

SILVERING (si) AND DIMINUTION (dm) OF COAT COLOR OF THE
GUINEA PIG, AND MALE STERILITY OF THE WHITE OR
NEAR-WHITE COMBINATION OF THESE^{1, 2}

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THE present paper is based on studies of the residual variability in the intensity of the colors due to the recognized genes in a largely self contained colony of guinea pigs. It is convenient to recognize seven major series of colors, each varying from a pale color, barely distinguishable from white to full intensity, primarily in accordance with the combination of *c* alleles, but secondarily because of the genes to be considered in this paper.

Empirical grades have been based on standard hair samples, chosen so that each grade is barely distinguishable from the preceding. One series of such standards has been used for the eumelanic colors (black, sepia, brown) and another for the phaeomelanic ones (yellow). Table 1 is taken from a previous paper to show the average grades and the standard deviations for the seven main series of colors (columns) and the various combinations of *c* alleles (WRIGHT 1949).

The standard deviations in Table 1 give an indication of the amount of residual variability in intensity but not fully. In describing these data, it was noted (WRIGHT 1949) "no dark eyed sepias from matings in this series of experiments have been excluded because their grades deviated unexpectedly much from the genotype which had to be assigned them. Thus a number of extremely light sepias of genotypes $c^d c^a$ and $c^r c^a$ (grades 7 to 9) segregated out and are included. Matings of such animals were, however, made in a different series of experiments designed to analyze extreme dilution and thus their progeny and descendants are not included here."

The same procedure was followed with unexpectedly light yellows, especially of genotypes $c^k c^r$, $c^k c^a$, $c^d c^r$, and $c^d c^a$ (grade 3 or less instead of the usual 4 or 5).

There were also unexpectedly light pale sepias known to be *EBCppF* by ancestry and breeding tests, but as low in intensity as 2 instead of the usual 8 to 13. In this case, it seemed best to exclude bodily a cluster of eight closely related matings in establishing the norm.

Correlations among residual variations

It was obvious from the first that extreme dilution of yellow and of dark-eyed sepia were largely due to common factors. They tended to segregate out from the

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same matings, and, in tortoise-shells, in the same animals. Following are data on 233 tortoise-shells $e^b B c^d c^a P F F$ from matings that could not produce any other c genotype except the easily recognized intense black-red (C) or albino ($c^a c^a$). Most of them are from the experiments on extreme dilution since tortoise-shells were avoided in the main experiments.

	233 tortoise-shells		1949 norm	
	Av.	S.D.	Av.	S.D.
Sepia	12.36	1.37	14.5	1.1
Yellow	3.05	0.78	4.2	0.6
$r = +.586 \pm .043$				

It may be noted that the means of both sepia and yellow are far below those in the main experiment. The correlation would undoubtedly have been higher if a larger number of tortoise-shells of typical intensity for $c^d c^a$ had been included. It would also probably have been higher if more accurate grades had been used. In 29 of them in fact, galvanometer readings of intensity of both sepia and yellow were taken by means of a reflection meter. The correlation between suitable functions of these readings was $+.72 \pm .09$. There is a similar relation in browns.

The aberrantly light pale sepias (pp) came largely from unrelated matings. The pink-eyed sepias with gene C that did segregate from matings that were producing exceptionally dilute yellows and dark-eyed sepias were of typical intensity (mean grade of 33 from such matings, $10.7 \pm .16$, in comparison with 9.7 from Table 1).

TABLE 1

Average empirical grades and standard deviations of indicated genotypes as presented in a previous paper (Wright 1949)

	Black dark sepia $EBP(F,ff)$		Pale sepia $EBppFF$		Dark brown $EbbP(F,ff)$		Pale brown $EbbppFF$		Brownish cream $E(B,bb)ppff$		Stable yellow $ee(B,b;P,p)FF$		Fading yellow $ee(B,b;P,p)ff$	
	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.	Av.	S.D.
$C-$	20.9	0.3	9.7	1.8	15.3	0.9	8.0	0.9	2.3	0.6	10.6	0.7	6.8	0.6
$c^k c^k$	20.1	0.6	9.0	1.0	15.0	0.9	7.2	0.8	0.0	0.0	7.0	0.3	1.9	0.5
$c^k c^d$	19.5	0.5	7.4	1.2	15.4	1.1	6.0	0.7	0.0	0.0	7.2	0.4	2.3	0.5
$c^k c^r$	20.5	0.6	6.7	1.3	15.1	1.1	5.9	1.0	..	..	4.8	0.6	..	..
$c^k c^a$	18.9	0.6	5.2	1.4	14.1	0.9	5.2	1.2	0.0	0.0	4.7	0.8	0.3	0.5
$c^d c^d$	18.1	1.0	4.7	1.1	14.2	0.9	5.4	1.4	0.0	0.0	6.9	0.5	2.1	0.9
$c^d c^r$	18.7	1.2	3.4	1.0	15.0	1.1	3.7	0.4	..	..	4.1	0.7	0.2	0.4
$c^d c^a$	14.5	1.1	2.7	0.8	12.4	0.9	2.7	1.0	0.0	0.0	4.2	0.6	0.3	0.4
$c^r c^r$	19.5	1.1	2.4	1.0	14.9	1.1	2.7	0.9	0.0	0.0	0.0	0.0	0.0	0.0
$c^r c^a$	15.0	1.7	0.7	0.6	12.5	1.1	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
$c^a c^a$	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Segregation of intensities of yellow with a given c genotype

The grade of yellow of any genotype becomes uniform to the eye under close inbreeding. Any young from inbred strain No. 35 ($e^p e^p c^k c^k FF$) (WRIGHT 1922) could be used as the standard for grade 7 as long as this strain was on hand. Similarly, ones from strain No. 2 ($e^p e^p CCFF$) could be used as standard for grade 10 and ones from strain No. 32 (also $e^p e^p CCFF$ but with plus modifiers) were standard for grade 13.

In the color experiments, there were many matings between homozygous dilutes ($c^d c^d \times c^d c^d$, $c^k c^k \times c^k c^k$) with offspring that showed no apparent variation in the intensity of yellow *within* litters. In some of these all of the young of all litters were assigned grade 7, in others all were assigned grade 6, but often, some whole litters were assigned one grade and other litters another, e.g. grades 7 and 8 or grades 6 and 7. These progenies can not be interpreted as segregating. In grading litters, the grades assigned to previous litters were not looked up. As a unit difference is just perceptible to the eye by definition, litters from matings characterized by a grade between 7 and 8, and no appreciable variability, might be graded 7 in some cases, 8 in others merely by accident of subjective judgment, and similarly at lower levels.

The situation was similar in the case of matings that produced only a single heterozygous type, $c^k c^r$, $c^k c^a$, $c^d c^r$ or $c^d c^a$. There were many cases in which there was no recognizable variability within or among litters, all litters being of grade 5, all of grade 4 or all of grade 3, but also many cases in which some litters were graded 5, others 6, or some 4, others 5, or some 3, others 4.

Where there was segregation of *c* alleles, there was usually no doubt about the assignment of *c* genotypes because of the high correlation between the grades of the homozygotes and heterozygotes, especially within litters.

Many of the matings also produced sepias either as self sepias or in tortoise-shells to which both sepia and yellow grades were assigned. While the sepia grades in these cases showed less uniformity within litters than the yellows, they also showed increased variability between litters.

It was evident in inbred clusters of matings that these differences among the mean grades of progenies were hereditary. Since all of those referred to above are "dilute" in comparison with intense "red" or "black" it will be convenient to describe the differences considered here in terms of diminution: diminished as opposed to normal or undiminished. The grades of diminution referred to above will be referred to as moderate in contrast with extreme diminution taken up later.

In marked contrast to the types of progeny considered above were many progenies in which there was obvious segregation of grades of yellow of a given *c* genotype *within* litters. We find such records as (667) (6677) (666677) in three successive litters in which all young were $c^d c^d$, and (34) (334) (344) (3334) (4) (335) in six successive litters in which all young were $c^d c^a$. There was rarely any doubt as to whether a mating that produced yellows was of the

nonsegregating or segregating type. The situation was similar with respect to sepias but with more frequent ambiguity because of the variability within litters even where the yellow grades indicated homogeneity.

Consideration of clusters of matings which included apparent segregation of normality and moderate diminution indicated a unit difference in most cases. Moderate diminution often appeared to segregate out as if recessive. There were, however, cases in which higher grades segregated from lower within litters as if the lower grade were dominant. Making allowance for the subjective errors in the absolute grades of different litters, it is possible to interpret the results in most clusters on the basis of a pair of alleles with intermediate heterozygotes. On the other hand, there were some cases in which normal dilutes, breeding as such, traced to diminished ancestors in such a way as to indicate the presence of more than one locus with this effect.

Some of these same matings of moderately diminished parents produced diminution of a more extreme sort: yellows, $c^d c^d$, of grade 5 or even 4, and creams known to be $c^d c^a$, $c^d c^r$, $c^k c^a$ or $c^k c^r$ of grade 2 or 1. Many matings were made between such extreme types in the attempt to produce true breeding strains. These would be expected to be homozygous diminished if they were merely extreme variants of the moderately diminished type but they always produced strongly segregating progenies. In some cases, normals, breeding as such, were derived in two generations from ancestors that were all extreme.

Anomalous whites

The clue to a fuller understanding of these variations in intensity came in the recognition that a hitherto unrecognized phenotypic class tended to appear whenever there was selection for extreme dilution. These were anomalous self whites or near-whites. They were overlooked for some time because of the possibility in many cases of interpretation in terms of known genes. Thus black-eyed whites might be interpreted as extreme piebald (ss) in progenies in which ss was segregating.

