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Genetic and Morphologic Studies on Ten Albino Stocks in *Hyla arborea japonica*

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(With 2 Text-figures and 14 Plates)

CONTENTS

INTRODUCTION

Albinism in amphibians is rather of rare occurrence in the field, although there are numerous references and unpublished records concerning accidental discoveries of albinos (Hensley, 1959; Brame 1962; Gilboa and Dowling, 1974). In Hylidae, albino *Hyla regilla* tadpoles reared by Jameson and Myers (1957) and 8 albino *Hyla arenicolor* collected by Van Devender (1969) have been reported as the first and second records in the United States. Sazima (1974) recorded an albino *Phrynohyas mesophaea* as the first one in the hylid frog in South America. In Europe, so far there have been only a few reports on albino *Hyla arborea* (Herkner, 1959; Boschwitz, 1962). While an albino tree-frog was sketched in a frog book published about 200 years ago in China, the first report on albino *Hyla arborea* was made by Yamaguchi (1956) who reared five of the 16 albino tadpoles discovered in a rice field at Toyoshina-cho, Nagano Prefecture. The second report was made by Daito (1968) on 14 albino tadpoles of the same species collected from Miyoshi, Hiroshima Prefecture located about 470 km away from Nagano Prefecture. On the other hand, recently two reports have been published on curious albino frogs; one was on a pinto *Eleutherodactylus planirostris* by Petrovic (1973) and the other on a mutant *Xenopus laevis* causing periodic albinism by Hoperskaya (1975).

The genetics of albinism in amphibians has fragmentarily been reported by Eales (1933), Smallcombe (1949), Tokunaga (1949), Browder (1967, '72), Humphrey (1967), Daito (1968), Benjamin (1970), Gill (Smith-Gill), Richards and Nace (1970, '72) and Hoperskaya (1975). Through their investigations, it has become clear that albinism in amphibians is inherited by a recessive gene, as known in the other classes of vertebrates. However, from the authors' voluminous crossing experiments using many albino *Hyla arborea japonica* collected from an area of about 6000 square kilometers surrounding Hiroshima, it is apparent that albinism in amphibians is not so simple as considered hitherto. In this species, there are three kinds of recessive albino genes at least, which give rise to albinos differing slightly from one another in back and eye color. There are, moreover, two kinds of dominant melanizing genes which affect a part of the albino

body. During the authors' crossing experiments, it became necessary to observe the pigment cells in the dorsal skin and eye of albinos under an electron microscope in order to elucidate the morphological characters of each kind of albinos.

The results of genetic and morphologic studies conducted by the authors during these eleven years will be reported in this paper.

MATERIALS AND METHODS

During the last thirteen years from 1963 to 1975, 113 albino tadpoles of *Hyla arborea japonica* GUENTHER were collected from twelve stations, of which nine are in six districts of Hiroshima Prefecture, two in Yamaguchi Prefecture and one in Okayama Prefecture. The place-names of these collecting stations are given in Table 1 (Fig. 1).

All the albinos from Hiroshima Prefecture were tadpoles when discovered. They were brought to the authors' laboratory and reared until sexual maturity. Six albinos from Okayama Prefecture were given to the authors by Dr. MORIYA, Okayama University, from among about 30 albino frogs, which he collected at the tadpole stage and reared until sexual maturity in his laboratory. Among these six albinos, there were two females and four males. Differing from usual albinos, they had black eyes.

Three albinos from Yamaguchi Prefecture were provided by Dr. SAMBUICHI, Yamaguchi University. He collected 3 albino tadpoles in 1974 from a place in the suburbs of Yamaguchi, and 22 in the next year from another place in the suburbs of the same city. The three albinos in 1974 were sexually matured by

TABLE 1

Twelve collecting stations and numbers of albino tadpoles

Year	Collecting station	No. of tadpoles
	Hiroshima Prefecture	
1963	1. Nakahara, Miyoshi	14
1964	〃	2
1965	〃	2
1970	2. Mr. S. KAWAMURA's rice-field, Mori, Tojo-cho, Hiba-gun	5
1970	3. Mr. HORIGOSHI's rice-field, Mizutani, Kake-cho, Yamagata-gun	3
1971	4. Mr. K. MASUDA's rice-field, Torinobu, Midori-cho, Takata-gun	1
1963	5. Spot A, Kitagawa, Yasuura-cho, Toyota-gun	12
1969	6. Spot B, Haragakiuchi, Yasuura-cho, Toyota-gun	1
1972	7. Spot C, (Mr. N. FUJIMOTO's rice-field), Akahosaka, Yasuura-cho, Toyota-gun	8
1972	8. Spot D, (Mr. I. KAKITA's rice-field), Akahosaka, Yasuura-cho, Toyota-gun	12
1973	〃	21
1974	9. Mr. MIKAMA's rice-field, Higashi, Saijo-cho, Higashihiroshima	4
	Okayama Prefecture	
1974	10. Suburbs of Niimi	6
	Yamaguchi Prefecture	
1974	11. Niho-shimosato, Yamaguchi	3
1975	12. Mr. KOHONO's rice-field, Yoshiki, Yamaguchi	19

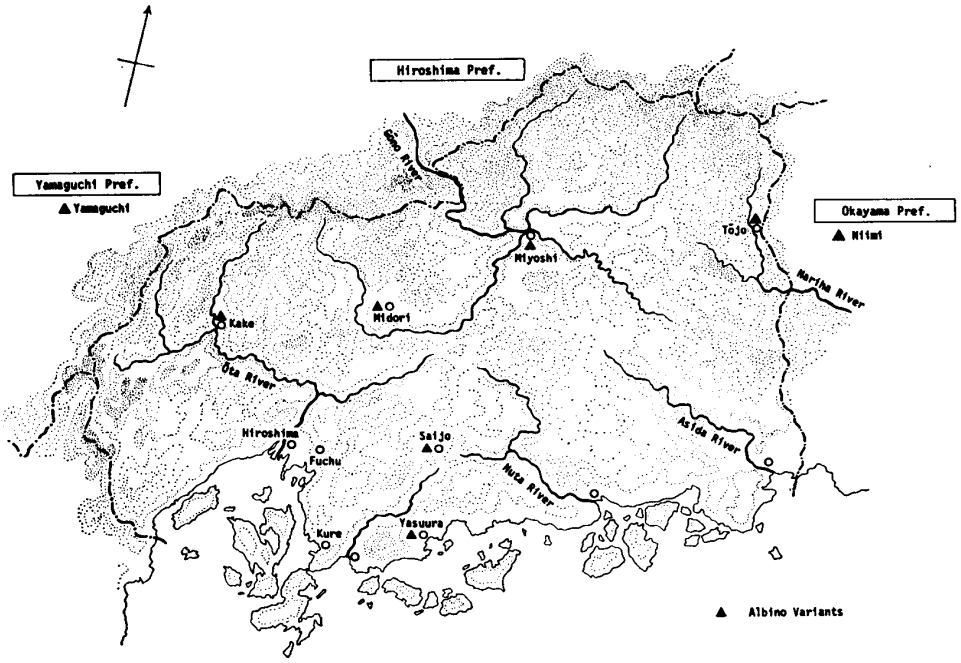

Fig. 1. Collecting stations of albino tadpoles. × 1/1,600,000.

him before they were made available to the authors; two were males and one was a female. Of the 22 albino tadpoles obtained in 1975, 19 were handed over to this laboratory immediately after metamorphosis and reared here. They gradually became green with growth. At sexual maturity, they were considerably similar to normal tree-frogs in dorsal color. Among 6 mature frogs, there were 3 females and 3 males.

The albinos from each locality tremendously increased in number from 1968 to 1976 by matings between albinos or wild-type frogs heterozygous for an albino gene, or by back-crossings of heterozygous frogs to albinos. Many albinos were also produced from heterozygous frogs by diploid gynogenesis. This method is as follows.

Sperm suspension obtained by crushing the testes of a male *Hyla arborea japonica* in a small quantity of tap-water is exposed for 2 minutes to UV emitted from a mercury lamp, GUL-5·J Type of Toshiba Co. make, 2537 Å in the main wave length, at a distance of 20 cm (2400 erg/cm^2/sec.). By such an exposure the nuclei become incompetent, although the spermatozoa are motile and enter into eggs. After the inseminated eggs are left as they are for 20 minutes at room temperature (20~25°C), they are exposed to low temperature (1~2°C) for about one hour. By this treatment, the nucleus of the second polar body is retained in the egg and fused with the egg pronucleus. Then the egg develops as a gynogenetic diploid.

Eggs were always obtained from females whose ovulation was accelerated by injecting suspension of frog pituitaries into the coelomic cavity. Matings were performed by artificial fertilization. Eggs taken out of the cloaca of a female were put on a glass plate and covered with a small quantity of sperm suspension.

Each of the male albinos collected from the field was usually used for several matings at long intervals. After a piece of a testis was utilized at a time, the wound of the abdominal wall was immediately sutured to keep the male alive.

The dermal chromatophores in the skin and the pigment cells in the choroid and retina of an eye were examined under an electron microscope to clarify the abnormalities of albinos in melanin synthesis. Tissues were fixed for 2 hours in 3% glutaraldehyde in 0.1 M phosphate buffer (pH 7.4) and postfixed in 2% OsO_4 in the same buffer. Dehydration was made in an ethanol series. After embedded in Epon 812, sections were cut on a Porter-Blum M-1 ultramicrotome with a glass knife, mounted on Formvar-coated grids and stained with the double stain of saturated uranyl acetate and alkaline lead citrate. A Hitachi HS-8 electron microscope was used for observation.

OBSERVATION

I. Ten albino stocks from twelve collecting stations

1. Miyoshi (My) stock

A total of 18 albino tadpoles (14 in 1963, two in 1964 and two in 1965) were collected from the suburbs of Miyoshi, Hiroshima Prefecture. Although all these tadpoles metamorphosed in the authors' laboratory, only one female and 2 male albinos collected in 1963 matured. Using these, Daito (1968) made crosses between male and female albinos as well as between albinos and normal frogs in 1965 and 1966. According to him, all the 20 offspring produced from male and female albinos were albinos when observed at the hatching stage, while the offspring between albinos and normal frogs were all of wild type. The authors reared 5 young heterozygous frogs produced by Daito from a mating between a normal female and a male albino. As four of them (3 females and one male) matured, they were used for producing their offspring in 1968 and 1970 (Table 2).

As normal ovulation occurred in one (My. Het. 66♀, No. 1) of the 3 heterozygous females by injecting frog pituitary suspension, she was mated with the only heterozygous male and a normal male from the field. In the mating with the heterozygous male (My. Het. 66♂, No. 1), 99% of 521 eggs cleaved normally, and 499 hatched. Of the hatched tadpoles, 410 were of the wild type and 89 albinos. While all these albinos died of abnormalities, most of the wild-type tadpoles metamorphosed normally. From the mating between the heterozygous female and the normal male, 65 wild-type frogs were produced.

The other two (My. Het. 66♀, Nos. 2 and 3) of the heterozygous females ovulated normally in the breeding season of 1970. The eggs obtained from each of the 2 females were divided into two parts. One part was induced to develop by diploid gynogenesis, and the other was fertilized with sperm of a normal male. Of 1048 eggs removed from the 2 females, 84% cleaved normally by diploid gynogenesis, and afterwards 34% hatched normally. The other eggs died of various abnormalities in embryonic stages. Of the hatched tadpoles, 309 (87.5%)

TABLE 2

Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1968	My. Het. 66, No. 1	My. Het. 66, No. 1	521	517 (99.2%)
		Wild 68, No. 1	102	84 (82.4%)
1970	My. Het. 66, No. 2	Gynogenetic Dip., No. 2	474	392 (82.7%)
		Wild 70, No. 2	471	394 (83.7%)
	My. Het. 66, No. 3	Gynogenetic Dip., No. 3	574	492 (85.7%)
		Wild 68, No. 3	91	87 (95.6%)
1972	My. Alb. 70, No. 1	Wild 72, No. 5	69	51 (73.9%)
1973	My. Alb. 70, No. 2	Wild 73, No. 6	25	20 (80.0%)
1974	My. Het. 72, Nos. 4~6	My. Het. 72, Nos. 2~4	322	252 (78.3%)
		Wild 74, No. 7	171	119 (69.6%)
1975	Wild 75, Nos. 16~18	My. Alb. 74, No. 1	412	406 (98.5%)
		Wild 75, No. 10	136	113 (83.1%)
Total	My. Hetero, Nos. 1~6	Gynogenetic Dip., Nos. 2, 3	1048	884 (84.4%)
		My. Hetero, Nos. 1~4	843	769 (91.2%)
		Wild, Nos. 1~3, 7	835	684 (81.9%)
	My. Albino, Nos. 1, 2	Wild, Nos. 5, 6	94	71 (75.5%)
	Wild, Nos. 16~18	My. Albino, No. 1	412	406 (98.5%)
		Wild, No. 10	136	113 (83.1%)

were of the wild type and 44 (12.5%) albinos. After many tadpoles died of abnormalities, 181 (17.3%) metamorphosed normally; only 17 were albinos and 164 of wild type. The scarcity of albinos which theoretically should be equal to wild-type frogs in number is probably attributable to weakness of albinos, especially at low temperature. Refrigeration of eggs at 1~2°C seems more fatal to albinos than to wild-type frogs. As it is believed that about half the number (442) of the normally cleaved eggs were homozygous for the albino gene, 398 and 27 of them, 425 (96.2%) in total, died of various abnormalities during the embryonic and the tadpole stage, respectively, while 133 and 145, 278 (62.9%) in total, of the eggs having no albino gene died, respectively. From the eggs of

individuals for an albino gene in the My stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
499 (95.8%)	410	89	367 (70.4%)	367	0
74 (72.5%)	74	0	65 (63.7%)	65	0
115 (24.3%)	103	12	45 (9.5%)	43	2
286 (60.7%)	286	0	182 (38.6%)	182	0
238 (43.5%)	206	32	136 (23.7%)	121	15
67 (73.6%)	67	0	59 (64.8%)	59	0
36 (52.2%)	36	0	12 (17.4%)	12	0
12 (48.0%)	12	0	4 (16.0%)	4	0
229 (71.1%)	138	91	160 (49.7%)	108	52
88 (51.5%)	88	0	72 (42.1%)	72	0
348 (84.5%)	348	0	260 (63.1%)	260	0
107 (78.7%)	107	0	105 (77.2%)	105	0
353 (33.7%)	309	44	181 (17.3%)	164	17
728 (86.4%)	548	180	527 (62.5%)	475	52
515 (61.7%)	515	0	377 (45.1%)	377	0
48 (51.5%)	48	0	16 (17.0%)	16	0
348 (84.5%)	348	0	260 (63.1%)	260	0
107 (78.7%)	107	0	105 (77.2%)	105	0

the 2 heterozygous females fertilized with sperm of the normal male, no albinos were produced.

