a rule during bastardisation, which, according to his view, is very characteristic of the period of xenia. From my observations on natural, periodical egg-colour changes in fowls the increased variability during hybridisation periods, lasting almost a whole year, as compared with the much shorter periods of pure culture in the experiments of v. Tschermak, is quite clear, and there is no need to attribute it to crosses with a foreign cock.

Nor do I now consider that importance can be attached to my earlier observations on Polish Greenlegs (Kopeć(6)). In these experiments Greenleg hens mated in 1919 with a cock of the same breed laid cream eggs of an average colour intensity 7.1 during April and May, whereas mated the next year with a Leghorn they produced during the same months much lighter eggs, i.e. of an average colour intensity 5.4 degrees on our scale. Considering the normal periodical variation of egg-colour in fowls, this difference might however have been exclusively fortuitous: owing to certain differences of egg-colour in the same months during separate years, the natural spring decrease of colour may have appeared earlier in 1920 than in the preceding year. This happened indeed during my present investigations: it may be observed in Figs. 1 and 2 that the average changes of egg-colour in separate months of the year 1924 were somewhat different than during the similar periods of the years 1923 or 1925.

In conclusion I want to lay stress on the fact that the phenomenon of xenia could not *a priori* be considered merely as a prejudice of numerous breeders but deserved careful examination. Little is yet known as to the nature of the pigments of the egg-shell, and students of genetics cannot therefore summarily reject the supposition that the resorbed sperm of a foreign breed may introduce into the female organism certain special substances. It was conceivable that the sexual duct might be "impregnated" by these substances, so that the eggs laid by the hens under examination would exhibit changes characteristic of xenia (cf. analogous considerations on telegony, Kopeć(7) and Löhner(10a)).

From the above inquiry we may draw the following conclusions:

1. The "white" eggs of the Leghorns, as well as the brown Orpington eggs, exhibit a distinct periodical variation of colour intensity. The intensity of pigmentation decreases from spring till autumn and increases during winter.

2. No other changes of egg-tint have been observed in the hens of both the breeds examined on interchanging the cocks.

3. Even repeated injections of Orpington testicles into Leghorn hens or Leghorn testicles into Orpington fowls did not cause any changes of egg-shell tint in the direction of the egg-colour of the breed of the cock used for the injection.

4. The egg-shell colour of the F_1 fowls of the cross ♀ Leghorn \times ♂ Orpington or *vice versa* is intermediate between the parental breeds.

5. The earlier observations on xenia in birds cannot be considered as decisive on account of various methodical inaccuracies. The appearance of xenia remarked by various authors may be fully explained by the misunderstanding caused by insufficient knowledge of the normal periodical variation in egg-colour.

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