Self white as the extreme of spotting has, however, been uncommon in this stock except in an inbred strain (No. 13) characterized by the highest median percentage of white (97.8 percent) in its spotting pattern of any strain. It produced 24 percent self whites while strain No. 2 with a somewhat lower median, 93.8 percent, produced only three percent self whites (WRIGHT and CHASE 1936). Cases accumulated, moreover, in which this explanation was untenable because of the absence of spotting of any grade.

It also became clear that the eyes of the anomalous whites gave a dark red reflection more easily than those of black-eyed litter mates. This suggested that they might be red-eyed whites of genotype $eeBc^r c^r P$. This genotype was in fact produced by many matings of the extreme dilution experiments but suitable tests soon showed that c^r was in fact absent from many other matings in which whites with dark red eyes were appearing. Neither of these explanations could account for cases in which such whites had small spots of very pale color on one or both

cheeks, overlooked in several of them until long after birth. A number of early breeding tests of these were frustrated by failure to produce any young.

In the early experiments on extreme dilution, there were 19 matings that produced whites or near-whites, 37 in number (in a total of 196 young) that could not be explained as of any hitherto known genotype. There were undoubtedly others that were producing this genotype but also producing red-eyed whites ($eec^r c^r P$), albinos, or extreme piebalds, from which it could not be distinguished with certainty. In seven of the above 19 matings, the anomalous near-whites could be distinguished but not the self whites. If one considers only the progenies in which the self whites as well as the near-whites must have been of this new genotype, there were 27 among 96 young. One of these produced 8 in 22, the others only one to three each. It appeared probable that, in some cases at least, those whites were segregating in a Mendelian 25 percent.

As noted in the preceding paper (WRIGHT 1959), what appeared to be the same type segregated from four matings of silvered black-red tortoise-shells from a cross of the pure silvered strain Ro with silvers from matings (LF) in which anomalous whites had appeared.

The new type was first definitely accepted as such in the progeny of a mating, L254, between unspotted pale yellows of grade 3 ($eec^d c^a Pp$), not included above. This mating produced two dark-eyed near-whites and seven dark-eyed self whites among 22 dark-eyed young. There were also five pink-eyed yellows ($eec^d c^d pp$ and $eec^d c^a pp$) and nine pink-eyed whites, the latter largely, no doubt, $c^a c^a$, but possibly including anomalous pink-eyed whites. The self yellows included six of grade 5, two of grade 4, eight of grade 3, and one of grade 2, all below the typical grades for $c^d c^d$ and $c^d c^a$. One of the anomalous whites had a small pale yellow spot of grade 3 back of the right eye. Another appeared at birth to have a trace of very pale yellow (grade 1) on the head, which was verified later.

Descendants of this mating were inbred to the seventh generation (119 young). A much larger number (some 1300) were derived from a cross between it and a mating (L263), between a pale yellow of grade 2 from L254 and a sepia 14-yellow 4 tortoise-shell. The latter was considered to be typical of $e^p eBBc^d c^a FFPP$ but probably was heterozygous for a diminution factor since many of the progeny were unexpectedly light. This mating produced no anomalous whites, however, and the same was true of four brother-sister matings made from it. Many appeared in later generations and also among some 2000 descendants of outcrosses.

Association of two kinds of diminution with anomalous whites

Two different types of moderate diminution ultimately became fixed in different lines within this group. A clear case of one of these was in the line of inbreeding from L254 referred to above. A brother-sister mating (L282) between a yellow 5 ($c^d c^d$) and a yellow 3 ($c^d c^a$) produced only four young (two of grade 3 ($c^d c^a$) and two of grade 5 ($c^d c^d$)). The latter were mated (L298) to give a progeny consisting of seven self yellows of grade 6, 17 self yellows of grade 5, of

which at least four had such light bellies as to suggest silvering, and eight white or near-white. The six near-whites all had spots of much paler yellow (grade 3) than any of the self yellows, on one or both cheeks (two on right cheek only, two on left cheek only, and two on both). This progeny with exactly 75 percent self yellow of grades 5 or 6 and 25 percent self white or near-white with yellow head spots of grade 3 gives an unusually uncomplicated illustration of segregation of the new genotype from extreme diminished parents.

The gene for silvering (*si*) had not been suspected in the ancestry and neither parent in L298 had an especially light belly. It became clear in the next generation of brother-sister mating (W1) between a yellow 5 ($c^d c^d$) and a yellow 6 ($c^d c^d$), neither apparently silvered, that silver was indeed being transmitted. Two of the 14 self yellow young, (five of grade 5, eight of grade 6, one of grade 7), were strongly silvered on the back, and others had light bellies. In addition there were two near-whites (small head spot of grade 3 on each) and one self white. A brother-sister mating in the next generation (W8, yellow 5 \times yellow 6, neither silvered) and two brother-sister matings from this (W30, both yellow 6; W33 both yellow 6, the dam strongly silvered) produced 23 yellow young which ranged from extreme diminished to fully typical in intensity (two (5), 16 (6), four (7), one (8)) of which four were considered to be strongly silvered and some half dozen others had bellies lighter than typical. None of these produced anomalous whites. A mating, W38, between two strongly silvered yellows of grade 6, one from W30, the other from W33, produced 15 yellow young (five (5), nine (6), one (7)) of which all but five of grade 6 were considered to be strongly silvered. Of these five, four were judged to have slightly light bellies, but one of grade 6 lacked even this indication of silvering. Breeding tests of one with a slightly light belly from this mating and a similar one from W33, by mating with strongly silvered black-reds from strain Ro, produced seven and five young respectively, all strongly silvered black-reds. The yellow parents thus were *sisi* in spite of the absence of actual silvering. None of the preceding four matings produced any anomalous whites among the 38 young. A brother-sister mating (W44) between two strongly silvered yellows of grade 5 from W38, on the other hand, produced an anomalous near-white (yellow 4 on nose) and two yellows of grade 6 with nearly white bellies and some irregular lightness on the back, like the others considered to be strongly silvered yellows. There is little doubt that matings W38 and W44 were both of type *sisi* \times *sisi* and all of the others either *sisi* \times *Sisi* or *Sisi* \times *Sisi* but that the effect of *sisi* in these yellows (all $eec^d c^d$) was manifested more in diminution of intensity especially of the belly, than in actual silvering.

Diminution was not due wholly to effect of *sisi*, however. The same yellow 6 male as in W8 was mated (W32) with a yellow female, grade 5, whose father was also a yellow 6 from W1, mother a yellow 3 ($c^d c^a$) from the strain from L254 \times L263). The 27 offspring, all yellow, consisted of 10 of grade 5, 15 of grade 6, and two of grade 7 of which only four were considered to have somewhat light bellies, but none so light as to indicate silvering. A male from the progeny (yel-

low 5) was mated back to the dam and produced eight young (one (4), three (5), three (6), one (7)), none silvered though two had somewhat light bellies. These two matings produced no anomalous whites.

Moderately diminished yellow not associated with silvering is shown more clearly in several lines derived from the crossbred group from L254 \times L263. Thus one cluster of four matings of which three traced through one or two brother-sister matings to the first, included 84 young, all $c^d c^d$, of which 66 were of yellow grade 6 and eight of yellow grade 7 (ten with no yellow grade). None of these were recorded as having light bellies or any other distinctive indication of silvering. There were other clusters of matings that gave similar progenies. A cluster of six matings (YDL-1 and descendants) one called yellow 6 \times yellow 7, the others all yellow 6 \times yellow 6, produced one grade 5, 89 of grade 6, no anomalous whites and no distinctive suggestion of silvering in any case.

Further evidence for two kinds of diminution of color below the norm for the c genotype comes from breeding tests that have been made of 29 diminished with no overt silvering, by matings with strong silvers. Eight were clearly $SiSi$, 13 clearly $Sisi$, and eight probably $sisi$. Unfortunately, four of the latter are doubtful because of small number of offspring or the occurrence of overlaps. The best established were two yellows of grade 6, both $c^d c^d$, a pale yellow of grade 2 ($c^d c^a$) and a sepia 10-yellow 2 ($c^d c^a$). Of the doubtful ones, one was a yellow grade 5 ($c^d c^d$), two yellows of grade 2 ($c^d c^a$) and one sepia 10-yellow 2 ($c^d c^a$). Some of these were described as having very light bellies but none as clearly silvered. The grades of those shown to be $SiSi$ or $Sisi$ were rather similar ($c^d c^d$) sepia grades 15 to 18, $c^d c^a$ and $c^r c^a$ sepia grades 10 to 13, $c^d c^d$ yellow, all grade 6, $c^k c^r$, $c^k c^a$, $c^j c^r$, $c^d c^a$ all yellow of grade 3 except one grade 2 and one grade 4.

The gene diminished (dm): Seven matings were made between typical yellows (grade 7) (from a cluster that produced 34 of grade 7 and four of grade 8) and diminished yellows from the YDL-1 group above (grade 6). Three of these matings produced 29 young, all of grade 7, suggesting dominance of the higher grade, but the other four produced 11 of grade 6 in addition to 27 of grade 7. It is possible that the more intense parent was heterozygous, $Sisi$, in some of these cases. More accurate grades, based on reflection meter readings, indicate, however, that F_1 was really intermediate in all cases. The difference between visual grades 6 and 7 is too small for accurate judgments of dominance.

Nine backcrosses of F_1 yellow, grade 7, to diminished yellows grade 6 (of the same strain as used to produce F_1) gave 22 yellow-6 and 37 yellow-7 (no indication of silvering). The persistence of at least 50 percent of the F_1 type tends to indicate segregation at a single locus in these progeny which are descended 75 percent from the strain for which grade 6 is characteristic. We assume provisionally the existence of a gene dm (diminished) which reduces yellow of $c^d c^d FF$ from a strong grade 7 in $DmDm$ to a weaker grade 7 in $Dmdm$ and typically 6 in $dmdm$. Comparison of the sepia in clusters judged to be wholly $dmdm$ by grade of yellow with that in typical $EBC^d c^d PDmDm$ indicates that the typical grades 18 or 19 are reduced to 16 or 17 in $dmdm$.