Two mature female albinos produced by diploid gynogenesis in 1970 were mated with normal males from the field in 1972 and 1973. Their eggs were extremely fragile; most of them were injured when taken out of the cloaca. Of 94 normally shaped eggs obtained from the 2 females, 76% cleaved normally after artificial insemination, and 51% hatched normally. Although all the hatched tadpoles were normal in appearance, they were remarkably low in viability; only 16 metamorphosed normally, and the other 32 died before the feeding stage.

In 1974, 3 heterozygous females (My. Het. 72♀, Nos. 4~6) were mated with

3 heterozygous males (My. Het. 72♂, Nos. 2~4) and a normal male collected from the field. The heterozygous males and females were those produced in 1972 from a female albino by mating with a normal male. In 3 matings between these heterozygous males and females, that is, My. Het. 72♀, No. 4×My. Het. 72♂, No. 2, My. Het. 72♀, No. 5×My. Het. 72♂, No. 3 and My. Het. 72♀, No. 6×My. Het. 72♂, No. 4, 78% of 322 eggs cleaved normally. Most of these eggs developed normally during the embryonic stage and 71% hatched. Of the hatched tadpoles, 138 (60.3%) were of the wild type and 91 (39.7%) albinos. The fact that the albino tadpoles were unexpectedly numerous in these matings may be attributable to the high inseminating capacity of the spermatozoa carrying the albino gene. Many tadpoles died before the feeding stage; 160 tadpoles metamorphosed normally. Of the metamorphosed frogs, 108 were of the wild type and 52 albinos. These figures show that the albino tadpoles were somewhat inferior to the wild-type in viability, as 39 of the 91 albinos died, while 30 of the 138 wild-type tadpoles perished.

In three matings between the 3 heterozygous females and a normal male, 70% of 171 eggs cleaved normally, and afterwards 51% and 42% hatched and metamorphosed, respectively. All these tadpoles and frogs were of the wild type.

In 1975, a male albino (My. Alb. 74♂, No. 1) obtained in 1974 from a mating between a heterozygous female and a heterozygous male was mated with a normal female from the field. In this mating, 99% of 412 eggs cleaved normally, while 83% of 136 control eggs did so. Of the eggs inseminated by sperm of the male albino, 84% and 63% hatched and metamorphosed, respectively. In the control mating, 79% and 77% hatched and metamorphosed, respectively. Accordingly, it was clear that the individuals produced from the male albino were somewhat inferior to the controls in viability during the tadpole stage. The tadpoles and frogs produced from the mating between the normal female and the male albino were all of wild type.

2. Tojo (Tj) stock

A total of 12 albinos were discovered at a rice-field in Tojo-cho, Hiba-gun, Hiroshima Prefecture in 1970. Five of them were reared until their sexual ma-

TABLE 3
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1971	Tj. Alb. 70, No. 1	Tj. Alb. 70, No. 1	249	193 (77.5%)
		Wild 71, No. 4	81	63 (77.8%)
	Wild 71, Nos. 1~3	Tj. Alb. 70, No. 1	579	569 (98.2%)
		Wild 71, No. 4	94	81 (86.2%)

turity; two were females and three males. From these albinos, numerous heterozygous frogs were produced by mating with normal frogs from the field. Using some of the heterozygous frogs and their offspring, many mating experiments were performed during the years 1971 to 1975 in order to obtain albino frogs (Table 3).

a. Matings between male and female albinos

Five matings in total were performed: one between a female (Tj. Alb. 70♀, No. 1) and a male (Tj. Alb. 70♂, No. 1) in 1971 and four between 4 females (Tj. Alb. 74♀, Nos. 3~6) and a male (Tj. Alb. 74♂, No. 4) in 1975. As a result, 73% of 2074 eggs in the 5 matings cleaved normally. About half the number of normally cleaved eggs died of edema, underdevelopment or some other abnormalities during the embryonic stage; 37% hatched normally. These hatched tadpoles were all albinos. In 1971, 121 hatched tadpoles obtained by the single mating all died of edema before the feeding stage. In the 4 matings performed in 1975, 36% of 1825 eggs hatched normally, while 466 tadpoles died of edema or underdevelopment at the tadpole stage, 188 (10.3%) metamorphosed normally at the ages of 50~75 days, 63.7 days on the average.

b. Matings between female albinos and normal males

In 1971 and 1972, 2 female albinos (Tj. Alb. 70♀, Nos. 1 and 2) were mated with 2 normal males from the field. As a result, 77% of 143 eggs cleaved normally and afterwards 53% hatched. All these tadpoles were of the normal type. While all the hatched tadpoles produced from one female albino (No. 1) in 1971 died before the feeding stage, only 5 of 41 tadpoles produced from the other female albino (No. 2) in 1972 died of edema and the other 36 metamorphosed normally at the age of 50~70 days, 60.1 days on the average.

c. Matings between female albinos and heterozygous males

In 1972, a female albino (Tj. Alb. 70♀, No. 2) was mated with 2 heterozygous males (Tj. Het. 71♂, Nos. 1 and 2) that were produced in 1971 from a mating between a normal female and a male albino. Of 160 eggs, 63% cleaved

individuals for an albino gene in the Tj stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
121 (48.6%)	0	121	0	0	0
35 (43.2%)	35	0	0	0	0
562 (97.1%)	562	0	477 (82.4%)	477	0
76 (80.9%)	76	0	63 (67.0%)	63	0

TABLE 3. Continued

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1972	Tj. Alb. 70, No. 2	Tj. Het. 71, Nos. 1, 2	160	101 (63.1%)
		Wild 72, No. 5	62	47 (75.8%)
	Tj. Het. 71, Nos. 1~3	Tj. Het. 71, Nos. 3~5	551	425 (77.1%)
1973	Tj. Het. 72, No. 4	Tj. Alb. 72, No. 2	35	34 (97.1%)
	Wild 73, No. 8	Tj. Alb. 72, No. 2	77	50 (64.9%)
	Tj. Het. 72, No. 5	Tj. Alb. 72, No. 3	30	9 (30.0%)
		Wild 73, No. 6	52	13 (25.0%)
	Wild 73, No. 8	Wild 73, No. 6	54	52 (96.3%)
1974	Tj. Het. 73, No. 6	Tj. Het. 73, No. 6	231	219 (94.8%)
		Wild 74, No. 7	126	102 (81.0%)
	Tj. Het. 73, No. 7	Tj. Het. 73, No. 7	164	137 (83.5%)
		Wild 74, No. 7	75	71 (94.7%)
1975	Tj. Alb. 74, Nos. 3~6	Tj. Alb. 74, No. 4	1825	1320 (72.8%)
	Wild 75, Nos. 16~18	Tj. Alb. 74, No. 4	482	428 (88.8%)
	Wild 75, Nos. 16~18	Wild 75, No. 10	136	113 (83.1%)
Total	Tj. Albino, Nos. 1~6	Tj. Albino, Nos. 1, 4	2074	1513 (73.0%)
		Tj. Hetero, Nos. 1, 2	160	101 (63.1%)
		Wild, Nos. 4, 5	143	110 (76.9%)
	Tj. Hetero, Nos. 1~7	Tj. Albino, Nos. 2, 3	65	43 (66.2%)
		Tj. Hetero, Nos. 3~7	946	781 (82.6%)
		Wild, Nos. 6, 7	253	186 (73.5%)
	Wild, Nos. 1~3, 8, 16~18	Tj. Albino, Nos. 1~4	1138	1047 (92.0%)
		Wild, Nos. 4, 6, 10	284	246 (86.6%)

normally, and afterwards 43% hatched. Of these hatched tadpoles, 46 were of the normal type and 22 albinos. The scarcity of albinos that theoretically should be equal to the wild-type tadpoles in ratio may be attributable to their low via-

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
68 (42.5%)	46	22	0	0	0
41 (66.1%)	41	0	36 (58.1%)	36	0
379 (68.8%)	280	99	132 (24.0%)	126	6
29 (82.9%)	15	14	22 (62.9%)	12	10
35 (45.5%)	35	0	30 (39.0%)	30	0
5 (16.7%)	3	2	3 (10.0%)	2	1
13 (25.0%)	13	0	10 (19.0%)	10	0
49 (90.7%)	49	0	42 (77.8%)	42	0
161 (69.7%)	122	39	68 (29.4%)	67	1
59 (46.8%)	59	0	14 (11.1%)	14	0
127 (77.4%)	97	30	86 (52.4%)	69	17
38 (50.7%)	38	0	35 (46.7%)	35	0
654 (35.8%)	0	654	188 (10.3%)	0	188
404 (83.8%)	404	0	320 (66.4%)	320	0
107 (78.7%)	107	0	105 (77.2%)	105	0
775 (37.4%)	0	775	188 (9.1%)	0	188
68 (42.5%)	46	22	0	0	0
76 (53.1%)	76	0	36 (25.2%)	36	0
34 (52.3%)	18	16	25 (38.5%)	14	11
667 (70.5%)	499	168	286 (30.2%)	262	24
110 (43.5%)	110	0	59 (23.3%)	59	0
1001 (88.0%)	1001	0	827 (72.7%)	827	0
232 (81.7%)	232	0	210 (73.9%)	210	0

bility. All the albino tadpoles actually died of edema before the feeding stage.

d. Matings between heterozygous females and male albinos

In 1973, 2 heterozygous females (TJ. Het. 72♀, Nos. 4 and 5) produced in 1972 from a mating between a female albino and a normal male were mated with 2 male albinos (TJ. Het. 72♂, Nos. 2 and 3) produced in 1972 from a mating between a heterozygous female and a heterozygous male. In the 2 matings, 66% of 65 eggs in total cleaved normally. While 9 of the normally cleaved eggs died of various abnormalities, 52% hatched normally. Of the latter, 18 were of the normal type and 16 albinos. During the tadpole stage, 4 wild-type individuals and 5 albinos died of edema. Eventually, 25 tadpoles metamorphosed normally; 14 were of the wild type and 11 albinos. While the wild-type tadpoles metamorphosed at the age of 48~63 days, 50.3 day on the average, the albinos did at the age of 49~70 days, 57.5 days on the average.

e. Matings between heterozygous females and males

Five matings between heterozygous females and males, that is, three between 3 females (TJ. Het. 71♀, Nos. 1~3) and 3 males (TJ. Het. 71♂, Nos. 3~5) in 1972 and two between 2 females (TJ. Het. 73♀, Nos. 6 and 7) and 2 males (TJ. Het. 73♂, Nos. 6 and 7) in 1974, were performed. In these 5 matings, 83% of 946 eggs in total cleaved normally, and afterwards 71% hatched. Of these hatched tadpoles, 499 (74.8%) were of the wild type and 168 (25.2%) albinos, as expected. During the tadpole stage, much more albinos died of edema, underdevelopment or some other abnormalities than wild-type individuals. Twenty-four albinos metamorphosed normally at the age of 52~73 days, 62.1 days on the average, while 262 wild-type tadpoles did so at the age of 48~65 days, 51.6 days on the average. The albinos did not distinctly differ from the wild-type individuals in viability after metamorphosis.

f. Matings between heterozygous females and normal males

In 1973 and 1974, 3 heterozygous females (TJ. Het. 72♀, No. 5 and TJ. Het. 73♀, Nos. 6 and 7) were mated with 2 normal males collected from the field. In the 3 matings, 74% of 253 eggs in total cleaved normally. Many of the normally cleaved eggs died of various abnormalities at the embryonic stage, and 43% hatched. All the tadpoles were of the wild type. Almost half of them died gradually before metamorphosis; 59 (23.3%) metamorphosed at the age of 50~67 days, 51.7 days on the average.

g. Matings between normal females and male albinos

In 1971, 1973 and 1975, 7 normal females from the field were mated with 3 male albinos (TJ. Alb. 70♂, No. 1, TJ. Alb. 72♂, No. 2 and TJ. Alb. 74♂, No. 4). In the seven matings, 92% of 1138 eggs in total cleaved normally, and afterwards 88% hatched. All the hatched tadpoles were of the wild type. Of these tadpoles, 827 (72.7%) metamorphosed normally at the age of 49~60 days, 52.3 days on the average.

h. Control matings

Seven matings between seven normal females and three normal males were performed in 1971, 1973 and 1975 as the control. All the males and females were those collected from the field. In the seven matings, 87% of 284 eggs in total cleaved normally, and afterwards 82% hatched. Of these hatched tadpoles, 210 (73.9%) metamorphosed normally at the age of 48～63 days, 51.2 days on the average.

3. Kake (Kk) stock

Six albino tadpoles were discovered at a rice-field in Kake-cho, Yamagata-gun, Hiroshima Prefecture in 1970. Three of them were brought to the authors' laboratory immediately after metamorphosis and reared there. They sexually matured in the breeding season of 1971; one was a female and two males. This year, the female (Kk. Alb. 70♀, No. 1) was mated with one (Kk. Alb 70♂, No. 1) of the males (Table 4). In this mating, 32% of 327 eggs cleaved normally, and afterwards 28% hatched. All the hatched tadpoles were albinos. However, all of them died of edema or underdevelopment before the feeding stage.

The albino female was mated in the same year with a normal male collected from the field. Although 24% of 238 eggs hatched normally and became wild-type tadpoles, all of them died of edema or underdevelopment before the feeding stage, too.

In 1971, 1972, 1974 and 1975, 11 normal females from the field were mated with 2 male albinos (Kk. Alb. 70♂, Nos. 1 and 2). In the eleven matings, 85% of 3061 eggs in total cleaved normally, and afterwards 72% hatched. These hatched tadpoles were all of the wild type. Many tadpoles died of underdevelopment or edema before metamorphosis. The other 1570 (51.3%) tadpoles metamorphosed at the age of 47～60 days, 51.3 days on the average.

As the control matings, the same 8 normal females as those used in the above matings were mated with 3 normal males in 1971, 1974 and 1975. As a result, 95% of 1099 eggs in total cleaved normally, and afterwards 84% hatched. While many of the hatched tadpoles died of underdevelopment before metamorphosis, 649 (59.1%) metamorphosed normally at the age of 47～58 days, 51.2 days on the average.

In 1973 and 1974, 5 normal females from the field were mated with 6 heterozygous males, of which one (Kk. Het. 71♂, No. 1) was produced in 1971 and five (Kk. Het. 72♂, Nos. 2～6) were in 1972 from matings between normal females and male albinos. In the 6 matings, 51% of 1131 eggs in total cleaved normally. Many of the cleaved eggs died of edema or some other abnormalities in embryonic stages; 36% hatched normally. All the hatched tadpoles were of the wild type. Most of them died of underdevelopment or edema, and 141 (12.5%) metamorphosed at the age of 46～69 days, 52.5 days on the average.

In 1975, 3 females (W♀×Het. 74♂, Nos. 1～3) produced in 1974 from a mating between a normal female and a heterozygous male were mated with a heterozygous male (Kk. Het. 74♂, No. 7) produced in 1974 from a mating between a normal female and a male albino. In the 3 matings, 89% of 800 eggs

TABLE 4

Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1971	Kk. Alb. 70, No. 1	Kk. Alb. 70, No. 1	327	106 (32.4%)
		Wild 71, No. 4	238	67 (28.2%)
	Wild 71, Nos. 1~3	Kk. Alb. 70, No. 1	477	453 (95.0%)
		Wild 71, No. 4	254	230 (90.6%)
1972	Wild 72, Nos. 4~6	Kk. Alb. 70, No. 2	1280	1205 (94.1%)
1973	Wild 73, Nos. 7, 8	Kk. Het. 71, No. 1	237	43 (18.1%)
1974	Wild 74, Nos. 11~13	Kk. Alb. 70, No. 2	414	109 (26.3%)
		Kk. Het. 72, Nos. 2~6	894	538 (60.2%)
		Wild 74, No. 7	142	110 (77.5%)
1975	Wild 75, Nos. 19, 20	Wild 75, No. 10	703	700 (99.6%)
		Kk. Alb. 70, No. 2	890	842 (94.6%)
	(W♀ × Het. ♂)74, No. 1	Kk. Het. 74, No. 7	481	472 (98.1%)
	(W♀ × Het. ♂)74, No. 2	Kk. Het. 74, No. 7	247	214 (86.6%)
	(W♀ × Het. ♂)74, No. 3	Kk. Het. 74, No. 7	72	25 (34.7%)
1976	Kk. Alb. 75, Nos. 2~6	Kk. Alb. 75, No. 3	700	463 (66.1%)
Total	Kk. Albino, Nos. 1~6	Kk. Albino, Nos. 1, 3	1027	569 (55.4%)
		Wild, No. 4	238	67 (28.2%)
	Wild, Nos. 1~8, 11~13, 19, 20	Kk. Albino, Nos. 1, 2	3061	2609 (85.2%)
		Kk. Hetero, Nos. 1~6	1131	581 (51.4%)
	Wild, Nos. 1~3, 11~13 19, 20	Wild, Nos. 4, 7, 10	1099	1040 (94.6%)
	(W♀ × Het. ♂), Nos. 1~3	Kk. Hetero, No. 7	800	711 (88.9%)

in total cleaved normally. Most of the cleaved eggs died of edema or underdevelopment in embryonic stages; 27% hatched normally. Of these hatched tadpoles, 172 were of the wild type and 45 albinos. Many tadpoles died, and 135 (16.9%) metamorphosed; 94 of the latter were of the wild type and 41 albinos. While the wild-type tadpoles metamorphosed at the age of 43~58 days,

individuals for an albino gene in the Kk stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
91 (27.8%)	0	91	0	0	0
56 (23.5%)	56	0	0	0	0
420 (88.1%)	420	0	316 (66.2%)	316	0
220 (86.6%)	220	0	191 (75.2%)	191	0
1008 (78.8%)	1008	0	797 (62.3%)	797	0
39 (16.5%)	39	0	32 (13.5%)	32	0
63 (15.2%)	63	0	34 (8.2%)	34	0
368 (41.2%)	368	0	109 (12.2%)	109	0
77 (54.2%)	77	0	30 (21.1%)	30	0
629 (89.5%)	629	0	428 (60.9%)	428	0
716 (80.4%)	716	0	423 (47.5%)	423	0
200 (41.6%)	157	43	130 (27.0%)	89	41
5 (2.0%)	5	0	0	0	0
12 (16.7%)	10	2	5 (6.9%)	5	0
414 (59.1%)	0	414	213 (30.4%)	0	213
505 (49.2%)	0	505	213 (20.7%)	0	213
56 (23.5%)	56	0	0	0	0
2207 (72.1%)	2207	0	1570 (51.3%)	1570	0
407 (36.0%)	407	0	141 (12.5%)	141	0
926 (84.3%)	926	0	649 (59.1%)	649	0
217 (27.1%)	172	45	135 (16.9%)	94	41

47.5 days on the average, the albinos did at the age of 44~67 days, 53.2 days on the average.

4. Midori (Md) stock

Two albino tadpoles were discovered at a rice-field in Midori-cho, Takata-

TABLE 5
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1972	Wild 72, No. 4	Md. Alb. 71, No. 1	252	243 (96.4%)
	Wild 72, No. 5	Md. Alb. 71, No. 1	264	202 (76.5%)
1973	Md. Het. 72, No. 1	Md. Het. 72, No. 1	30	10 (33.3%)
		Md. Het. 72, No. 2	55	42 (76.4%)
		Wild 73, No. 6	32	21 (65.6%)
	Wild 73, No. 7	Md. Het. 72, No. 1	26	14 (53.8%)
		Md. Het. 72, No. 2	25	11 (44.0%)
		Wild 73, No. 6	66	54 (81.8%)
1975	Wild 75, No. 21	Md. Alb. 73, No. 2	99	93 (93.9%)
	Wild 75, No. 22	Md. Alb. 73, No. 3	196	189 (96.4%)
	Wild 75, No. 23	Md. Alb. 73, No. 3	164	157 (95.7%)
Total	Wild, Nos. 4, 5, 7, 21~23	Md. Albino, Nos. 1~3	975	884 (90.7%)
		Md. Hetero, Nos. 1, 2	51	25 (49.0%)
		Wild, No. 6	66	54 (81.8%)
	Md. Hetero, No. 1	Md. Hetero, Nos. 1, 2	85	52 (61.2%)
		Wild, No. 6	32	21 (65.6%)

gun, Hiroshima Prefecture in 1971. One of them was brought to the authors' laboratory immediately after metamorphosis and reared until sexual maturity; it was a male. In 1972, this male albino was mated with 2 normal females from the field to obtain heterozygous frogs (Table 5). In the 2 matings, 86% of 516 eggs cleaved normally, and afterwards 47% hatched. All these hatched tadpoles were of the wild type. While 80 individuals died of underdevelopment or edema during the tadpole stage, 162 (31.4%) metamorphosed normally at the age of 43~65 days, 52.2 days on the average. Ten frogs matured in 1973; seven were females and three males.

In 1973, these 7 females heterozygous for the albino gene were injected with frog pituitary suspension. Although ovulation occurred in 5 females, one (Md. Het. 72♀, No. 1) of them was mated with 2 heterozygous males (Md. Het. 72♂, Nos. 1 and 2). In the 2 matings, 61% of 85 eggs cleaved normally, and after-

individuals for an albino gene in the MD stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
130 (51.6%)	130	0	79 (31.3%)	79	0
112 (42.4%)	112	0	83 (31.4%)	83	0
8 (26.7%)	6	2	5 (16.7%)	4	1
35 (63.6%)	26	9	17 (30.9%)	11	6
19 (59.4%)	19	0	15 (46.9%)	15	0
11 (42.3%)	11	0	7 (26.9%)	7	0
8 (32.0%)	8	0	5 (20.0%)	5	0
50 (75.8%)	50	0	41 (62.1%)	41	0
89 (89.9%)	89	0	48 (48.5%)	48	0
149 (76.0%)	149	0	114 (58.2%)	114	0
138 (84.1%)	138	0	111 (67.7%)	111	0
618 (63.4%)	618	0	435 (44.6%)	435	0
19 (37.3%)	19	0	12 (23.5%)	12	0
50 (75.8%)	50	0	41 (62.1%)	41	0
43 (50.6%)	32	11	22 (25.9%)	15	7
19 (59.4%)	19	0	15 (46.9%)	15	0

wards 51% hatched. Of the tadpoles, 32 were of the wild type and 11 albinos. While 17 wild-type and 4 albino tadpoles died of underdevelopment before the metamorphosing stage, 15 wild-type and 7 albino tadpoles metamorphosed normally. While the wild-type tadpoles metamorphosed at the age of 43~58 days, 47.5 days on the average, the albinos did at the age of 44~67 days, 53.2 days on the average. In a mating between the same heterozygous female (MD. Het. 72♀, No. 1) and a normal male from the field, 66% of 32 eggs cleaved normally and 59% hatched afterwards. Eventually, 15 (46.9%) metamorphosed at the age of 40~47 days, 43.7 days on the average.

In the same year, a normal female collected from the field was mated with two (MD. Het. 72♂, Nos. 1 and 2) of the 3 mature heterozygous males obtained in the same year. In the 2 matings, 49% of 51 eggs in total cleaved normally and afterwards 37% hatched. The hatched tadpoles were all of the wild type.

Twelve of them metamorphosed normally at the age of 42～49 days, 44.6 days on the average. In a mating between a normal female and a normal male from the field, 82% of 66 eggs cleaved normally and afterwards 76% hatched. Forty-one (62.1%) of them metamorphosed normally at the ages of 33～48 days, 37.5 days on the average.

In 1975, 3 matings between 3 normal females from the field and 2 male albinos (MD. Alb. 73♂, Nos. 2 and 3) produced in 1973 from a mating between a heterozygous female and a heterozygous male were performed. In these matings, 96% of 459 eggs in total cleaved normally and afterwards 82% hatched. A little less than one-third of the hatched tadpoles died before the metamorphosing

TABLE 6
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1973	YsI. Alb. 72, No. 1	YsI. Alb. 72, No. 1	24	16 (66.7%)
		Wild 73, No. 6	31	17 (54.8%)
	Wild 73, No. 9	YsI. Alb. 72, No. 1	50	32 (64.0%)
	Wild 73, Nos. 9, 10	YsI. Alb. 72, No. 2	89	51 (57.3%)
	Wild 73, No. 9	Wild 73, No. 6	53	43 (81.1%)
1974	YsI. Alb. 72, No. 1	YsI. Het. 73, No. 1	103	93 (90.3%)
		YsI. Alb. 72, No. 1	194	189 (97.4%)
	Wild 74, Nos. 14, 15	YsI. Alb. 72, No. 1	314	266 (84.7%)
		Wild 74, No. 7	142	110 (77.5%)
1975	YsI. Het. 74, No. 1	YsI. Het. 74, No. 2	414	264 (63.8%)
	YsI. Het. 74, No. 2	YsI. Het. 74, No. 3	331	268 (81.0%)
	YsI. Het. 74, No. 3	YsI. Het. 74, No. 4	207	110 (53.1%)
Total	YsI. Albino, No. 1	YsI. Albino, No. 1	218	205 (94.0%)
		YsI. Hetero, No. 1	103	93 (90.3%)
		Wild, No. 6	31	17 (54.8%)
	YsI. Hetero, Nos. 1～3	YsI. Hetero, Nos. 2～4	952	642 (67.4%)
	Wild, Nos. 9, 10, 14, 15	YsI. Albino, Nos. 1, 2	453	349 (77.0%)
		Wild, Nos. 6, 7	195	153 (78.5%)

stage, and 273 (59.5%) metamorphosed normally at the age of 41~63 days, 43.3 days on the average.

5. Yasuura I (YsI) stock

Twelve albino tadpoles were discovered in 1963 at place A, Yasuura-cho, Toyota-gun, Hiroshima Prefecture. An albino tadpole was later discovered in 1969 at place B of the same town. Eight albino tadpoles were again discovered in 1972 at place C of the same town. All these tadpoles were reared in the authors' laboratory. Although all of them metamorphosed normally, the 13 albinos collected in 1963 and 1969 died before sexual maturity. Five of the 8 albinos

individuals for an albino gene in the YsI stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
12 (50.0%)	0	12	2 (8.3%)	0	2
10 (32.3%)	10	0	6 (19.4%)	6	0
31 (62.0%)	31	0	17 (34.0%)	17	0
41 (46.1%)	41	0	28 (31.5%)	28	0
40 (75.5%)	40	0	35 (66.0%)	35	0
37 (35.9%)	19	18	13 (12.6%)	7	6
119 (61.3%)	0	119	15 (7.7%)	0	15
103 (32.8%)	103	0	79 (25.2%)	79	0
77 (54.2%)	77	0	56 (39.4%)	56	0
248 (60.0%)	191	57	195 (47.1%)	156	39
241 (72.8%)	179	62	178 (53.8%)	122	56
96 (46.4%)	68	28	86 (41.5%)	61	25
131 (60.1%)	0	131	17 (7.8%)	0	17
37 (35.9%)	19	18	13 (12.6%)	7	6
10 (32.3%)	10	0	6 (19.4%)	6	0
585 (61.4%)	438	147	459 (48.2%)	339	120
175 (38.6%)	175	0	124 (27.4%)	124	0
117 (60.0%)	117	0	91 (46.7%)	91	0

collected in 1972 matured sexually in the next year; two were females and three males. These albinos and their offspring were named Yasuura I (YsI) stock.

In 1973 and 1974, 2 matings were made between an albino female (YsI. Alb. 72♀, No. 1) and an albino male (YsI. Alb. 72♂, No. 1) by artificial fertilization (Table 6). As a result, 94% of 218 eggs in total cleaved normally. In embryonic stages, about one-third of the normally cleaved eggs died of edema, and 60% hatched. These hatched tadpoles were all albinos. Only 17 of them metamorphosed normally, while the others died of underdevelopment before the metamorphosing stage. Fifteen of the frogs were produced from the mating in 1974 and metamorphosed at the age of 45~60 days, 50.5 days on the average. Seven of them attained sexual maturity; four were females and three males.

In 1974, the same female albino was mated with a heterozygous male (YsI. Het. 73♂, No. 1) produced in 1973 from a mating between a female albino and a normal male from the field. In this mating, 90% of 103 eggs cleaved normally. Most of the normally cleaved eggs died of edema, and 36% hatched normally. Of the latter, 19 were of the wild type and 18 albinos as expected. Many of the wild-type as well as the albino tadpoles died of edema before the feeding stage. Eventually, 7 wild-type and 6 albino tadpoles metamorphosed normally at the age of 42~45 days, 43.7 days on the average, and 43~45 days, 44.1 days on the average, respectively.

In a mating performed in 1973 between the same female albino and a normal male from the field, 55% of 31 eggs cleaved normally, and afterwards 32% hatched. All the hatched tadpoles were of the wild type. Six of them metamorphosed normally.

In 1973 and 1974, 4 females from the field were mated with 2 male albinos (YsI. Alb. 72♂, Nos. 1 and 2). In the four matings, 77% of 453 eggs in total cleaved normally, and afterwards 39% hatched. All the hatched tadpoles were of the wild type. While 65 tadpoles died of various abnormalities before the hatching stage, the other 124 (27.4%) metamorphosed normally. Of the latter, 79 produced in 1974 metamorphosed at the age of 42~45 days, 43.2 days on the average.

In 1975, matings were performed between 3 heterozygous females (YsI. Het. 74♀, Nos. 1~3) and 3 heterozygous males (YsI. Het. 74♂, Nos. 2~4). These males and females were those produced in 1974 from a mating between a normal female from the field and a male albino (YsI. Alb. 72♂, No. 1). In the three matings, 67% of 952 eggs in total cleaved normally. While many of the normally cleaved eggs died of edema, underdevelopment or some other abnormalities at the embryonic stage, 61% hatched normally. Of these hatched tadpoles, 438 (74.9%) were of the wild type, and 147 (25.1%) albinos. Before the metamorphosing stage a small number of the tadpoles died of various abnormalities. Eventually, 459 (48.2%) metamorphosed normally; 339 wild-type tadpoles metamorphosed at the age of 43~60 days, 47.2 days on the average, and 120 albinos did at the age of 43~70 days, 52.5 days on the average.