Matings in which there is segregation of yellows of *c* genotypes $c^d c^r$ or $c^d c^a$ indicate that "diminished" reduces the typical grade (a weak 5) to about grade 3. These do not show the light bellies often associated with similar diminution of color in these *c* genotypes by *sisi* (WRIGHT 1959). Similarly this type of dilution reduces sepia of *c* genotypes $c^d c^a$ from typical 15–16 to 12–13. In $c^r c^a$ the grades are about one unit higher.

The effect of *dmdm* differs markedly from that of *sisi* in not affecting intense black or yellow (*C*) which are usually strongly silvered by *sisi* and, at least in the latter, diluted. This may be illustrated by a mating (LC-29) between an unsilvered dilute yellow of grade 6, $ee c^d c^d Si Sidm dm$ by ancestry, and an unsilvered intense yellow (grade 10), $ee C c^a Si Sidm dm$ also by ancestry. These produced 14 intense yellows of grade 10, three of grade 9 (the latter all in one litter) and 11 pale yellows all of grade 3 except for one called 2 and one called 4. There was no appreciable diminution of the intense yellows ($C c^d dmdm$). They were indeed unusually intense on the average by the reflection meter readings. The marked reduction from the typical intensity of $c^d c^a dmdm$ yellows was accompanied in only one case by a slightly greater than usual reduction on the belly.

The parents of anomalous whites

The characteristics of the parents of the anomalous whites must be taken into account in drawing conclusions on their genetics. Tables 2 and 3 show by *c* genotypes the grades of sepia and yellow respectively of all mated individuals that have produced this type and have grades. Tortoise-shells are entered under both their sepia and yellow grades. The average grades in the colony are repeated from Table 1 for comparison. As already noted, it is now apparent that some of these averages, especially those for genotypes involving c^d , are too low to be typical for genotypes that lack diminution factors since it has become clear that one of these

TABLE 2

Sepia (or brown) grades of parents of anomalous whites. No grades were assigned to silvered black in seven cases (six tortoise-shells) and a silvered red-eyed dark sepia ($c^r c^r sisi$).
Two pale sepias (E, e^p B $c^d c^a pp$) of grades 2 and 3 (1949 norm 2.7) are not entered

	AW	10	11	12	13	14	15	16	17	18	19	20	21	S?	Total (Excl. AW)	Mean	1949 Norm
<i>C</i>	.	.	.	.	.	.	.	.	.	.	.	3	.	.	3	20.0	20.9
<i>C sisi</i>	2	.	.	.	.	.	.	.	.	.	.	.	3	(7)	10	21.0	...
$c^r c^a$	.	.	.	.	.	.	.	.	1	1	.	.	.	.	2	17.5	18.9
$c^d c^d$	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	14.0	18.1
$c^d c^r$	.	.	.	.	.	.	1	1	1	1	.	.	.	.	4	16.7	18.7
$c^d c^a$	2	4	9	2	1	.	.	.	.	.	.	.	.	.	16	11.0	14.5
$c^r c^r sisi$	.	.	.	.	.	.	.	.	.	.	.	.	.	(1)	1	...	...
$c^r c^a$	.	1	3	2	.	.	.	.	.	.	.	.	.	.	6	11.2	15.0
$c^d c^a bb$	.	2	.	.	.	.	.	.	.	.	.	.	.	.	2	10.0	12.4

TABLE 3

Yellow grades of parents of anomalous whites. No grades were assigned to yellow in seven intense silvered tortoise-shells

	1	2	3	4	5	6	7	8	9	10	Y?	Total	Mean	1949 Norm
<i>C</i>	1	1	.	2	9.5	10.6
<i>C sisi</i>	1	5	1	1	(7)	15	8.2	...
<i>C ff</i>	2	.	.	.	.	2	7.0	6.8
<i>c^kc^k</i>	1	.	.	.	.	.	1	6.0	7.0
<i>c^kc^r</i>	.	.	1	.	.	.	.	.	.	.	.	1	3.0	4.8
<i>c^kc^a</i>	.	1	3	1	.	.	.	.	.	.	.	5	3.0	4.7
<i>c^dc^d</i>	.	.	.	1	5	1	.	.	.	.	.	7	5.0	6.9
<i>c^dc^d sisi</i>	.	.	1	1	3	2	.	.	.	.	.	7	4.9	..
<i>c^dc^r</i>	.	4	9	.	.	.	.	.	.	.	.	13	2.7	4.1
<i>c^dc^a</i>	.	12	20	2	.	.	.	.	.	.	.	34	2.7	4.2

(*dm*) was much more frequent in this main series of color experiments than had been suspected.

The data point in two directions. With respect to intense black parents (*BCP*), it may be noted that ten showed overt silvering and only three did not, apart from two that were anomalous whites themselves. Of the three unsilvered, two were known to be heterozygous, *Sisi*, because of a silvered parent or offspring and the other came from a mating of type *Sisi* × *Sisi*. With respect to intense yellow parents (*FFF*), 15 were overt silver and only two not, but both of these came from *Sisi* × *Sisi*. Allowing for eight tortoise-shells, there were 24 *C*-parents, of which 17 were silvers (*sisi*), two definitely *Sisi*, and three may well have been *Sisi* as coming from *Sisi* × *Sisi*, and two were anomalous whites.

The suggestion that anomalous whites are modified silvers, *sisi*, is unavoidable, as silvering was not common in the colony outside of strain Ro and derivatives, which were the source of only six of the above 17 silver parents.

Among parents, with lower *c* alleles, however, relatively few were overt silvers. There was one *c^rc^r* silvered black from *sisi* × *sisi* among 30 with sepia grades, and seven *c^dc^d* silvered yellows among 68 with yellow grades, or eight silvers among 80 parents, allowing for 18 tortoise-shells. In addition, six *c^dc^d*, three *c^dc^r*, seven *c^dc^a* and one *c^rc^a* are known by a silver parent or offspring to carry *si*. Thus the parents (L350) of two anomalous whites, which at the time were not known to have silver ancestry, were tested by mating with silvered black-reds from strain Ro. The male, a pale yellow of grade 2 (*c^dc^a*) turned out to be *sisi*, and the female, sepia 11-cream 3 (*c^dc^a*), turned out to be *Sisi*. The 55 in which presence or absence of *si* was unknown from appearance of *sisi* in a parent or offspring, were all closely related to silvers and there were none which can be asserted to be *SiSi*. There were also two parents, with lower *c* alleles, that were anomalous whites themselves.

On examining the sepia and yellow grades of the dilute parents of anomalous whites it may be seen that all of the yellow grades (except perhaps two *c^dc^a* of

yellow grade 4) and all of the sepia grades of $c^d c^a$ and $c^r c^a$ are below, and most of them far below the 1949 averages for their genotypes. To some extent this merely reflects the fact that anomalous whites have appeared only in experiment on extreme dilution (apart from ten from RoLF) but this is not the full explanation since many of the matings in these experiments involved typical grades. There is, in short, a strong implication that genes making for extreme dilution must be received from both parents to produce anomalous whites.

The complete absence of overt silvering among the many $c^d c^a$ parents is somewhat disconcerting. It has, however, been brought out earlier and in the preceding paper (WRIGHT 1959) that overt silvering is almost completely suppressed both in sepias and yellows of this genotype unless there is an accumulation of modifiers for very strong silvering as in derivatives of strain Ro. There is instead a uniform, moderate diminution of color on the back and a more extreme diminution on the belly.

There were two dilute browns, ($e^p b b c^d c^a P$), among the parents of anomalous whites, both of grade 10, which is less than the 1949 average, 12.4. There were two fading yellows ($ee C f f$ of grade 7) which gave no indication of any diminution of color below the norm, 6.8. There were two pink-eyed pale sepias $E e^p B c^d c^a$ of grades 2 and 3 which also gave no indication of excess diminution of color (1949 norm 2.7). Finally there were 22 albinos ($c^a c^a$) and four red-eyed whites ($ee B c^r c^r P$). One of the albinos was certainly and two probably *Sisi* by test. All of the animals above were related to ones known to transmit *si* and none were known to be *SiSi*.

Anomalous white as diminished silver (sisidmdm)

A considerable number of anomalous whites were mated with silvers but none of the males produced any young and the females few. One such female (from L298), however, produced 11 offspring, all silvered. Another produced four and two others three each, all silvered. One of them, in a mating with a brother ($c^d c^a$, pale yellow, grade 2), produced two anomalous whites, and no other classifiable young. As far as they go, these direct tests confirm the view that anomalous whites are *sisi*.

Their appearance is more in harmony with this interpretation than was realized until outcrosses and selection of silvered black-reds (strain RoXR, WRIGHT 1959) produced extreme silvers which bridged the phenotypic gap between the previously observed strong silvers with mere sprinkling of white over the back, nearly white belly, unsilvered head and feet, and the near-whites and whites from the experiments on extreme dilution. The three most extreme silvers in RoXR (grade 12) were like the anomalous near-whites in restriction of color to spots on the head and diminished intensity and silvering of these spots. The anomalous whites may be considered as silvers in which blotching has reduced color to small spots on the head (and rarely a few colored hairs on the back) and in which silvering and diminution are extended to these head spots. The anomalous white males differ from the extreme silvered males of RoXR in being sterile.

While it seems clear the anomalous whites are *sisi*, the modifier or modifiers that make them extreme seem to have no relation to those in RoXR. The diminution of intensity of color of their parents, below that expected from their *c* genotypes can be due only in part to the effect of *sisi* since it occurs where this parent is *Sisi* and exceeds that due to *sisi* alone when this parent is *sisi*. The extraction of another type of diminution (*dmdm*), not associated with a silvering effect, from the lines that produce anomalous whites suggests that the genotype of the latter is *sisidmdm*.