In three control matings performed in 1973 and 1974 between 3 females and

2 males collected from the field, 78% of 195 eggs in total cleaved normally, and afterwards 60% hatched. After a small number of tadpoles died of various abnormalities, 47% metamorphosed normally at the age of 43~58 days, 47.5 days on the average.

6. Yasuura II (YsII) stock

Twelve albino tadpoles were collected from place D in Yasuura-cho, Toyota-gun, Hiroshima Prefecture in 1972. This place is a rice-field about 500 m apart from place C in Yasuura-cho from where the Yasuura I stock were collected. In the next year, 21 albino tadpoles were again discovered at place D. All the albino tadpoles collected in 1972 and 1973 were reared in the authors' laboratory. As a result, 10 of the 12 tadpoles obtained in 1972 and all the 21 tadpoles in 1973 metamorphosed normally and attained sexual maturity. Of the 10 albinos collected in 1972, three were females and seven males. On the other hand, only two of the 21 albinos collected in 1973 were females, and 19 were males.

In 1973 and 1974, 3 matings were made between 3 female and 3 male albinos (Table 7). In two matings performed in 1973 between 2 females (YsII. Alb. 72♀, Nos. 1 and 2) and 2 males (YsII. Alb. 72♂, Nos. 1 and 2), 68% of 175 eggs in total cleaved normally. Of the normally cleaved eggs, 112 (64.0%) hatched and seven died of edema in embryonic stages. All the hatched tadpoles were albinos. These albinos all died of underdevelopment or edema before the feeding stage. In a mating performed in 1974 between a female albino (YsII. Alb. 72♀, No. 3) and a male albino (YsII. Alb. 72♂, No. 3), 90% of 165 eggs cleaved normally. Of the normally cleaved eggs, 89 died of edema in embryonic stages, and 59 (35.8%) hatched normally. All the hatched tadpoles were albinos, and only eight (4.8%) of them metamorphosed normally at the age of 47~63 days, 58.3 days on the average.

In 1973, one (YsII. Alb. 72♀, No. 2) of the two female albinos was mated with a normal male from the field. In this mating, 63% of 56 eggs cleaved normally, and afterwards 59% hatched. All the hatched tadpoles were of the wild type. Only five of them metamorphosed normally, while the others died of edema before the metamorphosing stage.

In 1974 and 1975, three matings were made between three heterozygous females and two male albinos; two of these matings were between two females (YsII. Het. 73♀, Nos. 1 and 3) and a male (YsII. Alb. 72♂, No. 4) from the field, and the other mating was between a female (YsII. Het. 74♀, No. 4) and a male (YsII. Alb. 74♂, No. 5) obtained by mating a heterozygous female with a heterozygous male. As a result, 89% of 462 eggs in total cleaved normally. While 95 of the normally cleaved eggs died of edema, underdevelopment or some other abnormalities in embryonic stages, the other 316 hatched normally. Of these hatched tadpoles, 162 (51.3%) were of the wild type and 154 (48.7%) albinos. While 23 wild-type and 40 albino tadpoles died of edema or underdevelopment before the metamorphosing stage, the others metamorphosed nor-

TABLE 7
Production of homo- or heterozygous individuals

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1973	YsII. Alb. 72, No. 1	YsII. Alb. 72, No. 1	92	46 (50.0%)
	YsII. Alb. 72, No. 2	YsII. Alb. 72, No. 2	83	73 (88.0%)
		Wild, 73, No. 6	56	35 (62.5%)
	Wild 73, No. 8	YsII. Alb. 72, Nos. 1, 2	86	33 (38.4%)
1974	YsII. Alb. 72, No. 3	YsII. Alb. 72, No. 3	165	148 (89.7%)
	YsII. Het. 73, No. 1	YsII. Alb. 72, No. 4	93	83 (89.2%)
	YsII. Het. 73, No. 2	YsII. Het. 73, No. 1	265	246 (92.8%)
	YsII. Het. 73, No. 3	YsII. Alb. 72, No. 4	205	165 (80.5%)
	Wild 74, Nos. 11, 12	YsII. Alb. 72, No. 3	354	301 (85.0%)
	Wild 74, No. 13	YsII. Alb. 72, No. 4	189	133 (70.4%)
		Wild 74, No. 8	167	129 (77.2%)
1975	YsII. Het. 74, No. 4	YsII. Alb. 74, No. 5	164	163 (99.4%)
	Wild 75, No. 16	YsII. Alb. 74, No. 5	255	234 (91.8%)
Total	YsII. Albino, Nos. 1～3	YsII. Albino, Nos. 1～3	340	267 (78.5%)
		Wild, No. 6	56	35 (62.5%)
	YsII. Hetero, Nos. 1～4	YsII. Albino, Nos. 4, 5	462	411 (89.0%)
		YsII. Hetero, No. 1	265	246 (92.8%)
	Wild, Nos. 8, 11～13, 16	YsII. Albino, Nos. 1～5	884	701 (79.3%)
		Wild, No. 8	167	129 (77.2%)

mally. Of the latter, 139 wild-type tadpoles metamorphosed at the age of 43～58 days, 47.5 days on the average, and 114 albinos did at the age of 43～67 days, 53.2 days on the average.

In 1974, a mating between a heterozygous female (YsII. Het. 73♀, No. 2) and a heterozygous male (YsII. Het. 73♂, No. 1) was made. In this mating, 93% of 265 eggs cleaved normally, and afterwards 77% hatched. Of the hatched tadpoles, 152 (74.1%) were of the wild type and 53 (25.9%) albinos, as expected. After a small number of tadpoles died of various abnormalities by the metamorphosing stage, 156 (58.9%) metamorphosed normally; 116 wild-type and 40

for an albino gene in the YsII stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
41 (44.6%)	0	41	0	0	0
71 (85.5%)	0	71	0	0	0
33 (58.9%)	33	0	5 (8.9%)	5	0
26 (30.2%)	26	0	16 (18.6%)	16	0
59 (35.8%)	0	59	8 (4.8%)	0	8
60 (64.5%)	34	26	53 (57.0%)	31	22
205 (77.4%)	152	53	156 (58.9%)	116	40
106 (51.7%)	56	50	78 (38.0%)	43	35
181 (51.1%)	181	0	149 (42.1%)	149	0
79 (41.8%)	79	0	39 (20.6%)	39	0
123 (73.7%)	123	0	102 (61.1%)	102	0
150 (91.5%)	72	78	122 (74.4%)	65	57
210 (82.4%)	210	0	170 (66.7%)	170	0
171 (50.3%)	0	171	8 (2.4%)	0	8
33 (58.9%)	33	0	5 (8.9%)	5	0
316 (68.4%)	162	154	253 (54.8%)	139	114
205 (77.4%)	152	53	156 (58.9%)	116	40
496 (56.1%)	496	0	374 (42.3%)	374	0
123 (73.7%)	123	0	102 (61.1%)	102	0

albino tadpoles metamorphosed at the age of 43～62 days, 47.2 days on the average and of 43～70 days, 52.4 days on the average, respectively.

In 1973, 1974 and 1975, five normal females from the field were mated with the five male albinos (YsII. Alb. 72♂, Nos. 1 and 2, YsII. Alb. 72♂, Nos. 3 and 4 and YsII. Alb. 74♂, No. 5). In these five matings, 79% of 884 eggs in total cleaved normally, and afterwards 56% hatched normally. The others of the normally cleaved eggs died of edema, underdevelopment or some other abnormalities in embryonic stages. All the hatched tadpoles were of the wild type. After most of the tadpoles died of edema or underdevelopment, 374 (42.3%)

metamorphosed at the age of 40~61 days, 50.9 days on the average.

In the control mating performed in 1974 between a normal female and a normal male collected from the field, 77% of 167 eggs cleaved normally, and afterwards 74% hatched. Of the hatched tadpoles, 102 (61.1%) metamorphosed at the age of 43~58 days, 47.7 days on the average.

7. Saijo (SJ) stock

Five albino tadpoles were discovered at a rice-field in Saijo-cho, Higashihiroshima City, Hiroshima Prefecture in 1974. Four of them were reared in our laboratory; 3 attained sexual maturity. One was a female and the other two were males.

In 1975, three matings were performed between 3 normal females from the field and one (SJ. Alb. 74♂, No. 1) of the two male albinos. In these matings, 83% of 842 in total cleaved normally (Table 8). While many of the normally cleaved eggs died of various abnormalities at the embryonic stage, 52% hatched

TABLE 8
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1975	Wild 75, Nos. 21~23	SJ. Alb. 74, No. 1	842	701 (83.3%)
1976	SJ. Het. 75, Nos. 1, 2	SJ. Het. 75, Nos. 1, 2	369	334 (90.5%)

TABLE 9
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1975	NM. B-Alb. 74, No. 1	NM. B-Alb. 74, No. 1	325	212 (65.2%)
		Wild 75, No. 10	56	32 (57.1%)
	Wild 75, Nos. 21~23	NM. B-Alb. 74, No. 1	474	328 (69.2%)
		Wild 75, No. 10	42	30 (71.4%)
1976	Wild 76, No. 24	NM. R-Alb. 75, No. 2	297	257 (86.5%)
	NM. B-Alb. 75, No. 2	Gynogenetic Dip., No. 2	622	86 (13.8%)
	NM. B-Alb. 75, No. 3	Gynogenetic Dip., No. 3	55	24 (43.6%)
	NM. B-Alb. 75, No. 4	Gynogenetic Dip., No. 4	61	26 (42.6%)
	NM. Het. 75, No. 1	NM. Het. 75, No. 1	—	—
	NM. Het. 75, No. 2	NM. Het. 75, No. 2	—	—

normally. All the hatched tadpoles were of the wild type. Of these tadpoles, 255 metamorphosed normally at the age of 32~39 days, 34.6 days on the average, while the other 181 died of edema or underdevelopment during the tadpole stage.

In 1976, two matings between 2 heterozygous females (SJ. Het. 75♀, Nos. 1 and 2) and 2 heterozygous males (SJ. Het. 75♂, Nos. 1 and 2) were made. In these matings, 91% of 369 eggs cleaved normally, and afterwards 86% hatched. Of the hatched tadpoles, 250 (78.9%) were of the wild type and 67 (21.1%) were albinos.

8. Niimi (NM) stock

About 30 albino tadpoles were discovered in the suburbs of Niimi City, Okayama Prefecture in 1974. Dr. MORIYA, Okayama University, reared them and made them sexually matured. In the breeding season of 1975, he gave the authors six of them; two were females and four males. All these albinos were pe-

individuals for an albino gene in the SJ stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
436 (51.8%)	436	0	255 (30.3%)	255	0
317 (85.9%)	250	67			

individuals for an albino gene in the NM stock

No. of hatched tadpoles				No. of frogs			
Total	Wild	Albino		Total	Wild	Albino	
		Red-eyed	Black-eyed			Red-eyed	Black-eyed
146 (44.9%)	0	38	108	44 (13.5%)	0	6	38
30 (53.6%)	30	0	0	22 (39.3%)	22	0	0
299 (63.1%)	299	0	0	191 (40.3%)	191	0	0
28 (66.7%)	28	0	0	22 (52.4%)	22	0	0
232 (78.1%)	232	0	0	198 (66.7%)	198	0	0
44 (7.1%)	0	13	31				
4 (7.3%)	0	2	2				
7 (11.5%)	0	3	4				
210	162	0	48				
455	342	0	113				

culiar in having reddish black eyes. In the same year, one of the 2 females ovulated normally after pituitary injection. All the eggs were normal in color. A mating was performed between a female albino (NM. B-Alb. 74♀, No. 1) and a male one (NM. B-Alb. 74♂, No. 1). In this mating, 65% of 325 eggs cleaved normally, and afterwards 45% hatched, while 20% died of edema, underdevelopment or some other abnormalities in embryonic stages. All the hatched tadpoles were albinos; 38 (26.0%) had red eyes, and the other 108 (74.0%) had black eyes (Table 9). While most of these tadpoles died also of edema, underdevelopment or some other abnormalities by the metamorphosing stage, 44 metamorphosed normally. Of the black-eyed albino tadpoles, 70 died and the other 38 metamorphosed at the ages of 27~43 days, 33.1 days on the average. Of the red-eyed albinos, six metamorphosed at the age of 27~31 days, 29.6 days on the average, while 32 died during the tadpole stage.

At the same time as the above mating was made, three matings were done between 3 normal females from the field and the male albino (NM. B-Alb. 74♂, No. 1) to produce heterozygous frogs. In these matings, 69% of 474 eggs in total cleaved normally, and afterwards 63% hatched. Although all the hatched tadpoles were of the wild type, 108 of them died of underdevelopment or some other abnormalities. Eventually, 191 (40.3%) metamorphosed normally at the age of 30~37 days, 33.7 days on the average.

In 1976, a mating between a male red-eyed albino (NM. R-Alb. 75♂, No. 2) and a normal female (Wild. 76♀, No. 24) from the field was made. In this mating, 87% of 297 eggs cleaved normally, and afterwards 78% hatched. All the hatched tadpoles were of the wild type.

In this year, 3 female black-eyed albinos (NM. B-Alb. 75♀, Nos. 2~4) ovulated normally by injection of frog pituitary suspension. Eggs were normal in color. They were induced to develop by diploid gynogenesis. Of 738 eggs taken out of the three females, 18% cleaved normally, and afterwards 7% hatched normally, while the others died of various abnormalities in embryonic stages. Of the hatched tadpoles, 18 were red-eyed albinos and 37 were black-eyed ones. The scarcity of the red-eyed albinos which should theoretically be equal to the black-eyed albinos in number is probably attributable to their weakness, especially at low temperature.

In the same year, 2 heterozygous females (NM. Het. 75♀, Nos. 1 and 2) obtained in 1975 from a mating between a normal female and a male albino (NM.

TABLE 10
Production of heterozygous individuals

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1975	Wild 75, Nos. 21~23	YMI. Alb. 74, No. 1	1277	889 (69.6%)
1976	Wild 76, Nos. 24, 25	YMI. Alb. 74, No. 2	333	228 (68.5%)

B-Alb. 74♂, No. 1) were mated with 2 heterozygous males (NM. Het. 75♂, Nos. 1 and 2) obtained from the same mating. As a result, 665 hatched tadpoles were obtained; 504 (75.8%) of them were of the wild type and 161 (24.2%) were black-eyed albinos.

9. Yamaguchi I (YmI) stock

In 1974, 3 albino tadpoles were discovered in the suburbs of Yamaguchi City. They were reared and matured by Dr. SAMBUICHI, Yamaguchi University in his laboratory. One was a female and the other two were males. He gave the authors all these albinos in the breeding season of 1975. As no ovulation occurred in the female albino by injection of frog pituitary suspension, one of the male albinos was mated with 3 normal females collected from the field to produce heterozygous frogs (Table 10). In the three matings, 70% of 1277 eggs in total cleaved normally. After 168 of the normally cleaved eggs died of edema, underdevelopment or some other abnormalities, 56% hatched. All the hatched tadpoles were of the wild type. Nearly half of the tadpoles died of abnormalities similar to those found in embryonic stages; 374 (29.3%) metamorphosed normally at the age of 31～43 days, 36.3 days on the average.

In 1976, two matings were made between 2 normal females from the field and the remaining male albino (YmI. Alb. 74♂, No. 2) in order to produce heterozygous frogs. In these matings, 68% of 333 eggs cleaved normally, and afterwards 68% hatched. All the hatched tadpoles were of the wild type.

10. Yamaguchi II (YmII) stock

In June, 1975, 22 albino tadpoles were collected from the suburbs of Yamaguchi City by Dr. SAMBUICHI. After they had been reared by him until the completion of metamorphosis, 19 of them were given to the authors. Most of them died shortly after metamorphosis, owing to their constitutional weakness; only six frogs matured. After metamorphosed frogs began to take food, their back became tinged with green. This green gradually became deeper with the growth of the frog. At the sexually mature stage, the one-time albinos were hardly distinguishable from wild-type frogs in dorsal color, except that their back was still partially whitish and their eyes were not deep black. Of the 6 mature albinos, 3 were females and 3 males. The authors named the albinos of the Yamaguchi II stock the colored albinos, as they have a coloring gene which pro-

for an albino gene in the YmI stock

No. of hatched tadpoles			No. of frogs		
Total	Wild	Albino	Total	Wild	Albino
721 (56.5%)	721	0	374 (29.3%)	374	0
225 (67.6%)	225	0	198 (59.5%)	198	0

TABLE 11
Production of homo- or heterozygous

Year	Parents		No. of eggs	No. of normal cleavages
	Female	Male		
1976	YmII. C-Alb. 75, No. 1	YmII. C-Alb. 75, No. 1	69	53 (76.8%)
		Wild 76, No. 11	41	23 (56.1%)
	YmII. C-Alb. 75, No. 2	YmII. C-Alb. 75, No. 2	154	133 (86.4%)
		Wild 76, No. 11	59	47 (79.7%)
	Wild 76, Nos. 24, 25	YmII. C-Alb. 75, Nos. 1, 2	178	96 (53.9%)

duce melanin in the dorsal skin and the eyeball.

In 1976, 2 of the 3 mature females ovulated normally after pituitary injection. All the eggs were white and quite similar in appearance to those of red-eyed albinos. Matings were made between these two females (YmII. C-Alb. 75♀, Nos. 1 and 2) and two males (YmII. C-Alb. 75♂, Nos. 1 and 2) of the same stock (Table 11). As a result, 83% of 223 eggs cleaved normally. While 95 normally cleaved eggs died of various abnormalities in embryonic stages, 91 (40.8%) hatched normally and became swimming tadpoles. Of the latter, 64 were colored albinos which were similar to those collected from the suburbs of Yamaguchi City, and the other 27 were red-eyed albinos. These two kinds of albinos should theoretically be produced in a ratio of 3: 1, although the actual number of colored albinos was somewhat smaller than the expected one.

The same two females were mated with two normal males collected from the field. As a result, 70% of 100 eggs cleaved normally. Thirty of the normally cleaved eggs hatched normally, while 40 died of various abnormalities during the embryonic stage. All the tadpoles were of the wild type. The white eggs of the females belonging to the YmII stock were low in developmental capacity like those of the other albino stocks.

Matings were made between the two male colored albinos (YmII. C-Alb. 75♂, Nos. 1 and 2) and two normal females collected from the field. As a result, 54% of 178 eggs cleaved normally, and 51% hatched. All the hatched tadpoles were of the wild type.

II. Matings among the ten stocks

1. Females of the TJ stock and males of eight other stocks

During the years 1971~1976, matings were performed between female albinos or heterozygous females of TJ stock and male albinos or heterozygous males of nine stocks (Table 12). The female albinos of the TJ stock produced albino tadpoles alone by mating with male albinos of the TJ, YsI, SJ or NM stock and

individuals for an albino gene in the YmII stock

No. of hatched tadpoles				No. of frogs			
Total	Wild	Albino		Total	Wild	Albino	
		Red-eyed	Colored			Red-eyed	Colored
24 (34.8%)	0	8	16				
12 (29.3%)	12	0	0	10 (24.4%)	10	0	0
67 (43.5%)	0	19	48				
18 (30.5%)	18	0	0	15 (25.4%)	15	0	0
91 (51.1%)	91	0	0	40 (22.5%)	40	0	0

wild-type tadpoles alone by mating with male albinos of the YsII, Md, Kk, My or YmI stock. Of 376 albino tadpoles produced from 3 matings between 3 female albinos of the Tj stock and a male black-eyed albinos of the Nm stock, 174 were red-eyed and the other 202 black-eyed albino tadpoles. Heterozygous females of the Tj stock produced nearly equal number of wild-type and albino tadpoles by mating with male albinos of the YsI stock, and wild-type tadpoles alone by mating with male albinos of the YsII or Kk stock, heterozygous males of the

TABLE 12

Results of the matings between females of the Tj stock and males of eight other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
Tj. Alb., Nos. 1～5	Tj. Alb., Nos. 1, 4	2074	1521 (73.3%)	775 (37.4%)	0	775	0
Tj. Alb., No. 2	YsI. Alb., No. 2	154	111 (72.1%)	94 (61.0%)	0	94	0
Tj. Alb., Nos. 3～5	Sj. Alb., No. 1	622	614 (97.7%)	466 (74.9%)	0	466	0
Tj. Alb., Nos. 3～5	Nm. B-Alb., No. 1	675	618 (91.6%)	376 (55.7%)	0	174	202
Tj. Alb., No. 2	YsII. Alb., No. 1	101	63 (62.4%)	52 (51.5%)	52	0	0
Tj. Alb., No. 2	Md. Alb., No. 1	125	97 (77.6%)	81 (64.8%)	81	0	0
Tj. Alb., No. 1	Kk. Alb., No. 2	161	135 (83.9%)	93 (57.8%)	93	0	0
Tj. Alb., No. 3	My. Alb., No. 1	217	186 (85.7%)	122 (56.2%)	122	0	0
Tj. Alb., Nos. 3～5	YmI. Alb., No. 1	774	749 (96.8%)	582 (75.2%)	582	0	0
Tj. Het., Nos. 3～5	YsI. Alb., Nos. 1～4	286	221 (77.3%)	148 (51.7%)	71	77	0
Tj. Het., Nos. 3～5	YsII. Alb., Nos. 1～4	186	124 (66.7%)	99 (53.2%)	99	0	0
Tj. Het., Nos. 4, 5	Md. Het., Nos. 1, 2	128	101 (78.9%)	65 (50.8%)	65	0	0
Tj. Het., Nos. 6, 7	(My. Alb. ♀ × Md. Alb. ♂), No. 1	116	76 (65.5%)	60 (51.7%)	60	0	0
Tj. Het., Nos. 6, 7	Kk. Alb., No. 2	165	151 (91.5%)	104 (63.0%)	104	0	0

MD stock or a male obtained from a mating between a female albino of the MY stock and a male albino of the MD stock. From the results of these matings, it was evident that the TJ stock differs from the YsII, MD, KK, MY and YMI stocks in the kind of albino genes.

2. Females of the MY stock and males of nine other stocks

During the years 1972~1976, matings were made between female albinos or heterozygous females of the MY stock and male albinos of the TJ, YsI, YsII, MD, KK, YMI and YMII, or heterozygous males of the TJ, KK, MD, YMI, SJ and NM stocks (Table 13). The tadpoles produced from a mating between a female albino of the MY stock and a male albino of the KK stock were all albinos. Of 46 tadpoles produced from matings between a female albino of the MY stock and two heterozygous males of the KK stock, 23 were of the wild type and 23 albinos, as expected. The matings between female albinos of the MY stock and male albinos of the TJ, YsI, YsII or MD stock or heterozygous males of the TJ stock produced no other than wild-type tadpoles.

From the two matings between a heterozygous female of the MY stock and two heterozygous males of the KK stock, 67 wild-type and 26 albino tadpoles were

TABLE 13

Results of the matings between females of the MY stock and males of nine other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
MY. Alb., Nos. 2, 3	TJ. Alb., Nos. 2, 3	31	14 (45.2%)	7 (22.6%)	7	0	0
MY. Alb., No. 3	YsI. Alb., Nos. 1, 2	252	180 (71.4%)	144 (57.1%)	144	0	0
MY. Alb., No. 3	YsII. Alb., Nos. 1, 2	145	111 (76.6%)	101 (69.7%)	101	0	0
MY. Alb., Nos. 1, 2	MD. Alb., No. 1	416	394 (94.7%)	192 (46.2%)	192	0	0
MY. Alb., No. 2	KK. Alb., No. 2	302	286 (94.7%)	169 (56.0%)	0	169	0
MY. Alb., No. 2	TJ. Het., Nos. 1, 2	396	359 (90.7%)	269 (67.9%)	269	0	0
MY. Alb., No. 3	KK. Het., Nos. 1, 2	83	52 (62.7%)	46 (55.4%)	23	23	0
MY. Het., No. 4	KK. Het., Nos. 1, 2	122	95 (77.9%)	93 (76.2%)	67	26	0
MY. Het., No. 4	YsI. Alb., Nos. 1, 2	197	162 (82.2%)	142 (72.1%)	142	0	0
MY. Het., No. 4	YsII. Alb., Nos. 1, 2	236	179 (75.8%)	145 (61.4%)	145	0	0
MY. Het., No. 4	(MY. Alb. ♀ × MD. Alb. ♂), No. 1	75	62 (82.7%)	59 (78.7%)	44	15	0
MY. Het., Nos. 5~8	YMI. Alb., No. 2	1104	1078 (97.6%)	896 (81.2%)	441	455	0
MY. Het., Nos. 5~8	YMII. C-Alb., No. 1	505	462 (91.5%)	404 (80.0%)	404	0	0
MY. Het., Nos. 9~11	(NM. B-Alb. ♀ × YMI. Alb. ♂), Nos. 1~4	202	169 (83.7%)	157 (77.7%)	119	38	0
	SJ. Het. 75, No. 2	56	38 (67.9%)	34 (60.7%)	34	0	0
	NM. Het. 75, No. 1	71	52 (73.2%)	49 (69.0%)	49	0	0

produced. From a mating between the same female and a male wild-type offspring of a female albino of the My stock and a male albino of the Md stock, 44 wild-type and 15 albino tadpoles were produced. However, the heterozygous female of the My stock produced no albino tadpoles by mating with two male albinos of the YsI or YsII stock.

Of 896 tadpoles produced from 4 matings between 4 heterozygous females of the My stock and a male albino (No. 2) of the YmI stock, 441 were of the wild type and 455 albinos; these numbers show approximately a 1 : 1 ratio. Accordingly, it was confirmed that the albino gene of the My stock occupied the same locus as that of the YmI stock. From matings between the same four heterozygous females of the My stock and a male albino of the YmII stock, 404 tadpoles of the wild type were produced. Three other heterozygous females were mated with 4 males obtained from a mating between a female black-eyed albino of the Nm stock and a male red-eyed albino of the YmI stock. Of 157 tadpoles produced

TABLE 14

Results of the matings between females of the YsI stock and males of nine other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles				
						Albino		
Female	Male			Total	Wild	Red-eyed	Black-eyed	Colored
YsI. Alb., No. 1	YsI. Alb., No. 1	218	205 (94.0%)	131 (60.1%)	0	131	0	0
YsI. Alb., No. 1	Tj. Alb., Nos. 1~4	447	240 (53.7%)	191 (42.7%)	0	191	0	0
YsI. Alb., Nos. 3~5	Sj. Alb., No. 1	853	688 (80.7%)	404 (47.4%)	0	404	0	0
YsI. Alb., No. 5	Nm. B-Alb., No. 1	32	26 (81.3%)	14 (43.8%)	0	6	8	0
YsI. Alb., No. 1	YsII. Alb., No. 1	96	20 (20.8%)	11 (11.5%)	11	0	0	0
YsI. Alb., No. 1	Md. Alb., No. 1	58	52 (89.7%)	49 (84.5%)	49	0	0	0
YsI. Alb., No. 2	Kk. Alb., No. 2	116	97 (83.6%)	81 (69.8%)	81	0	0	0
YsI. Alb., No. 1	My. Alb., No. 1	93	85 (91.4%)	56 (60.2%)	56	0	0	0
YsI. Alb., No. 5	YmI. Alb., No. 1	55	41 (74.5%)	33 (60.0%)	33	0	0	0
YsI. Alb., Nos. 6, 7	YmII. C-Alb., No. 1	164	163 (99.4%)	119 (72.6%)	0	59	0	60
YsI. Alb., Nos. 8~11	YmII. Het., No. 1	140	138 (98.6%)	79 (56.4%)	37	42	0	0
	YmII. Het., No. 2	228	215 (94.3%)	95 (41.7%)	51	44	0	0
	YmII. Het., No. 3	190	186 (97.9%)	16 (8.4%)	8	0	0	8
	YmII. Het., No. 4	167	152 (91.0%)	83 (49.7%)	43	0	0	40
	YmII. Het., No. 5	142	140 (98.6%)	74 (52.1%)	39	0	0	35
	YmII. Het., No. 6	174	171 (98.3%)	27 (15.5%)	12	0	0	15
YsI. Alb., No. 1	Kk. Het., No. 1	59	32 (54.2%)	15 (25.4%)	15	0	0	0
YsI. Het., Nos. 3~5	Nm. B-Alb., No. 1	792	618 (78.0%)	412 (52.0%)	205	99	108	0
YsI. Het., Nos. 3~5	YmI. Alb., No. 1	992	743 (74.9%)	529 (53.3%)	529	0	0	0

from these matings, 119 were of the wild type and 38 red-eyed albinos. The tadpoles produced from the same three heterozygous females by mating with a heterozygous male of the SJ or NM stock were all of the wild type (Table 13).

3. Females of the YsI stock and males of nine other stocks

During the years 1973~1976, matings were made between female albinos or heterozygous females of the YsI stock and male albinos or heterozygous males of the ten stocks (Table 14). As a result, 859 tadpoles produced from the matings between female albinos of the YsI stock and male albinos of the YsI, TJ, SJ, NM and YMII stocks were all albinos. Of these tadpoles, 14 were produced from a mating between a female albino of the YsI stock and a male black-eyed albino of the NM stock; 6 of them were red-eyed albinos and 8 were black-eyed ones. Of the other tadpoles, 119 were produced from 2 matings between 2 female albinos of the YsI stock and a male colored albino of the YMII stock; 59 were red-eyed albinos and 60 colored ones.

From matings between 4 female albinos of the YsI stock and 2 heterozygous males (Nos. 1, 2) of the YMII stock, 174 tadpoles were produced; 88 were of the wild type and 86 red-eyed albinos. The same 4 females produced 200 tadpoles by mating with 4 (Nos. 3~6) heterozygous males of the YMII stock; 102 were of the wild type and 98 colored albinos.