Analysis of a large network of matings

A systematic attempt was made to test whether the data from the large, rather tightly knit group descended from L254 and L263, and outcrosses is consistent with this interpretation. After considerable experimentation the following rough norms were set up for the effects of *si* and *dm* in sepia and yellow in the *c* genotypes of most importance in the above group of matings (Table 4).

In this scheme, the same diminution effect is attributed to *si* and *dm*. This must be qualified in the case of *eeC-* in which silvering (*sisi*++) has seemed to be clearly associated with reduction from yellow of grade 10 or more to about grade 9 while genotype ++*dmdm* is apparently not associated with any diminution. These grades refer to the dorsal color. Ventrally, *si* seems to be associated with a greater reduction of intensity than *dm*. Finally *si* tends to be associated with sprinkling with white hairs in the higher *c* genotypes (*C* and usually *c^dc^d*) while no effect of this sort whatever can be attributed to *dm*. Indeed there is no evidence that *dm* behaves as a modifier that extends silvering in the narrow sense except in *sisidmdm*.

It is not likely that the effects of *si* and *dm* are really identical for lower *c* alleles. An initial attempt, however, to interpret *si* as having a more extreme diminution effect than *dm* throughout, based on particular cases, broke down. An attempt to interpret ++*si*+*dm* as more intense than *sisi*++ or ++*dmdm* (i.e.

TABLE 4

Postulated typical grades of si-dm genotypes in sepias and yellows in most frequent c- genotypes

	Sepia				Yellow		
	<i>E-C-</i>	<i>E-d^dc^d</i>	<i>E-c^dc^a</i>	<i>E-c^rc^a</i>	<i>eeC-</i>	<i>eeC^dc^d</i>	<i>ee(c^dc^a,c^dc^r)</i>
++++	21	18-19	15-16	16-17	10	8	5
+++ <i>dm</i>	21	17-18	14-15	15-16	10	7	4
+ <i>si</i> ++							
++ <i>dmdm</i>	21	16-17	12-13	13-14	10	6	3
+ <i>si</i> + <i>dm</i>							
<i>sisi</i> ++							
+ <i>sidmdm</i>	20	14-15	10-11	11-12	9	5	2
<i>sisi</i> + <i>dm</i>							
<i>sisi dmdm</i>	0	0	0	0	0	0	0

to interpret *si* and *dm* as more nearly recessive than dominant) also broke down. The evidence on *sis**i**+**+* from the above group of matings is not very extensive. There is some reason from other matings referred to in the preceding paper (WRIGHT 1959) to consider that this actually has slightly less diminution effect than *++dmdm*. The hypothesis of equal diminution effects here, however, seemed to be an adequate first approximation for analysis of these data.

There were indications that the effects on *c^b* genotypes are similar but slightly less than on *c^a* genotypes. There were also indications of effects on brown, parallel to those on sepia (little or no diminution with *C*, appreciably more with lower *c* alleles). In the pale sepias, there was no evidence of any effect in the presence of *C* except for silvering of *sis**i*. There were probably effects in the presence of lower *c* alleles, but the evidence was very scanty.

The attempt was made to assign a formula to every mating in this group of matings on the basis of (1) the possibilities provided by the formulae of the parental matings, (2) the grades of the mated individuals, (3) the general level of intensity of the progeny, (4) the indications of segregation in intensity in the progeny, (5) the occurrence and frequency of anomalous whites in the progeny and finally (6), the results of all breeding tests of offspring. Especial weight was given in (2), (3), and (4) to grades obtained by reflection meter readings of some 1,500 young in these experiments which are not discussed in this paper. In the end, as a result of (1) and (6), the formulae throughout the entire network of matings form a self-consistent set.

No doubt errors have been made in these assignments, especially in matings with small number of offspring and few or no breeding tests of the latter. Such cases are relatively unimportant. There was usually no choice in the case of the key matings with many offspring and several of these mated. Analysis of the reflection meter grades will be made elsewhere.

The important point here is that it proved possible at all to obtain a consistent interpretation of this entire network of matings without doing serious violence to the observed grades at any point.

Segregation of anomalous whites

The only cases in which there is sufficient phenotypic discontinuity to permit clear-cut Mendelian ratios are those in which *sisidmdm* segregates from other genotypes. There are nine possible types of mating with respect to *si* and *dm* from which such segregation is expected (combining reciprocal types and assuming that *sisidmdm* males are sterile, a matter discussed in detail later).

There were 59 matings in the cluster in which genotypes were assigned, that were capable of producing *sisidmdm*. These include 17 which did not have any offspring that were certainly of this genotype. The offspring of each mating, excluding one discussed later, were classified into the following categories, using *c^x* for a *c* allele other than *c^a*.

- (1) Dark eyed (*c^x-P-*) from matings incapable of producing *eec^rc^{ra}P*.
- (2) Pink eyed (*c^x-pp*) from matings incapable of producing *c^ac^a*.

- (3) Pink-eyed white ($c^a c^a P-$) from matings incapable of producing pp .
- (4) Pink eyed from matings capable of producing both $c^a c^a$ and pp .

Those from (1), (2) and (4) that are neither white nor near-white are considered as not *sisidmdm*. In categories (1) and (2), whites and near-whites are considered to be *sisidmdm*. There is a possibility of confusion from high grade spotting due to *ss* which segregated out in a few matings. It is believed that errors of classification of near-whites were avoided by taking account of size and intensity of the head spots. It is not likely that there were any errors from the rare occurrence of self white due to *ss*. Category (3) cannot be classified as *sisidmdm* or not, by appearance. One albino male (mating type 8) was, however, undoubtedly $c^a c^a \textit{sisidmdm}$ (very small testes). Another (mating type 5) was probably of this genotype (sterile in seven months of mating after maturity). In category 4, pink-eyed near-whites are definitely $c^x \textit{-ppsisidmdm}$ but pink-eyed self whites of this genotype cannot be distinguished by appearance from albinos ($c^a c^a$) which may or may not be $c^a c^a \textit{sisidmdm}$. One self white male was undoubtedly *sisidmdm* (very small testes) and two others (mating types 3 and 8 were sterile in matings of three and six months duration respectively. The expected numbers of $c^x \textit{-ppsisidmdm}$ and of albinos were calculated for each mating but no attempt was made to apportion the former between near-white and white.

Genotypes $c^r c^r$ and $c^r c^a$ segregated from several matings but there was only one (L358, mating type 5) in which *ee* also segregated out making possible red-eyed white of genotype $eec^r c^a PP$ which might be mistaken for anomalous white. This mating ($e^b ec^a c^r PP \times e^b ec^a c^a P-$) produced 13 definitely not near-white or white, two definitely near-white (*sisidmdm*) and seven dark eyed whites (four born dead) which cannot be classified with respect to *sisidmdm*. This mating is excluded from Tables 5 and 6.

Table 5 gives a summary of the offspring of the 58 matings, according to mating type and the above phenotypic and genotypic categories. There are no important deviations from expectation, if the near-whites and self whites of columns 9 and 10 are combined. ($\chi^2=17.7$, $n=26$ on grouping entries that are unduly small) From the grand totals it appears that only about 23 percent ($=\frac{4}{16.9}$) of

$c^x \textit{-ppsisidmdm}$ (column 9 expected) are near-white (column 9 observed) in progenies in which those that are self white are indistinguishable from albinos and thus are included in column 10.

Table 6 gives a summary by expected ratio, restricted to the categories 1 and 2 combined, in which all whites and near-whites can be attributed with confidence to *sisidmdm*. Agreement is good ($\chi^2=2.8$, $n=4$).

This agreement is favored to some extent by circular reasoning since ratio was taken into account in assigning formulae. It was, however, only one of the six things that were taken into account, as has been noted. The important point is that the data can be interpreted consistently with the theory in this matter as well as in all others.

TABLE 5

Offspring of matings derived from L254, L263 and outcrosses that were capable of producing anomalous white (AW=sisidmdm). These matings are classified by type with respect to si and dm. Offspring are classified as dark eyed or pink eyed. Pink eyed (c^x-pp) from matings incapable of producing albinos, and dark eyed are unequivocally AW or not AW. Albinos (c^xc^sP) from matings incapable of producing pp cannot be classified phenotypically with respect to AW. Pink eyed from matings capable of producing both c^xc^sa and pp can be classified as AW if near-white, as not AW if neither white nor near-white but are unclassifiable if self white. Expected values are given for all classes except those for column 9 include all c^x-ppsisidmdm, near white or self white while that for column 10 is for c^xc^sa and thus does not include self white c^x-ppsisidmdm which is included in the observed figure

Mating type	No. matings	Dark eyed (c ^x -p-)		(c ^x -pp)		Pink eyed (c ^x -pp)		e ^c e ^s pp		Total
		AW	Not AW	AW	Not AW	Self W	Not AW	Self W	Not AW	
1 sisi + dm X sisi dmdm	2	3	7	..	..	0	1	1	1	12
		4.5	4.5	..	..	(0.6)	(1.7)	(1.7)	0.7	
2 + si dmdm X sisi dmdm	1	4	4	..	..	..	..	..	..	8
		4.0	4.0	..	..	..	..	..	..
3 sisi + dm X sisi + dm	5	5	18	2	5	0	6	6	6	48
		6.3	18.8	1.7	5.3	(1.2)	(6.5)	(6.5)	3.7	
4 sisi + dm X + si dmdm	11	30	77	18	59	2	39	39	16	242
		26.0	78.1	19.3	57.8	(6.4)	(33.5)	(33.5)	19.2	
5 + si dmdm X + si dmdm	15	22	67	1	0	2	55	55	13	186
		22.1	66.2	0.5	1.5	(6.2)	(39.5)	(39.5)	18.5	
6 + si dm X sisi dmdm	0	..	..	..	..	..	..	..	..	0
7 + si + dm X sisi + dm	2	2	17	..	..	..	..	..	..	25
		2.0	13.8	..	..	..	..	..	..
8 + si dm X + si dmdm	14	14	80	0	8	1	27	27	16	204
		12.1	84.5	1.0	7.0	(2.5)	(25.0)	(25.0)	17.4	
9 + si + dm X + si + dm	8	1	55	1	19	..	..	..	..	76
		3.7	56.0	1.0	15.3	..	..	..	..
Total	58	81	325	22	91	4	98	128	52	801
		80.7	325.9	23.5	86.9	(16.9)	(101.4)	(106.2)	59.5	

TABLE 6

Summary of data in columns 4 to 7, Table 5, combining young from categories in which classification as definitely *sisi dmdm* or not is possible. Expected values based on totals for these categories

Mating type	Expected Not AW:AW	Not <i>sisi dmdm</i> Obs. Exp.		<i>sisi dmdm</i> Obs. Exp.		Total
(1) (2)	1:1	11	9.0	7	9.0	18
(3) (4) (5)	3:1	226	228.0	78	76.0	304
(7) (8)	7:1	105	105.9	16	15.1	121
(9)	15:1	74	71.2	2	4.8	76
Total		416	414.1	103	104.9	519

*The colored spots of guinea pigs of genotype *sisidmdm* (silver-whites)*

We begin here a more detailed consideration of the characteristics of genotype *sisidmdm*, which it will now be convenient to call "silver-white." Tables 7 and 8

TABLE 7

Numbers of dark-eyed silver-whites called white at birth but spotted later W', of others white at birth (W), and numbers and grades of sepia and yellow spots at birth. R indicates red-eyed segregant, c^rc^a. A from matings from which self whites must be *sisidmdm*.

B from matings in which self whites need not be *sisidmdm* and are not entered. One with a tortoise-shell spot is indicated by an asterisk

	White		No.	Sepia Grade	Yellow		Total	
	W	W'			No.	Grade	A	B
C	.	.	1	(17)	3	(7,7,8)	3	1
Cff	.	.	.	.....	1	(4)	.	1
c^kc^a	1	.	.	.....	1	(2)	2	.
c^dc^a	25	.	4	(4,5,7,10)	1	(1)	29	1
c^rc^a	1	.	1	(7)	.	.....	1	1
1C:1c^kc^a	1	.	.	.....	1	(8)	2	.
1C:1c^dc^a	.	.	2	(13,15)	.	.....	2	.
2C:1c^dc^d:1c^dc^a	3	.	1	(19)	.	.....	4	.
2C:1c^dc^r:1c^dc^a	1	1	2	(5,11)	.	.....	4	.
2C:1c^dc^a	2	.	3	(8,14,15*)	2	(6,7*)	4	2
1C:1c^dc^a	1	.	2	(14,14)	1	(3)	4	.
1c^kc^k:1c^kc^a	1	.	.	.....	.	.....	1	.
1c^kc^k:2c^kc^a	1	.	.	.....	3	(1,1,3)	4	.
1c^kc^r:1c^rc^r	.	1	.	.....	.	.....	.	1
1c^dc^d:1c^dc^r:1c^dc^a:1c^rc^a	.	.	2	(4R,6)	.	.....	.	2
1c^dc^d:1c^dc^a	3	.	.	.....	1	(3)	4	.
1c^dc^d:2c^dc^a	15	3	1	(8)	3	(2,3,4)	22	.
1c^rc^r:2c^rc^a	2	.	8	(2,2,3,7,7,8,8,11)	.	.....	10	.
A	57	4	21	.....	14	.....	96	.
B	..	1	6*	.....	3*	.....	.	9

TABLE 8

Numbers and grades of pink-eyed silver-whites. Otherwise as in Table 13. One with a tortoise-shell spot is indicated by an asterisk

	White		No.	Sepia Grade	Yellow		Total	
	W	W'			No.	Grade	A	B
$c^k c^r$	.	.	.	.....	1	(2)	.	1
$c^d c^d$	3	.	.	.....	8	(3,3,3,3, 3,3,3,4)	11	.
$c^d c^r$	10	1	.	.....	2	(1,1)	13	.
$c^d c^a$	.	1	.	.....	1	(2)	.	2
1C:1 $c^k c^a$	1	.	.	.....	.	.....	1	.
1C:1 $c^d c^d$	2	1	.	.....	1	(6)	4	.
2C:1 $c^d c^d$:1 $c^d c^a$	1	.	.	.....	.	.....	1	.
2C:1 $c^d c^r$:1 $c^d c^a$	2	1	.	.....	1	(8)	4	.
1 $c^k c^k$:2 $c^k c^a$	.	.	.	.....	1	(3)	.	1
1 $c^d c^d$:1 $c^d c^r$	1	.	.	.....	1	(1)	2	.
1 $c^d c^d$:2 $c^d c^r$	.	.	.	.....	5	(1,2,2,2,2,)	.	5
1 $c^d c^d$:2 $c^d c^a$	.	.	.	.....	2	(2,2)	.	2
1 $c^d c^d$:2 $c^d c^{ra}$	.	.	1	(2*)	1	(2*)	.	1
1 $c^r c^r$:2 $c^r c^a$	.	1	.	.....	.	.....	.	1
A	20	3	.	.....	13	.....	36	.
B	.	2	1*	.....	11*	.....	.	13

give a classification by possible c genotype and grade of all recognized silver-whites (dark-eyed (P) in Table 7, pink-eyed (pp) in Table 8). Those that were self-white as far as observed are called W. These are entered only from matings (A) that could produce no other genotype that could be confused with *sisidmdm*. Those that were recorded as white at birth but on which very pale cream (in two cases with a few sepia hairs) was observed later on the cheeks, are called W' and are entered both for matings of type A and also from the other matings (B). Many of those called W were born dead or died soon after birth.

In many cases c genotypes can be definitely assigned from the nature of the mating. In a larger number, however, there was segregation of the two or more c genotypes, and the genotype can only be inferred from the intensity of the head spots if any. The self-whites can only be apportioned on the basis of expected ratios.

We note first that the head spots of known C 's may be of sepia grade 17 and yellow of grade 7 or 8. It may also be seen that several yellows of grades 6 to 8 are found where C is expected (both among dark-eyed and pink-eyed young), but none above grade 4 otherwise. The highest grade of sepia assigned any possible C segregant is 19. A tortoise-shell, sepia 15-yellow 7, indicates that the grade of C -*sisidmdm* may be at least as low as 15. Grade 14 occurs where $c^d c^a$ is the only other c genotype than C , and in view of other data may be assigned the latter. We conclude that sepia head spots of C *sisidmdm* range from grade 14 to 19. The distributions for this and other genotypes are shown in Table 9. The average for seven believed to be C is 15.4 ± 0.7 . Similarly, we conclude that yellow head spots of C -*sisidmdm* range from grade 6 to 8 (irrespective of P or pp). The dis-

TABLE 9

Grades of sepia at birth in colored spots of *sisidmdm*. The *c* genotypes apportioned in segregating litters as described in the text

	Intensity of sepia spots																			Total	Mean
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		
<i>C</i>	3	2	.	1	.	1	7	15.4±0.7
<i>c^dc^d</i>	1	.	.	.	.	.	.	2	12.0±1.0
<i>c^dc^r</i>	1	.	.	.	.	.	.	.	.
<i>c^dc^a</i>	.	.	1	2	1	1	2	.	1	.	.	.	.	.	.	.	.	.	.	8	6.6±0.7
<i>c^rc^r</i>	2	.	1	.	.	.	.	.	.	.	.	.	.	3	9.0±1.0
<i>c^rc^a</i>	.	2	1	1	.	.	3	.	.	.	.	.	.	.	.	.	.	.	.	7	4.6±0.9

tribution for yellows is given in Table 10. The average for eight believed to be *C* is 7.12 ± .30. These averages are not only much lower than expected of typical *C* (black 21, yellow 10 or 11) but also lower than in genotype *C-sisiDmdm* (black about 20, yellow about 9).

It should be added that in all of these cases the head spots were strongly silvered with white hairs. The grades are intended, however, to apply to the unsilvered hairs. In one case, a few scattered sepia hairs were observed on the back of an otherwise dark-eyed white.

Yellow in known *c^dc^dsisidmdm* was of grade 3 in seven cases and grade 4 in one. It was probably as low as grade 2 in segregating progenies. What little evidence there is on *c^kc^ksisidmdm* indicates grade 3 as typical for this also. The distributions are shown in Table 10 based, in segregating progenies, on the expected ratios and the assumption that *c^dc^d* and *c^kc^k* tend to be more intense than *c^kc^r*, *c^kc^a*, *c^dc^r*, and *c^dc^a*. The mean for *c^kc^ksisidmdm* and *c^dc^dsisidmdm* combined is 3.00 ± .14. This again is not only much lower than for typical *c^kc^k* or *c^dc^d* (about 7) but also for *c^dc^aSisidmdm* or *c^dc^asisiDmdm* (about grade 5). The head spots in these cases appeared to be uniform pale yellow rather than silvered.