From 3 matings between 3 heterozygous females of the YsI stock and a male black-eyed albino of the NM stock, 205 wild-type, 99 red-eyed albino and 108 black-eyed albino tadpoles were produced. Of these three kinds of tadpoles, 135 wild-type tadpoles metamorphosed at the age of 33~50 days, 37.4 days on the average, 87 red-eyed did at the age of 34~57 days, 43.2 days on the average, and 101 black-eyed did at the age of 33~60 days, 42.5 days on the average, while the others died of various abnormalities during the tadpole stage. The matings between female albinos or heterozygous females of the YsI stock and male albinos of the YsII, MD, KK, MY or YMI stock or a heterozygous male of the KK produced no albino tadpoles.

4. Females of the YsII stock and males of nine other stocks

During the years 1973~1976, female albinos or heterozygous females of the YsII stock were mated with male albinos of the ten stocks, heterozygous males of 3 stocks or a male wild-type offspring between a female albino of the MY stock and a male albino of the MD (Table 15). From 2 kinds of matings between 3 or 2 female albinos of the YsII stock and 3 male albinos of the YsII or a male albino of the MD stock, a total of 171 or 51 albino tadpoles were produced. From a mating between a female albino of the YsII stock and a heterozygous male of the MD stock, 12 wild-type and 22 albino tadpoles were produced. A mating between a heterozygous female of the YsII stock and a heterozygous male of the MD stock produced 19 wild-type and 5 albino tadpoles. Two matings between 2 heterozygous females of the YsII stock and a male wild-type offspring of a female albino of the MY stock and a male albino of the MD produced 6 wild-type and 3 albino tadpoles. The

TABLE 15

Results of the matings between females of the YsII stock and males of nine other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
YsII. Alb., Nos. 1～3	YsII. Alb., Nos. 1～3	340	267 (78.5%)	171 (50.3%)	0	171	0
YsII. Alb., Nos. 1, 2	Tj. Alb., No. 3	64	15 (23.4%)	11 (17.2%)	11	0	0
YsII. Alb., Nos. 1, 2	YsI. Alb., No. 2	93	10 (10.8%)	8 (8.6%)	8	0	0
YsII. Alb., No. 3	Sj. Alb., No. 1	65	30 (46.2%)	15 (23.1%)	15	0	0
YsII. Alb., No. 3	Nm. B-Alb., No. 1	52	37 (71.2%)	25 (48.1%)	25	0	0
YsII. Alb., Nos. 1, 2	Md. Alb., No. 1	121	82 (67.8%)	51 (42.1%)	0	51	0
YsII. Alb., No. 3	Kk. Alb., No. 2	146	108 (74.0%)	42 (28.8%)	42	0	0
YsII. Alb., Nos. 1, 2	My. Alb., No. 1	66	53 (80.3%)	45 (68.2%)	45	0	0
YsII. Alb., No. 3	YmI. Alb., No. 1	52	24 (46.2%)	19 (36.5%)	19	0	0
YsII. Alb., Nos. 4, 5	YmII. C-Alb., No. 1	311	166 (53.4%)	163 (52.4%)	163	0	0
YsII. Alb., No. 3	Md. Het., No. 2	107	54 (50.5%)	34 (31.8%)	12	22	0
YsII. Alb., No. 3	Kk. Het., No. 3	87	30 (34.5%)	15 (17.2%)	15	0	0
YsII. Alb., No. 3	(My. Alb. ♀ × Md. Alb. ♂), No. 3	115	96 (83.5%)	30 (26.1%)	14	16	0
YsII. Alb., No. 3	Tj. Het., No. 7	93	78 (83.9%)	28 (30.1%)	28	0	0
YsII. Het., No. 1	Md. Het., No. 4	55	34 (61.8%)	24 (43.6%)	19	5	0
YsII. Het., Nos. 2, 3	(My. Alb. ♀ × Md. Alb. ♂), No. 3	40	10 (25.0%)	9 (22.5%)	6	3	0
YsII. Het., Nos. 2, 3	Kk. Alb., No. 2	340	60 (17.6%)	60 (17.6%)	60	0	0
YsII. Het., Nos. 2, 3	Tj. Het., No. 7	50	46 (92.0%)	34 (68.0%)	34	0	0
YsII. Het., No. 4	Nm. B-Alb., No. 1	308	256 (83.1%)	218 (70.8%)	218	0	0
YsII. Het., No. 4	Sj. Alb., No. 1	295	264 (89.5%)	214 (72.5%)	214	0	0
YsII. Het., No. 4	YmI. Alb., No. 1	340	312 (91.8%)	279 (82.1%)	279	0	0
YsII. Het., Nos. 5, 6	YmII. C-Alb., No. 1	610	521 (85.4%)	483 (79.2%)	483	0	0

matings between female albinos or heterozygous females of the YsII stock and a male albino of the Tj, YsI, Sj, Nm, Kk, My, YmI or YmII stock, or a heterozygous male of the Kk or Tj stock produced wild-type tadpoles alone.

5. Females of the Md stock and males of nine other stocks

In the years 1974～1976, matings were made between heterozygous females of the Md stock and male albinos of the YsII, YsI, Tj, YmI, YmII, Sj or Nm stock or a heterozygous male of the My or Kk stock (Table 16). From 3 matings between 3 heterozygous females of the Md stock and 3 albinos of the YsII stock, 42 wild-type and 45 albino tadpoles were produced. Of these tadpoles, 31 albino tadpoles metamorphosed at the age of 45～60 days, 51.8 days on the aver-

TABLE 16

Results of the matings between females of the MD stock and males of nine other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
MD. Het., Nos. 2~4	YsII. Alb., Nos. 1~3	237	165 (69.6%)	87 (36.7%)	42	45	0
MD. Het., Nos. 3, 4	YsI. Alb., Nos. 1, 2	92	32 (34.8%)	23 (25.0%)	23	0	0
MD. Het., Nos. 3, 4	KK. Het., No. 1	81	34 (42.0%)	22 (27.2%)	22	0	0
MD. Het., Nos. 3, 4	TJ. Alb., Nos. 2, 3	87	50 (57.5%)	38 (43.7%)	38	0	0
MD. Het., No. 5	YmI. Alb., No. 1	95	42 (44.2%)	34 (35.8%)	34	0	0
MD. Het., No. 5	SJ. Alb., No. 1	121	73 (60.3%)	62 (51.2%)	62	0	0
MD. Het., No. 5	NM. B-Alb., No. 1	109	75 (68.8%)	51 (46.8%)	51	0	0
MD. Het., No. 5	MY. Het., No. 2	124	69 (55.6%)	47 (37.9%)	47	0	0
MD. Het., No. 6	YmII. C-Alb., No. 1	57	36 (63.2%)	31 (54.4%)	31	0	0

age, while 36 wild-type tadpoles did at the age of 45~49 days, 46.8 days on the average. Matings between heterozygous females of the MD stock and male albinos of the YsI, TJ, YmI, YmII, SJ or NM stock or a heterozygous male of the

TABLE 17

Results of the matings between females

Parents		No. of eggs	No. of normal cleavages
Female	Male		
NM. B-Alb., No. 1	NM. B-Alb., No. 1	325	212 (65.2%)
	TJ. Alb., No. 4	98	64 (65.3%)
	YsI. Alb., No. 5	75	63 (84.0%)
	SJ. Alb., No. 1	77	61 (79.2%)
	YsII. Alb., No. 5	53	39 (73.6%)
	MD. Alb., No. 2	57	26 (45.6%)
	KK. Alb., No. 2	60	51 (85.0%)
	MY. Alb., No. 1	74	62 (83.8%)
	YmI. Alb., No. 1	88	64 (72.7%)
	YsI. Het., No. 2	50	46 (92.0%)
	(MY. Alb. ♀ × MD. Alb. ♂), No. 2	22	9 (40.9%)
NM. B-Alb., Nos. 2, 3	YmII. C-Alb., No. 1	533	423 (79.4%)

Kk or My stock produced wild-type tadpoles alone. Of these tadpoles, 43 metamorphosed at the age of 43～50 days, 46.2 days on the average.

6. Females of the Nm stock and males of nine other stocks

In 1975, a female black-eyed albino of the Nm stock was mated with a male albino of the Nm, Tj, YsI, Sj, YsII, Md, Kk, My or YmI stock, a heterozygous male of the YsI or a male wild-type offspring between a female albino of the My stock and a male albino of the Md stock (Table 17). One of these matings, that is, a mating between a female and a male black-eyed albino of the Nm stock produced 38 red-eyed and 108 black-eyed albino tadpoles. Three matings between the same female of the Nm stock and 3 male albinos of the Tj, YsI and Sj stocks produced 57 red-eyed and 70 black-eyed albino tadpoles in total. The smaller number of the red-eyed albino tadpoles seemed attributable to their inferior viability. After the hatching stage, they were also weaker than black-eyed albino tadpoles. From a mating between the same female albino of the Nm stock and a heterozygous male of the YsI stock, 21 wild-type tadpoles and 9 red-eyed and 11 black-eyed albinos were produced. Only wild-type tadpoles were produced from matings between the same female albino of the Nm stock and male albinos of the YsII, Md, Kk, My and YmI stocks or a male offspring between a female albino of the My stock and a male albino of the Md stock.

of the Nm stock and males of nine other stocks

No. of hatched tadpoles					
Total	Wild	Albino			
		Red-eyed	Black-eyed	Colored	Black-eyed and colored
146 (44.9%)	0	38	108	0	0
38 (38.8%)	0	16	22	0	0
45 (60.0%)	0	21	24	0	0
44 (57.1%)	0	20	24	0	0
19 (35.8%)	19	0	0	0	0
22 (38.6%)	22	0	0	0	0
44 (73.3%)	44	0	0	0	0
44 (59.5%)	44	0	0	0	0
43 (48.9%)	43	0	0	0	0
41 (82.0%)	21	9	11	0	0
6 (27.3%)	6	0	0	0	0
406 (76.2%)	0	92	105	102	107

In 1976, two female black-eyed albinos of the NM stock were mated with a male colored albino of the YMII stock. As a result, 406 tadpoles at the hatching stage were produced. Of these, 194 were red-eyed albinos and 212 black-eyed ones. When these tadpoles began to eat several days later, 102 of the red-eyed albinos became colored albinos, while the other 92 remained as they were. At the same time, the black-eyed albinos were divided into 2 groups of 105 black-eyed albinos and 107 black-eyed, colored ones.

7. Females of the KK stock and males of nine other stocks

A mating was performed in 1972 between a female albino of the KK stock and a male albino of the TJ stock (Table 18). As a result, all the 91 tadpoles produced from this mating were of the wild type. All of them died of edema before the feeding stage.

TABLE 18

Results of the matings between females of the KK stock and males of nine other stock

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
KK. Alb., No. 1	TJ. Alb., No. 1	262	97 (37.0%)	91 (34.7%)	91	0	0
KK. Alb., Nos. 2~6	KK. Alb., No. 3	700	463 (66.1%)	414 (59.1%)	0	414	0
	YsI. Alb., No. 6	227	65 (28.6%)	50 (22.0%)	50	0	0
	YsII. Alb., No. 6	797	507 (63.6%)	459 (57.6%)	459	0	0
	MD. Alb., No. 4	461	309 (67.0%)	291 (63.1%)	291	0	0
	NM. B-Alb., No. 3	396	67 (16.9%)	66 (16.7%)	66	0	0
	YMI. Alb., No. 2	802	507 (63.2%)	503 (62.7%)	0	503	0
	YMII. C-Alb., No. 1	292	77 (26.4%)	73 (25.0%)	73	0	0
KK. Alb., Nos. 2~6	SJ. Het., No. 1	112	32 (28.6%)	29 (25.9%)	29	0	0
	MY. Het., No. 5	136	74 (54.4%)	63 (46.3%)	32	31	0

In 1975, a heterozygous female (No. 1) produced by a mating between a normal female (No. 11) and a heterozygous male (No. 2) of the KK stock was mated with a heterozygous male (No. 7) of the KK stock. As 5 female albinos (KK. Alb. 75♀, Nos. 2~6) obtained from this mating matured sexually and ovulated after pituitary injection, they were mated with male albinos or heterozygous males of the YsI, YsII, MD, NM, YMII and SJ stocks. The tadpoles produced from these matings were all of the wild type. The same five female albinos were mated with a male albino (YMI. Alb. 74♂, No. 2) of the YMI stock; all the tadpoles produced were albinos (Table 18). They were also mated with a hetero-

zygous male of the MY stock; 32 of 63 tadpoles produced were of the wild type and 31 were red-eyed albinos.

8. Females of the YMII stock and males of four other stocks

In 1976, 74 tadpoles were produced from matings between two albino females of the YMII stock and a male albino (No. 6) of the YsI stock (Table 19). Of these, 35 were red-eyed albinos and 39 were colored ones. The tadpoles produced from the same females by mating with male albinos of the YMI, KK, and YsII stocks were all of the wild type.

TABLE 19

Results of the matings between females of the YMII stock and males of four other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Colored
YMII. C-Alb., No. 1	YMI. Alb., No. 2	42	16 (38.1%)	7 (16.7%)	7	0	0
	KK. Alb., No. 3	53	51 (96.2%)	41 (77.4%)	41	0	0
	YsI. Alb., No. 6	52	34 (63.4%)	31 (59.6%)	0	15	16
	YsII. Alb., No. 6	82	77 (93.9%)	53 (64.6%)	53	0	0
YMII. C-Alb., No. 2	YMI. Alb., No. 2	64	64 (100%)	37 (57.8%)	37	0	0
	KK. Alb., No. 3	91	89 (97.8%)	49 (53.8%)	49	0	0
	YsI. Alb., No. 6	67	50 (74.6%)	43 (64.2%)	0	20	23
	YsII. Alb., No. 6	66	55 (83.3%)	30 (45.5%)	30	0	0

9. Females of the SJ stock and males of eight other stocks

Four heterozygous females of the SJ stock were mated with heterozygous males of the MY, MD, YsII, KK and YMI stocks (Table 20). All the tadpoles produced from these matings were of the wild type. However, among 32 tadpoles produced from the same females by mating with a heterozygous male of the YsI stock, there were 23 wild-type tadpoles and 9 red-eyed albinos. Of 92 tadpoles produced from the same females by mating with a male albino of the TJ stock, 49 were of the wild type and 43 were red-eyed albinos. Of 78 tadpoles produced from the same females by mating with a heterozygous male of the NM stock, 56 were of the wild type and 22 were black-eyed albinos.

10. Females from matings between different stocks and males of various sources

a. A female from YsI. Alb. ♀ × YsII. Alb. ♂

A female and a male produced from a mating in 1974 between a female albino

TABLE 20

Results of the matings between females of the SJ stock and males of eight other stocks

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
SJ. Het., Nos. 1~4	YsI. Het., No. 5	72	38 (52.8%)	32 (44.4%)	23	9	0
	TJ. Alb., No. 5	107	96 (89.7%)	92 (86.0%)	49	43	0
	MY. Het., No. 5	100	91 (91.0%)	86 (86.0%)	86	0	0
	NM. Het., No. 1	106	89 (84.0%)	78 (73.6%)	56	0	22
	MD. Het., No. 5	103	86 (83.5%)	82 (79.6%)	82	0	0
	YsII. Het., No. 5	123	117 (95.1%)	114 (92.7%)	114	0	0
	KK. Het., No. 8	49	26 (53.1%)	19 (38.8%)	19	0	0
	YmI. Het., No. 1	92	85 (92.4%)	79 (85.9%)	79	0	0

TABLE 21

Results of the matings between females produced from crosses of different stocks and males of various sources

Parents		No. of eggs	No. of normal cleavages	No. of hatched tadpoles			
				Total	Wild	Albino	
Female	Male					Red-eyed	Black-eyed
(YsI. Alb. ♀ × YsII. Alb. ♂), No. 1	(YsI. Alb. ♀ × YsII. Alb. ♂), No. 1	260	240 (92.3%)	200 (76.9%)	150	50	0
(MY. Alb. ♀ × MD. Alb. ♂), Nos. 1~3	(MY. Alb. ♀ × MD. Alb. ♂), Nos. 1~3	236	149 (63.1%)	127 (53.8%)	78	49	0
(MY. Alb. ♀ × MD. Alb. ♂), Nos. 1~3	KK. Alb., No. 2	345	279 (80.9%)	159 (46.1%)	90	69	0
(MY. Alb. ♀ × MD. Alb. ♂), Nos. 1~3	KK. Het., Nos. 2~4	146	31 (21.2%)	27 (18.5%)	17	10	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	(MY. Alb. ♀ × MD. Alb. ♂), No. 3	112	70 (62.5%)	22 (19.6%)	22	0	0
(TJ. Alb. ♀ × YsI. Alb. ♂), No. 3	MD. Het., No. 5	28	27 (96.4%)	18 (64.3%)	18	0	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	TJ. Het., No. 7	124	117 (94.4%)	70 (56.5%)	40	30	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	YsI. Alb., No. 1	174	172 (98.9%)	134 (77.0%)	0	134	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	YsI. Het., Nos. 1, 2	305	254 (83.3%)	171 (56.1%)	87	84	0
(TJ. Alb. ♀ × YsI. Alb. ♂), No. 1	YsII. Alb., No. 3	56	47 (83.9%)	26 (46.4%)	26	0	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	YsII. Het., No. 2	117	109 (93.2%)	74 (63.2%)	74	0	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	KK. Alb., No. 2	97	93 (95.9%)	57 (58.8%)	57	0	0
(TJ. Alb. ♀ × YsI. Alb. ♂), Nos. 1~3	KK. Het., No. 2	56	47 (83.9%)	35 (62.5%)	35	0	0

of the YsI stock and a male albino of the YsII stock were mated with each other in 1975 (Table 21). As described above, the mating performed in 1974 produced offspring which were all of the wild type. From the mating performed in 1975,

200 tadpoles were produced; 150 were of the wild type and 50 albinos. The smaller number of the albinos than that expected seemed attributable to their low viability. All the wild-type and albino tadpoles died before the metamorphosing stage.

b. Females from My. Alb. ♀ × Md. Alb. ♂

Three female offspring between a female albino of the My stock and a male albino of the Md stock were mated with 3 kinds of males (Table 21). The offspring between the female albino of the My and the male albino of the Md were all of the wild type, as described above. From 3 matings between the 3 female offspring and their 3 brothers, 127 tadpoles were produced; 78 were of the wild type and 49 albinos. After many tadpoles died of various abnormalities, 25 albinos metamorphosed at the age of 47～64 days, 53.6 days on the average, while 43 wild-type tadpoles did at the age of 47～59 days, 51.2 days on the average.

The three female offspring between a female albino of the My stock and a male albino of the Md stock were mated with a male albino of the Kk stock. Of 159 tadpoles in total produced from the 3 matings, 90 were of the wild type and 69 albinos. After many of these tadpoles died of edema or various abnormalities, 34 albinos metamorphosed at the age of 47～73 days, 54.1 days on the average, while 70 wild-type tadpoles did at the age of 47～60 days, 52.0 days on the average.

The same three females were mated with 3 heterozygous males of the Kk stock. From these three matings, 17 wild-type and 10 albino tadpoles were produced. Although most of these tadpoles died of edema or underdevelopment, five wild-type and three albino tadpoles metamorphosed at the age of 48～50 days and 49～50 days, respectively.

c. Females from Tj. Alb. ♀ × YsI. Alb. ♂

One (No. 1 or 3) or three (Nos. 1～3) female offspring between a female albino of the Tj stock and a male albino of the YsI stock were mated with nine kinds of males (Table 21). As described above, all the offspring between the female albino of the Tj and the male albino of the YsI were albinos.

From three matings between the 3 albino females Nos. 1～3 and a male albino (No. 1) of the YsI stock, 134 albino tadpoles were produced. Most of these tadpoles died of edema; 52 metamorphosed normally at the age of 47～63 days, 55.3 days on the average.

The same three albino females were mated with a heterozygous male (No. 7) of the Tj stock and 2 heterozygous males (Nos. 1 and 2) of the YsI stock. From the former male, 40 wild-type and 30 albino tadpoles were produced, while 87 wild-type and 84 albino tadpoles were from the latter males. Most of these wild-type and albino tadpoles died of edema or some other abnormalities. Eventually, 42 albinos metamorphosed at the age of 47～65 days, 57.4 days on the average, while 46 wild-type tadpoles did at the age of 46～59 days, 51.6 days on the aver-

TABLE 22

Results of the matings between female black-eyed albinos produced from a cross,

Parents		No. of eggs	No. of normal cleavages
Female	Male		
(YsI. Het. ♀ × Nm. B-Alb. ♂) B-Alb., Nos. 1~3	YmII. Het., No. 1	343	247 (72.0%)
	YmII. Het., No. 2	316	269 (85.1%)
	YmII. Het., No. 3	270	238 (88.1%)
	YmII. Het., No. 4	244	137 (56.1%)
	YmII. Het., No. 5	261	151 (57.9%)
	YmII. Het., No. 6	266	112 (42.1%)

age.

Matings were also performed between one (No. 1 or 3) or all the three (Nos. 1 ~3) albino females and 6 kinds of males belonging to 4 stocks, a wild-type male (No. 3) from My. Alb. ♀ × Md. Alb. ♂, a heterozygous male (No. 5) of the Md stock, a male albino (No. 3) and a heterozygous male (No. 2) of the YsII stock and a male albino (No. 2) and a heterozygous male (No. 2) of the Kk stock. From these matings a total of 232 wild-type tadpoles were produced; no albinos were obtained. After most of the tadpoles died of abnormalities, 94 metamorphosed normally at the age of 46~55 days, 52.7 days on the average.

d. Females from YsI. Het. ♀ × Nm. B-Alb. ♂

Six matings were made between 3 female black-eyed albinos obtained from a heterozygous female of the YsI stock by mating with a male black-eyed albino of the Nm stock and six heterozygous males obtained from a mating between a normal female from the field and a male colored albino of the YmII stock (Table 22). From two of these matings, 254 tadpoles were produced; 124 of them were of the wild type, 54 red-eyed albinos and 76 black-eyed ones. Of 452 tadpoles produced from the remaining 4 matings, 250 were of the wild type, 115 colored albinos and 87 black-eyed, colored ones.

11. Summary of the results from the mating experiments

a. Albino genes

The results of mating experiments performed among the 10 stocks showed that the latter were sorted into three groups. The first group consisted of the YsI, Tj, Sj, Nm and YmII stocks, the second did of the YsII and Md stocks and the third did of the Kk, My and YmI stocks. It was noteworthy that the collecting place of the YsI stock of the first group was not more than 500 m apart from that of the YsII stock of the second group.

Different stocks belonging to the same group produce albinos by mating,

YsI. Het. ♀ × Nm. B-Alb. ♂, and heterozygous males of the YmII stock

No. of hatched tadpoles					
Total	Wild	Albino			
		Red-eyed	Black-eyed	Colored	Black-eyed and colored
148 (43.1%)	71	34	43	0	0
106 (33.5%)	53	20	33	0	0
197 (73.0%)	119	0	0	41	37
91 (37.3%)	46	0	0	28	17
92 (35.2%)	45	0	0	29	18
72 (27.1%)	40	0	0	17	15

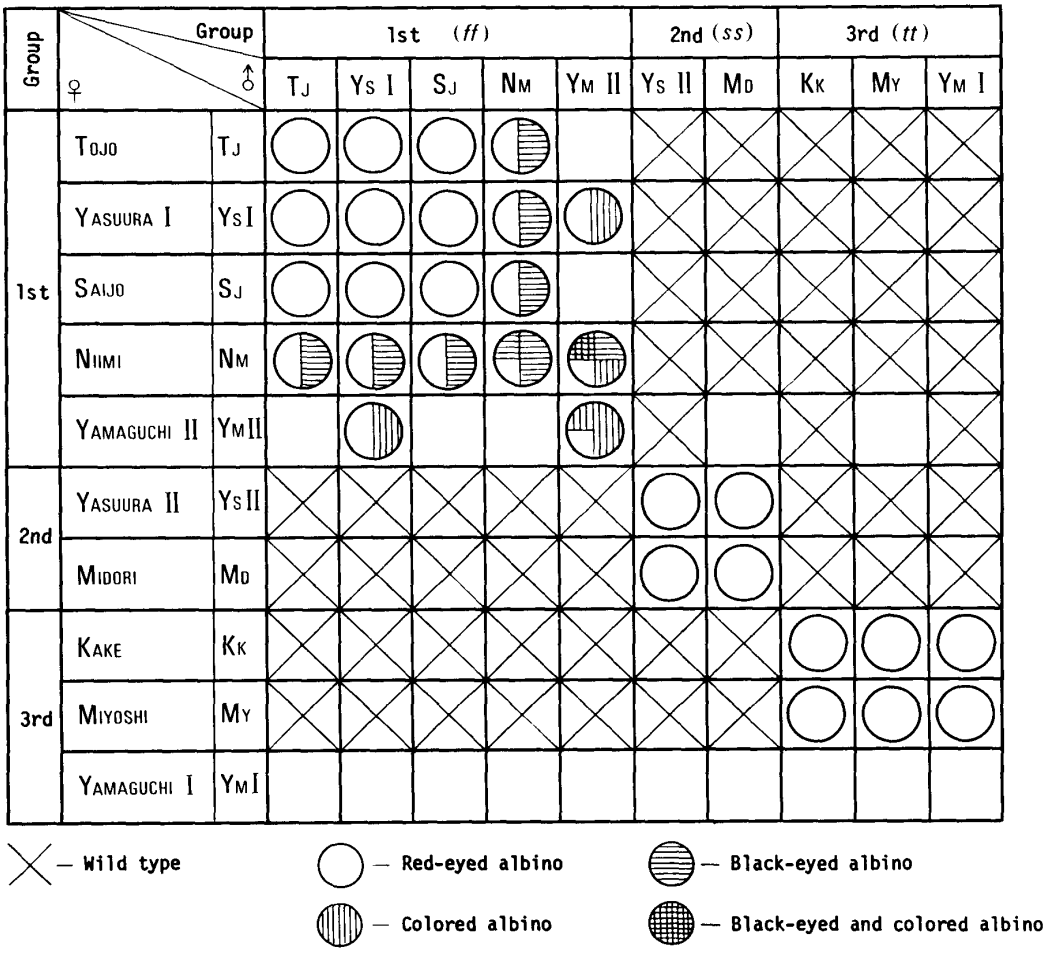

Fig. 2. Results of crosses between different albino stocks.

while those belonging to different groups produce wild-type tadpoles alone (Fig. 2). From these facts, it is clear that the albino genes of the stocks belonging to

the same group are the same or allelic, while those of stocks belonging to different groups are different from each other in locus. However, whether they are located in the same chromosome or in different chromosomes is unknown at present. The albino gene for each of the three groups is named as follows: first albino (*f*) for the first group, second albino (*s*) for the second group and third albino (*t*) for the third group. The gene for the black eyes in the NM stock is dominant over that the gene *f* for the red eyes of albinos belonging to the first group. The gene that makes the red eyes of albinos black is named Black eye (*B*). The male and female of the NM stock that were collected in 1974 and used for matings in the next year were *ffBb*, as both black-eyed and red-eyed tadpoles were produced from a mating between them, as well as from matings between these and albinos or heterozygous frogs belonging to the other stocks of the first group. In the presence of the dominant gene *F*, the whole body including eyes is of the wild type, even if *bb* exists.

The gene producing melanin in the dorsal skin and the eyeball in the frogs of the YMII stock is dominant over the albino gene *f* of the first group. This gene is named Coloring (*C*), as it makes the back of a red-eyed albino green and the eyes reddish black. The two male and two female colored albinos which were collected in 1975 and used in the next year for mating experiments (Table 11) were presumed to be *ffCc* in gene constitution, as two kinds of albinos, colored and red-eyed, were produced. These two kinds of albinos were also produced from male and female colored albinos of the YMII stock by mating with male and female red-eyed albinos of the other stocks belonging to the first group (Tables 14 and 22). Nearly the same numbers of red-eyed, black-eyed, colored, and black-eyed, colored albinos were produced by mating the male colored albinos with female black-eyed albinos of the NM stock (Table 17).

The figures obtained by mating experiments performed in each stock as well as between different stocks can be totalled as those of each of the three groups. In the first group, 3414 tadpoles produced from matings between female and male albinos (*ff*♀ × *ff*♂) were all albinos (*ff*). From matings between female albinos and heterozygous males (*ff*♀ × *Ff*♂), 520 tadpoles were produced; 276 were of the wild type (*Ff*) and 244 (47%) were albinos (*ff*). Of 686 tadpoles produced from matings between heterozygous females and male albinos (*Ff*♀ × *ff*♂), 343 were of the wild type (*Ff*) and 343 (50%) were albinos (*ff*). From matings between heterozygous females and males (*Ff*♀ × *Ff*♂), 2344 tadpoles were produced; 1770 were of the wild type (1*FF*+2*Ff*) and 574 (25%) were albinos (*ff*). From matings between female albinos of the first group (*ff*) and male albinos of the second (*ss*) or third (*tt*) group, only wild-type tadpoles (*FfSs*, *FfTt*) were produced.

In the second group, all the 222 tadpoles produced from matings between female and male albinos (*ss*♀ × *ss*♂) were albinos (*ss*). From a mating between a female albino and a heterozygous male (*ss*♀ × *Ss*♂), 34 tadpoles were produced; 12 were of the wild type (*Ss*) and 22 (65%) were albinos (*ss*). From matings between heterozygous females and male albinos (*Ss*♀ × *ss*♂), 403 tadpoles were

produced; 204 were of the wild type (*Ss*) and 199 (49%) were albinos (*ss*). Of 272 tadpoles produced from heterozygous females and males (*Ss*♀×*Ss*♂), 203 were of the wild type (1*SS*+2*Ss*) and 69 (25%) were albinos (*ss*). From matings between female albinos of the second group (*ss*) and male albinos of the first (*ff*) or third group (*tt*), only wild-type tadpoles (*FfSs*, *SsTt*) were produced.