Genotypes *c^kc^r*, *c^kc^a*, *c^dc^r*, and *c^dc^a* typically have yellow of about grade 5. This is reduced to about grade 2 as a rule when the above *c* genotypes are combined with *Sisidmdm* or *sisiDmdm*. The head spots of near-whites, *sisidmdm* of these *c* genotypes are assigned grades 1 or 2 with one dubious exception (grade 3 in an animal born dead and wet when found). The average for the 17 believed to be of

TABLE 10

Grades of yellow at birth in colored spots of *sisidmdm*. The *c* genotypes apportioned in segregating litters as described in the text

	Intensity of yellow spots								Total	Mean
	1	2	3	4	5	6	7	8		
<i>C</i>	.	.	.	.	.	2	3	3	8	7.12±.30
<i>c^kc^k</i>	.	.	2	.	.	.	.	.	15	3.00±.14
<i>c^dc^d</i>	.	2	9	2	.	.	.			
<i>c^kc^r</i>	.	1	.	.	.	.	.	.	17	1.65±.15
<i>c^kc^a</i>	2	1	.	.	.	.	.
<i>c^dc^r</i>	3	.	.	.	.	.	.
<i>c^dc^a</i>	2	7	1	.	.	.	.

these genotypes was $1.65 \pm .15$. This, however, is undoubtedly too high since the great majority in these cases were recorded as self white at birth. We have not indeed included the eight probably of these genotypes which were recorded as self white at birth but in which very pale cream spots were observed later.

The grades of sepia in head spots of four known $c^d c^a \text{sisidmdm}$ indicate a range of at least 4 to 10. Apportionment in segregating litters suggests four more cases, in this range, with average for all eight of 6.6 ± 0.7 . In the case of $c^r c^a \text{sisidmdm}$ there are two known cases of grades 4 and 7. There are probably five other cases, ranging from 2 to 7 from three matings segregating in $c^r c^a$ and $c^r c^r$. The average for these seven is 4.6 ± 0.9 . These were silvered but this could be because they were tortoise-shells. These averages are again far below the typical grades of $c^d c^a$ and $c^r c^a$ (15 to 17) and below those for $c^d c^a$ or $c^r c^a$ combined with *Sisidmdm* or *sisiDmdm* (about 10 to 12).

With the apportionment indicated above for progenies segregating in $c^r c^r$ and $c^r c^a$, three cases of $c^r c^r \text{sisidmdm}$ range from sepia grades 8 to 11 with average 9.0 ± 1.0 , far below the typical grade of about 19 or 20. The average for $c^r c^r \text{Sisidmdm}$ and $c^r c^r \text{sisiDmdm}$ are uncertain but is probably about 17 or 18. One of those considered $c^r c^r \text{sisidmdm}$ (grade 8) was one of three silver-whites observed to have a few dark hairs on the back.

There are few data on the intensity of sepia in head spots of other *c* genotypes. One of grade 13 is probably $c^d c^d$ and one of grade 11 is probably $c^d c^r$, which as in the other cases are far below the typical grades.

There was only one pink-eyed silver-white with pale sepia in a head spot. This was a pink-eyed white with a pale sepia 2-yellow 2 spot, probably $c^d c^d \text{ppsisidmdm}$. The typical grade for $c^d c^d \text{pp}$ is about 4.7. It is notable that dilute pale sepia is not completely eliminated.

There was one probable fading yellow of genotype $eeC\text{-ffsisidmdm}$. This was a near-white with a head spot of grade 4 that segregated out from a brother-sister mating (LF122), both parents probably $eeC^r \text{ffSisiDmdm}$, that produced 13 self or near-self yellows of grades 6 to 8 ($eeC\text{ff}$), seven red-eyed whites ($ee c^r c^r \text{ff}$) and the above near-white. It is remarkable that no silvered yellows ($eeC\text{-ffsisidm-}$) were recorded but low grade silvering of yellow was often not noted at the time. One grandparent was certainly and the other probably *Sisi*. The gene *dm* was present in the ancestry but apparently produces no effect in *Cff* except in the combination $C\text{ffsisidmdm}$. Several other near-whites, all $eeC\text{F-sisidmdm}$ segregated out in related matings, as well as silvered yellows $eeC\text{ffsisidm-}$.

Table 11 shows the frequency of self white (at birth) and near-whites with sepia or yellow on the head, according to probable *c* genotype, among the progenies in which all self whites could be attributed to *sisidmdm*. It appears that about 52 percent of *sisidmdm* with *C*, $c^k c^k$, or $c^d c^d$ (in which yellow as well as sepia head spots should almost always be apparent at birth), showed such spots, leaving 48 percent self white. Among those of genotypes $c^k c^a$, $c^d c^r$, and $c^d c^a$, in which pale cream head spots are hardly distinguishable at birth, only about 21 percent were recorded as having head spots. This could mean that the frequency of potentially spotted areas is actually much reduced in the latter, but it is more

TABLE 11

Self white (at birth), sepia spot and yellow spot among animals from matings of Type A. The c genotypes apportioned in segregating litters as described in the text

	<i>sisi dmdm</i>			Total	Percent with spot	
	Self white	Sepia spot	Yellow spot			
C	8	5	6	19	57.9	52.2
<i>c^kc^k</i>	1	0	1	2	50.0	
<i>c^dc^d</i>	13	1	11	25	48.0	
<i>c^kc^a</i>	4	0	3	7	42.9	21.3
<i>c^dc^r</i>	12	1	3	16	25.0	
<i>c^dc^a</i>	43	6	3	52	17.3	
<i>c^rc^r</i>	0	3	0	3	100.0	
<i>c^rc^a</i>	3	5	0	8	62.5	
Total	84	21	27	132	36.4	

probable, in view of the considerable proportions of surviving pure whites that later were found to have very pale head spots, that the percentage with potential spots is independent of the *c* genotype and that the amount of pigment developed in those with lower *c* genotypes is usually almost or quite imperceptible.

Differential mortality

The experiments with silver-whites were frustrated unduly often by early death. Table 12 shows the numbers born dead, that died before weaning, and that reached weaning among identifiable *sisidmdm*, unclassifiable self-whites and non-whites in all litters that contained the first. There is clearly heterogeneity with respect to mortality ($\chi^2 = 22.7, n = 4$).

Upon comparing merely the unclassifiable whites (largely albinos) and the non-whites, no significant difference is found ($\chi^2 = 4.4, n = 2$).

TABLE 12

Number of identifiable silver-whites (sisidmdm), of pink-eyed white littermates (largely albinos c^ac^a, some sisidmdm), and of non silver-white littermates born dead, dying between birth and weaning, and raised to weaning

	Born dead	Died	Raised	Total
Silver-white	43	40	69	152
Pink-eyed white	22	4	54	80
Non silver-white	51	28	125	204
Total	116	72	248	436

Upon comparing those born alive with those born dead, there is no significant difference whether the unclassifiable whites are combined with the non-whites ($\chi^2 = 0.5, n = 1$) or omitted ($\chi^2 = 0.3, n = 1$).

On considering only those born alive a highly significant difference is found between those that died before weaning and those that were raised. This holds if the unclassifiable whites are combined with the non-whites ($\chi^2=17.9$, $n=1$) or omitted ($\chi^2=10.3$, $n=1$), 85.5 percent of the non-whites were raised of those born alive but only 60.7 percent of those definitely *sisidmdm*. It is clear that there is no appreciable differential mortality up to birth but that the viability of *sisidmdm* is definitely lower than normal thereafter.

Sterility of male silver-whites

In the course of experiments intended to multiply or to test the silver-whites, it became apparent that no offspring were being obtained from males that were unequivocally of this type. In estimating the effective duration of matings, these were treated as starting with the month in which the male reached four months of age (average 3.5 months) or with the month following that in which the mating was made, if the male was already more than three months old at mating. The mating was treated as continuing through the month in which the female died or was disposed of. The first litter is usually produced so promptly (after a gestation period of about 68 days), that nonproductive matings of even three months duration by the above reckoning are uncommon among normal animals. The females referred to in this section were not silver-whites unless so stated (two cases).

The eighteen mated non silver-white brothers of silver-white males were all fertile and produced 190 litters in 281 months of mating on average of 3.84 per year (Table 13).

It became apparent that the testes of silver-white males remained abnormally small. These were dissected out and weighed in a number of cases as noted below. In three fertile non silver-white males, the combined weights of the testes including the epididymides were 5.3, 6.0, and 7.2 grams. The first was sepia 11-yellow 3, $c^d c^a ++ dmdm$, the second a very strong silver (grade 11), from RoXR, with a poor breeding record (three litters in 18 months), and the last a brown that produced only one litter near the beginning of nine months of mating. In three apparently unproductive males that were not silver-whites (duration of matings—3, 4, and 7 months) the testes plus epididymides weighed 5.0, 5.8, and 6.0 grams. The first was a silver, grade 5 ($c^d c^a sisi ++$), the second a black ($C + si + dm$) and the third a black with silvering of grade 7 ($C sisi ++$). The average for all six not *sisidmdm* is 5.9 grams. In all of these, the epididymides were white and distended with sperm.

Three black-eyed white males produced no young in matings of 5, 6 and 6 months duration. In one (δ 4781, discussed later) the combined weight of the testes was 1.95 grams. The epididymides were glassy and empty. In two unmated black-eyed whites (δ 6756 and δ 6798, discussed later) single testes weighed only 0.40 and 0.25 grams. Three black-eyed near-white males produced no litters in 8, 8 and 14 months. In one, the combined weight of testes and epididymides was 1.0 grams. The latter were again glassy and empty. Seven pink-eyed near-whites produced no litters in 5, 6, 7, 7, 13, 21 and 21 months. The testes were dis-

TABLE 13

Productivity of silver-white males and of their brothers (all fertile) with non silver-white females, and of silver-white females and of their sisters (all fertile) with non silver-white males. Thirteen of the males (first row) were definitely sisidmdm by parentage and color, four (second row) were pink-eyed whites that could be sisidmdm or merely c^ac^a by color and parentage but are believed to be sisidmdm by their sterility and (in two cases) diminutive testes. The silver-white females were all definitely sisidmdm. They are divided according to apparent sterility or fertility. BA=born alive, RBA=raised of these born alive and R=raised

Test parent Sex Genotype	Duration		Mo./md.	Litters (L)		No. 1./year	No.	Offspring (O) 0/L.	0./year	%BA	%RBA	Fate %R	R/yr.
	No.	Mo.		No.	1./year								
♂ sisidmdm	13	127	9.8	0	0	0	0	...	0	...	...	...	0
♂ sisidmdm (c ^a c ^a possible)	4	27	6.7	0	0	0	0	...	0	...	...	...	0
♂ sisidmdm total	17	154	9.1	0	0	0	0	...	0	...	...	...	0
♂ not sisidmdm (brothers of tested ♂ ♂)	18	281	15.6	190	3.84	345	3.83	14.7	70.7	79.9	56.5	8.33	
♀ sisidmdm (sterile)	10	69	6.9	0	0	0	0	...	0	...	...	...	0
♀ sisidmdm (fertile)	11	91	8.3	28	3.69	79	2.82	10.4	63.0	87.0	54.8	5.52	
♀ sisidmdm total	21	160	7.6	28	2.10	79	2.82	5.9	63.0	87.0	54.8	3.08	
♀ not sisidmdm (sisters of tested ♀ ♀)	26	261	10.0	84	3.86	287	3.42	13.2	74.4	84.0	62.5	8.25	

sected out in two. The combined weight with epididymides were 1.3 and 1.6 grams. In these also, the latter were glassy and empty. Five pink-eyed self whites from matings that produced silver-whites, produced no young in 3, 4, 6, 7 and 10 months. None of these was necessarily *sisidmdm* since two were certainly and three possibly albinos, $c^a c^a$. The mating of only three months duration was with a *sisidmdm* female and may have been unproductive for this reason. In two of the others, the testes and epididymides were weighed, the totals being 1.2 and 1.7 grams and the condition of the epididymides as before.

The average weight for the six unproductive whites or near-whites is 1.3 grams (and single testes of two other silver-whites averaged only 0.3 grams) in contrast with 5.9 grams for both testes plus epididymides of six not *sisidmdm*.

There was a considerable number of pink-eyed self whites from matings that produced undoubted *sisidmdm* that were fertile but these could all have been merely albinos. One pink-eyed self white from such a mating produced no litters in three months with a female known to be fertile, but is believed to have been merely an inadequately tested ordinary albino since the weight of the testes and epididymides was 5.0 grams and the latter were white and distended as in the control males. A white male with sepia-cream head spot produced no young in five months but had normal testes and white, distended epididymides, total weight 5.0 grams. The absence of young in this case was undoubtedly due to the female. She was a sister, undoubtedly $c^d c^a$ *sisidmdm* (white with a small sepia head spot of grade 5), ovaries cystic, uterus grossly enlarged (2 cm in diameter, horns each 1.2 cm in diameter, lumen very fine). The head spots in the male in contrast were no lighter than in other low grade dilutes produced by this and other matings (sepia 12-cream 2). It was moreover evident from other offspring from the mating (L348) that high grade white spotting was segregating. It seems reasonably certain that this was merely an example of high grade spotting, $c^d c^a$ *ssSisidmdm*. The only other tested male (four litters in 18 months) which had been thought to be possibly a silver-white was a white with large sepia (grade 10) spots on both sides of the head. His parents (brother-sister) were siblings of two undoubted silver-whites. None of the seven other offspring were silver-whites but one showed moderately high grade spotting. Again the most probable interpretation is that this male was a high grade spotted segregant of the extreme dilute type, $c^d c^a$ *ssSisidmdm*. Fortunately high grade spotting segregated out in only a few of the matings, and there were very few whites or near-whites about which there was any serious doubt on this account.

Histologic and experimental studies of probable *sisidmdm* males were begun by PROFESSOR C. R. MOORE but were interrupted by his fatal illness. Following are the notes which he made on the three cases which he completed.

“ ♂ 4181 black-eyed white from mating W12, born April 5, 1952

Jan. 16, 1953. Autopsy. Body weight 885 g.

Testis not palpable in scrotum. No evident pathology of viscera. Testis small, epididymis glassy. No spermatozoa present. Seminal vesicles well distended with secretion (indicates plenty of male hormone secretion).

Vas deferens on right entered middle of seminal vesicle instead of common ejaculatory duct (atypical).

Weight

2 testes (without epididymis)	1.95 g.
2 seminal vesicles	3.15 g.
2 adrenals	.76 g.
2 thyroids	.20 g.
pituitary	.020 g.

Testis slide failed to show any spermatogenetic activity. Single row of basal cells in seminiferous tubules. Interstitial tissue prominent and in general excessive. Thyroid and adrenal essentially normal histologically. Pituitary slides suggest some abnormality but not yet completely convinced that it is atypical histologically.

♂ 6756 *black-eyed white* from L348, born Dec. 14, 1952

- May 4, 1953. Right testis removed; weight 0.40 gms. (slide 284A) given one guinea pig pituitary implant per day for 15 days.
- No external signs of testis descent. Abdomen opened, small testicular biopsy taken through puncture through tunica albuginea (slide 284B). Then gave 14 daily subcutaneous injections of gonadal stimulating hormone (gonadogen-equine gonadotrophin, 10 rat units or 200 international units).
- Autopsy June 1 (5½ months old)

Organs in general normal; adhesions had developed after operation between rough surface of testis and inside lining of body wall; testis could not have descended.

At autopsy

body weight	460 gm.
left testis (earlier biopsy)	0.72 g. (slide 284C)
2 seminal vesicles	2.7 g. plenty of secretion

Testis slide 284A (before treatment) no spermatogenesis; single basal row of cells in seminiferous tubules.

Testis slide 284B (biopsy after 15 pituitary implants) no appreciable change from untreated.

Testis slide 284C (15 pituitary implants then 14 daily gonadotrophin injections). Testis larger than original one (heavier) but no improvement in spermatogenesis; interstitial tissue greatly stimulated.

♂ 6798 *black-eyed white* from L350, born Dec. 18, 1952

May 4, 1953. Testes not palpable. Body weight 315 gm. Age 4½ months. Right testes removed: weight 0.25 gm. Slide 285A. Injected testosterone propionate, 0.5 mgs daily, 14 days. No external signs of change. Then testosterone propionate increased to 2.5 mgm daily for 14 days. (Slide 285B)

Autopsy June 1. Body weight 340 gm.

All organs normal in appearance except testis. Testis high in abdomen (could have descended). Left testis weight 0.17 gm., 2 seminal vesicles 1.17 gm. distended with secretion. Slide 285B (left testis following 14 days injection of testosterone propionate 0.5 mgm daily, then 14 days, 2.5 mgm daily) does

not show appreciable change from right testis removed before treatment. These dosages of male hormone did not stimulate spermatogenesis."

From these cases it appears that there is a primary failure of spermatogenesis, due presumably to absence of spermatogonia. There is no evidence of deficiency of interstitial cells in the testis or of male hormone, nothing abnormal in the histology of the adrenals or thyroid, nothing clearly atypical in the pituitary and no indication of spermatogenesis by pituitary implants, equine gonadotrophin or testosterone propionate.

Table 13 gives a summary of the breeding records of the 13 males believed to be *sisidmdm* by color and ancestry, the four pink-eyed whites, probably *sisidmdm* by color, ancestry and record, and the 18 brothers definitely not *sisidmdm*, all mated with normal females.

Low productivity of female silver-whites

One case of abnormality in the reproductive tract of an *sisidmdm* female has been referred to. No gross abnormalities were found in a number of other cases, however, and many were fertile—yet productivity was clearly subnormal. The most important results are summarized in Table 13 in which the records of the sisters of the tested *sisidmdm* females are used as controls. Duration is calculated as described for the tests of males. The shortest durations entered were of three months for each of two *sisidmdm* females one with one litter, one with none, and of two months for each of two controls, each with one litter. In the cases of two silver-whites, litters of three each were removed before birth, but close to term, and a litter of two, near term, from a control female, at the time of disposal of the guinea pig colony. As these could not be included in the categories born alive (BA), raised of those born alive (RBA) or raised (R), duration is shortened by two months in each case before calculating the number of young raised per year. Only matings with normal males are considered.

Among the 21 silver-white females, ten produced no litters although mated on the average 6.9 months each. All of the 26 normal sisters were fertile. It should be said that there was one sister, not included, that produced no litter in ten months but in this case the male produced no litter in 10 months with another normal female and was thus probably responsible for the failure. This difference in fertility between *sisidmdm* and their sisters is highly significant ($\chi^2 = 12.7$, one degree of freedom).

Considering only the fertile matings, there is little difference in the number of litters per year, 3.69 for the silver whites *vs.* 3.86 for their normal sisters. There is a greater difference in mean size of litter, 2.82 for *sisidmdm* *vs.* 3.42 for their sisters but the significance is doubtful (standard deviation 1.42 for silver-whites, 1.49 for the controls, $t = 1.90$). A considerably smaller percentage of the offspring of silver-whites were born alive (63.0 percent *vs.* 74.4 percent) but a slightly larger percentage of those born alive were raised (87.0 percent *vs.* 84.0 percent). The percentage raised of all young (product of preceding percentages) was less for silver-whites (54.8 percent *vs.* 62.5 percent), but not significantly. The number of offspring raised per year, the over-all estimate of reproductive

efficiency, is much smaller for the silver-whites (5.52 *vs.* 8.25) but the standard deviations are such (4.20 for silver white, 4.49 for the controls) that the difference is only 1.77 times its standard error.

If, however, records of all mated silver-white females are compared with those of their normal sisters, the discrepancy becomes much greater because of the large proportion of the former that were apparently sterile. The average number of litters per year becomes 2.10 for the silver-whites as opposed to 3.86 for their sisters, the offspring per year becomes 5.93 *vs.* 13.20 and the number raised per year 3.08 *vs.* 8.25.

It may be seen that the records of the normal brothers of the tested silver-white males and those of the normal sisters of tested silver-white females were rather similar (except in average duration).

Anemia of silver-whites

I am indebted to DR. W. K. SILVERS for determinations of hemoglobin in a number of silver-whites and of non silver-whites from the same or closely related matings. Two determinations were made for each guinea pig (average difference 26.2 on the scale used). The average for seven control guinea pigs was 606.4, for 10 silver-whites 456.1, giving a difference of 150.3 with a standard error of 16.2. The difference is thus highly significant (9.3 SE).

Three of the controls were males (average 631.3) and four females (average 595.2). Two of the silver-whites were males (average 445.5) and eight females (average 458.7). Thus there is no consistent sex difference with the numbers tested.

Paired comparisons could be made on the basis of six matings represented by both silver-whites and controls. Two silver-whites from one mating and two controls from another are averaged in each case. Three of the silver-whites had no controls from the same mating and are omitted. The difference, 146.2 is 6.7 times its standard error which is significant at the .001 level. All of the matings were so closely related, however, that the unpaired comparison may be taken as valid.

Thus silver-whites have only about 75 percent of the hemoglobin concentration of their normal relatives. This may contribute to the low viability and low productivity of females of genotype *sisidmdm*. It can hardly have any direct relation to the absence of spermatogenesis in the males.

Possible earlier references to dm

The guinea pig colony in which the present data were obtained traces largely to a colony of the Bureau of Animal Industry, U.S. Department of Agriculture (which contained the color factors $e^b, e; A, a; B, C, c^k, c^a; P, F, f; S, s; Si, si$ and Dm ; and a few animals kindly presented by DR. W. E. CASTLE in 1916 which introduced E, b, c^d, c^r, p and almost certainly dm . The initial intensity of c^j genotypes, probably associated with $dmdm$, was increased by matings with albinos of the U.S.D.A. stock though not to such a degree that there was overlap of c^d sepias with c^k sepias. An association of c^d with dilution modifiers persisted for a long

time in certain largely isolated strains (cf. WRIGHT 1949, p. 254). It now appears that this was due to the gene here designated *dm*.

CASTLE (1912) described an experiment in which he selected for extreme dilution in a strain of light sepias, creams and albinos by mating the lightest sepias and lightest creams. One of the matings produced an animal with a white coat except for a spot on the right side of the head and a small one on the body of a very pale color, described as like that of a pink-eyed (*pp*) mouse. Gene *p*, it may be noted, was not introduced into the colony until a year later. The eyes were described as pink but with a faintly pigmented streak in the iris.

This is like a silver-white of genotype $Eec^d c^a sisidm dm$, except that the eyes of the latter, while lighter (dark red) than the black eyes of sepia or cream litter mates would not be described as pink. Silvering was present in other strains in DR. CASTLE'S laboratory. If *si* and *dm* were present at all in the foundation stock of the section experiment, individuals of genotype (*Ee* or *ee*) $c^d c^a Sisidm dm$ would tend to be selected for mating because of their extreme dilution and should have produced some silver-whites. Other factors for dilution assembled by the selection, but not present in my colony, might have been responsible for the greater dilution of eye color than that which I have observed in silver-whites.

In a later paper (1916) CASTLE described crosses between the Peruvian cavy (*Cavia cutleri*) believed to be the wild ancestor of the guinea pig, and animals of two guinea pig strains. *Cavia cutleri* is paler than a cream agouti guinea pig. "The fur is agouti-ticked and the belly light, but the yellow of the ticking and belly is so pale as to resemble a dirty white or very pale cream shade." On crossing with albinos from an otherwise very intense black strain (race B: $E aa BB c^a c^a PP FF$) the offspring were intense agoutis (with red ticking and belly) as intense as those produced from crosses with blacks of the same strain. It was concluded that *cutleri* transmitted gene *C* and must owe its dilution to factors independent of the *c* series, which had just been described (WRIGHT 1915). As none of the 58 F₂ animals was as light as the *cutleri* grandparent, it was also concluded that "the darker coloration introduced by the cross, apparently through the albino parent, does not behave as a simple Mendelian character, either dominant or recessive."

The other strain with which the wild cavies were crossed was one (race C) in which the animals were either very pale brown-eyed creams ($ee aa bb c^a c^a PP FF$) or the corresponding albinos ($c^a c^a$). The hybrids from either the creams or the albinos, while more intense than either the wild cavies or the creams, were "much lighter than the hybrids produced in the cross with race B albinos." Among 81 F₂ young from F₁ pairs that produced albinos ($Cc^a \times Cc^a$), 11 were very pale. It appears that race C has one or more dilution factors in common with *cutleri*, absent in race B, as well as intensity factors, probably in common with race B, but replaced by dilution factors in the wild species. As race C seems to have been the source of *dm* of our colony the question is raised whether *dm* may not be present in the wild species and thus the type allele at its locus. As *dm* has no appreciable effect in our colony in the presence of *C* (except in association with *sisi*) it must be supposed that the wild species differs from race C at some other locus or loci responsible jointly with *dm* for its dilution in the presence of gene *C*. This can hardly be *si* in view of the self white or near-white character of *sisi*

dmdm, as well as the sterility of males of this genotype. If we let *dc* represent such a gene in *Cavia cutleri*, the hypothesis in its simplest form is as follows:

<i>Cavia cutleri</i>	<i>CC dmdm dcdc</i>	very dilute
Race C, cream	<i>c^dc^a dmdm DcDc</i>	very dilute
F ₁ (<i>cutleri</i> × race C albino)	<i>Cc^a dmdm Dcdc</i>	moderately dilute
Like race C except C for c ^d	<i>CC dmdm DcDc</i>	intense
F ₁ (<i>cutleri</i> × race B albino)	<i>Cc^a Dmdm Dcdc</i>	intense
Race B black	<i>Cc^a DmDm DcDc</i>	very intense

The failure to recover the dilution of *cutleri* in 58 F₂'s from the cross with race B albinos, indicates that it must differ in one or more additional factors. The segregation of only 11 pale-colored in 81 F₂ hybrids with race C albinos, probably indicates at least one additional factor of type *dc* in *cutleri*.

IBSEN (1932) listed the variations from the typical colors associated with combinations of major color factors that were present in his colony and assigned genic symbols in each case. He implied, however, that adequate data had not been obtained in all cases. No data were given and it is not clear which ones were considered to be demonstrated. He described extreme dilution of dilute yellow (*ee c^dc^a*) as due to a recessive gene *li*. This might have been merely an effect of *si* (almost certainly the same as his *Ro*, studied by IBSEN and GOERTZEN (1951) on a black background, and thus present in the colony). If not, it is possible that our *dm* is the same as his *li*. There is the apparent difference that *li* is stated to be recessive while *Dmdm* is as intermediate as *Sisi*. There is also the apparent difference that no effect on sepia (or brown) is ascribed to *li*, while such an effect (in tortoise-shells for example) is obvious in the case of *dm*. It is not stated, however, that effects were looked for on any other than a yellow background. It is also quite possible that there is both a specific modifier of light yellow (*li*) that was present in his stock but not mine and a general modifier of pigmentation (*dm*) with a peculiar interaction effect with silver that was present in my colony but not his.

In a brief reference in a previous paper (1956), the symbol *di* was used for the gene that is here called *dm*, overlooking the fact that IBSEN had assigned the symbol *di* to a wholly different variation, dilution at the base of black hair, in his 1932 paper.

SUMMARY

The first order variations in intensity of dark eyed sepias in the guinea pig colony under consideration were due to the *c* series of alleles (*C*, *c^k*, *c^d*, *c^r*, *c^a*). Those in yellow are due to the *c* series and *F*, *f*. Most of the residual variability in sepia and yellow must have been due to common factors in view of the strong correlation between the intensities of sepia and yellow segregants, or within tortoise-shells, of the same *c* genotype (and *FF*). Most of the residual variability of pink-eyed pale sepias (*pp*) was independent.

Most of the residual variability in intensity of dark eyed sepia and yellow depended on two genes silvering (*si*) and diminished (*dm*). The former tends to produce silvering (sprinkling with white), blotching (irregularity in degree of

silvering even in symmetrically placed areas) and dilution. The silvering and blotching are most conspicuous with higher *c* genotypes, (especially with *C* in blacks, reds and pink-eyed pale sepias), the dilution in lower ones (especially $c^d c^a$ in which dilution, uniform except for light belly, largely replaces silvering in both sepias and yellows). The gene *dm* has somewhat similar effects with lower *c* genotypes, but no silvering effect and no effect with *C* except in *sisi dmdm*.

The dilution effects of the loci act cumulatively to produce extreme dilution in *Sisidmdm* and *sisiDmdm*.

In the combination *sisidmdm* the coat is usually wholly white except (in about 50 percent) for one or two small spots of pale color on the cheeks. With *C*, these spots are strongly silvered. With $c^d c^a$ they are so pale as to be easily overlooked at birth. Eye color (if *P* is present) is slightly reduced.

Silver-whites (*sisidmdm*) have a higher mortality rate after birth than their normal litter mates. The males are sterile as far as known. Those examined have testes of about 25 percent normal weight.

Spermatogenesis was found to be wholly absent in those examined and could not be induced by testosterone propionate, pituitary implants, or gonadotrophin. Interstitial tissue and amount of male hormone seemed normal. (C. R. MOORE).

About 50 percent of the silver-white females have been sterile. The others are probably somewhat low in productivity.

Silver-whites have about 75 percent of the hemoglobin concentration of normals of the same strain. (W. K. SILVERS).

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