In the third group, 1177 tadpoles produced from matings between female and male albinos (*tt*♀×*tt*♂) were all albinos (*tt*). From matings between a female albino and 2 heterozygous males (*tt*♀×*Tt*♂), 109 tadpoles were produced; 55 were of the wild type (*Tt*) and 54 (50%) were albinos (*tt*). Of 896 tadpoles produced from matings between heterozygous females and male albinos (*Tt*♀×*tt*♂), 441 were of the wild type (*Tt*) and 455 (51%) were albinos (*tt*). From matings between heterozygous females and males (*Tt*♀×*Tt*♂), 1038 tadpoles were produced; 787 were of the wild type (1*TT*+2*Tt*) and 251 (24%) were albinos (*tt*). The tadpoles produced from matings between female albinos of the third group and male albinos of the first or second group were all of the wild type (*FfTt*, *SsTt*).

Of 127 tadpoles produced from matings between a female black-eyed albino and male red-eyed albinos of the first group (*ffBb*♀×*ffbb*♂), 70 (55%) were black-eyed albinos (*ffBb*) and 57 (45%) were red-eyed albinos (*ffbb*). From a mating between a female black-eyed albino and a red-eyed heterozygous male (*ffBb*♀×*Ffbb*♂), 41 tadpoles were produced; 21 were of the wild type (*FfBb*, *Ffbb*), 11 (27%) were black-eyed albinos (*ffBb*) and 9 (22%) were red-eyed albinos (*ffbb*). Of 146 tadpoles produced from a mating between a female and a male black-eyed albino (*ffBb*♀×*ffBb*♂), 108 (74%) were black-eyed albinos (1*ffBB*+2*ffBb*) and 38 (26%) were red-eyed albinos (*ffbb*). Matings between female red-eyed albinos and a male black-eyed albino of the first group (*ffbb*♀×*ffBb*♂) produced 210 (54%) black-eyed (*ffBb*) and 180 (46%) were red-eyed (*ffbb*) albino tadpoles. From matings between heterozygous females of the first group and a male black-eyed albino (*Ffbb*♀×*ffBb*♂), 412 tadpoles were produced; 205 (50%) were of the normal type (*FfBb*, *Ffbb*), and 108 (26%) were black-eyed albinos (*ffBb*) and 99 (24%) were red-eyed ones (*ffbb*).

Of 119 tadpoles produced from matings between two female red-eyed albinos and a male colored albino of the first group (*ffcc*♀×*ffCc*♂), 59 (50%) were red-eyed albinos (*ffcc*) and 60 (50%) were colored ones (*ffCc*). From matings between two female colored albinos and a male red-eyed albino (*ffCc*♀×*ffcc*♂), 74 tadpoles were produced; 35 (47%) were red-eyed albinos (*ffcc*) and 39 (53%) were colored ones (*ffCc*). From matings between two female black-eyed albinos and a male colored albino (*ffBbcc*♀×*ffbbCc*♂), 406 tadpoles were produced; 92 (23%) were red-eyed (*ffbbcc*), 105 (26%) were black-eyed (*ffBbcc*), 102 (25%) were colored (*ffbbCc*) and 107 (26%) were black-eyed, colored albinos (*ffBbCc*). Matings between two female colored albinos and two male colored albinos of the first group (*ffCc*♀×*ffCc*♂) produced 27 (30%) red-eyed (*ffcc*) and 64 (70%) colored (1*ffCC*+2*ffCc*) albinos.

b. Linkage group

From matings between 3 heterozygous females (*Ttbb*) belonging to the third group of albinos and 4 wild-type males (*ftBb* or *ftbb*) obtained by mating a female black-eyed albino (*ffBb*) of the first group with a male red-eyed albino (*ttbb*) of the third group, 157 tadpoles were produced. While 119 of these were of the wild type (*TfBb*, *tfBb*, *TtBb*, *Tfbb*, *tfbb* or *Ttbb*), 38 (24%) were red-eyed albinos (*ttbb*); no black-eyed albinos (*ttBb*) were produced. On the other hand, no red-eyed albinos (*ffbb*) were produced from matings between 4 heterozygous females (*Ffbb*) of the first group of albinos and a heterozygous male (*FfBb*) obtained from a normal female (*FFbb*) by mating with a black-eyed albino (*ffBb*). Among 78 tadpoles produced from these matings, there were 56 wild-type ones (*FFbb*, *Ffbb* and *FfBb*) and 22 (28%) black-eyed albinos (*ffBb*). From the results of the above two kinds of matings, it was clear that the two genes *B* and *f* made a linkage group.

It became clear that the gene *C* belonged to the same linkage group as that of *f* and *B*, from the results of matings between 4 female albinos of the first group (*ffcc*) and 6 heterozygous males (*Ffcc* or *FfCc*) obtained from a normal female (*FFcc*) by mating with a male colored albino (*ffCc*). When *Ffcc* males were used, 88 of 174 tadpoles produced from 2 matings were of the wild type (*Ffcc*) and 86 (49%) were red-eyed albinos (*ffcc*). When *FfCc* males were used, 102 of 200 tadpoles produced from 4 matings were of the wild type (*Ffcc*) and 98 (49%) were colored albinos (*ffCc*). No red-eyed albinos (*ffcc*) were produced from these matings (Table 14). Accordingly, it was clear that the two genes *C* and *f* were linked with each other.

When 3 black-eyed albinos of the first group (*ffBbcc*) were mated with 4 males (*FfbbCc*) which were heterozygous for the two genes *f* and *C*, 250 (55%) of 452 tadpoles produced from these matings were of the wild type (*FfBbcc* and *Ffbbcc*), 115 (25%) were colored albinos (*ffbbCc*) and 87 (19%) were black-eyed, colored albinos (*ffBbCc*) (Table 22). This showed that each of the genes *B* and *C* was linked with *f*.

III. Sex

1. Miyoshi (My) stock

From two females heterozygous for the albino gene (*t*), 181 frogs were produced by diploid gynogenesis. Of these frogs, 117 were kept alive, while the others were killed immediately after metamorphosis to examine their sex. Of the frogs kept alive, 76 matured sexually, while the others died sooner or later after metamorphosis. Sex was examined on 65 frogs which were killed or died immediately after metamorphosis as well as on the mature frogs (Table 23). As a result, all these frogs were females. Of 803 frogs produced from matings between 4 heterozygous females and 4 heterozygous males, between 2 female albinos and 2 normal males from the field, and between 3 normal females from the field and a male

albino, 185 were continuously reared, and eventually 144 matured sexually. Of the latter, 74 were females and 70 were males. From control matings between 3 normal females and a normal male from the field, 105 frogs were produced. Fifty of the latter were continuously reared; 48 of them matured sexually. Of the latter, 23 were females and 25 were males. The albinos did not differ from the wild-type frogs in sex ratio.

2. Kake (Kk) stock

From matings between 11 normal females and 2 male albinos collected from the field, 1570 heterozygous frogs were produced. The sex of 429 immature and 532 mature frogs of the latter was examined (Table 23). As a result, a total of 961 heterozygous frogs were all males. Six of these heterozygous males were mated with 5 normal females from the field and produced 141 frogs. The sex of 44 immature and 70 mature frogs of the latter was examined; in total, 55 (48%) were females and 59 were males. Three of these females were mated with a heterozygous male and produced 94 wild-type and 41 albino frogs. Fifty wild-type frogs and all the albinos were continuously reared. As a result, 38 wild-type and 38 albino frogs attained sexual maturity; 19 (50%) wild-type and 23 albino frogs were females, and the others were males. As three albinos that died shortly after metamorphosis were males, 56% of albino frogs were females. Of the total of wild-type and albino frogs, 53% were females (Table 23).

From 8 control matings between 8 normal females and 3 normal males from the field, 649 frogs were produced. Although 300 of them were continuously reared, 259 matured sexually; 128 (49%) were females and 131 were males.

On the other hand, all the 116 mature wild-type frogs produced from one (No. 2) of the two male albinos of the Kk stock collected from the field by mating with a female albino and two heterozygous females of the Tj stock were males (Table 24). When two heterozygous males (Nos. 1 and 2) of the Kk stock were mated with a heterozygous female (No. 4) of the My stock, 52 wild-type and 19 albino frogs were produced. Of these frogs, 25 wild-type and 16 albino frogs matured sexually. Among each kind of frogs, there was nearly equal number of males and females (Table 24). One (No. 1) of the two heterozygous males was mated with two heterozygous females of the Md stock. From this mating, 12 wild-type frogs were produced, and matured sexually; five were females and seven were males.

On the basis of the results of these mating experiments, it was found that the two male albinos Nos. 1 and 2 collected from the field were YY in sex-chromosome constitution. When these YY males were mated with normal females (XX) (Table 23), a female albino (XX) of the Tj stock or females (XX) heterozygous for this albino gene (Table 24), the frogs produced were all males (XY). When males (XY) heterozygous for the albino gene (*t*) of the Kk stock were mated with females (XX) heterozygous for the albino gene (*t*) of the Kk or My stock, nearly equal numbers of females (XX) and males (XY) were produced among both albino and wild-type frogs (Tables 23 and 24).

TABLE 23

Sex of mature frogs produced from matings in each of ten stocks

Locality	Parents		Phenotype
	Female	Male	
Miyoshi (My)	Hetero, Nos. 2, 3	GD	Wild type
			Albino
	Hetero, Nos. 1, 4～6	Hetero, Nos. 1～4	Wild type
			Albino
	Albino, Nos. 1, 2	Wild, Nos. 5, 6	Wild type
	Wild, Nos. 16～18	Albino, No. 1	Wild type
	Wild, Nos. 16～18	Wild, No. 10	Wild type
Kake (Kk)	Wild, Nos. 1～6, 11～13, 19, 20	Albino, Nos. 1, 2	Wild type
	Wild, Nos. 7, 8, 11～13	Hetero, Nos. 1～6	Wild type
	(W♀ × Het. ♂), Nos. 1～3	Hetero, No. 7	Wild type
			Albino
	Wild, Nos. 1～3, 11～13, 19, 20	Wild, Nos. 4, 7, 10	Wild type
Tojo (Tj)	Albino, Nos. 3～6	Albino, No. 4	Albino
	Albino, No. 2	Wild, No. 5	Wild type
	Hetero, Nos. 4, 5	Albino, Nos. 2, 3	Wild type
			Albino
	Hetero, Nos. 1～3, 6, 7	Hetero, Nos. 3～7	Wild type
			Albino
	Hetero, Nos. 5～7	Wild, Nos. 6, 7	Wild type
	Wild, Nos. 1～3, 8, 16～18	Albino, Nos. 1, 2, 4	Wild type
	Wild, Nos. 1～3, 8, 16～18	Wild, Nos. 4, 6, 10	Wild type
Midori (Md)	Wild, Nos. 4, 5, 21～23	Albino, Nos. 1～3	Wild type
	Wild, No. 7	Hetero, Nos. 1, 2	Wild type
	Hetero, No. 1	Hetero, Nos. 1, 2	Wild type
			Albino
	Hetero, No. 1	Wild, No. 6	Wild type
	Wild, No. 7	Wild, No. 6	Wild type
Yasuura I (YsI)	Albino, No. 1	Albino, No. 1	Albino
	Albino, No. 1	Hetero, No. 1	Wild type
			Albino
	Hetero, Nos. 1～3	Hetero, Nos. 2～4	Wild type
			Albino
	Wild, Nos. 9, 10, 14, 15	Albino, Nos. 1, 2	Wild type
	Wild, Nos. 9, 14, 15	Wild, Nos. 6, 7	Wild type
Yasuura II (YsII)	Albino, No. 3	Albino, No. 3	Albino
	Albino, No. 2	Wild, No. 6	Wild type
	Hetero, Nos. 1, 3, 4	Albino, Nos. 4, 5	Wild type
			Albino
	Hetero, No. 2	Hetero, No. 1	Wild type
			Albino
	Wild, Nos. 8, 11～13, 16	Albino, Nos. 1～5	Wild type
	Wild, No. 13	Wild, No. 8	Wild type
Niimi (Nm)	Albino, No. 1	Albino, No. 1	Albino
	Albino, No. 1	Wild, No. 10	Wild type
	Wild, Nos. 21～23	Albino, No. 1	Wild type
	Wild, Nos. 21～23	Wild, No. 10	Wild type
Saijo (Sj)	Wild, Nos. 21～23	Albino, No. 1	Wild type

(The number in parentheses is that of immature frogs.)

No. of frogs	No. of raised frogs	Sex of mature frogs		
		Total	♀	♂
164	100	71 (+53)	71 (+53)	0
17	17	5 (+12)	5 (+12)	0
475	60	54	26	28
52	50	24	13	11
16	10	2	1	1
260	65	64	34	30
105	50	48	23	25
1570		532 (+429)	0	532 (+429)
141		70 (+44)	34 (+21)	36 (+23)
94	50	38	19	19
41	41	38 (+3)	23	15 (+3)
649	300	259	128	131
188	60	51	27	24
36	36	10	5	5
14	14	13	6	7
11	11	9	4	5
262	60	60	31	29
24	24	20	11	9
59	50	30	14	16
827	300	276	142	134
210	210	111	56	55
435	250	203	102	101
12	12	12	6	6
15	15	15	7	8
7	7	7	4	3
15	15	15	9	6
41	41	36	17	19
17	17	7	4	3
7	7	4	2	2
6	6	6	3	3
339	60	57	28	29
120	60	36	21	15
124	60	28	13	15
91	50	34	18	16
8	8	5	3	2
5	5	2	1	1
139	50	22	12	10
114	50	35	24	11
116	50	39	21	18
40	40	25	12	13
374	50	38	19	19
102	50	50	26	24
44	44	26	17	9
22	22	13	6	7
191	70	67	39	28
22	22	21	10	11
255	60	55	32	23

TABLE 23 Continued

Locality	Parents		Phenotype
	Female	Male	
Yamaguchi I (YmI)	Wild, Nos. 21～23	Albino, No. 1	Wild type
	Wild, No. 24	Albino, No. 2	Wild type
	Wild, No. 25	Albino, No. 2	Wild type
Yamaguchi II (YmII)	C-Albino, No. 1	Wild, No. 11	Wild type
	C-Albino, No. 2	Wild, No. 11	Wild type
	Wild, Nos. 24, 25	C-Albino, Nos. 1, 2	Wild type

TABLE 24

Sex of mature frogs produced from the matings between different stocks

(The number in parentheses is that of immature frogs.)

Parents		Phenotype	No. of frogs	Sex of mature frogs		
Female	Male			Total	♀	♂
Tj. Albino, Nos. 3～5	Nm. Albino, No. 1	Albino	37	6	2	4
	YmI. Albino, No. 1	Wild type	263	23	0	23
	Sj. Albino, No. 1	Albino	156	50	30	20
Tj. Albino, No. 1	Kk. Albino, No. 2	Wild type	32	32	0	32
Tj. Hetero, Nos. 3～5	YsI. Albino, Nos. 1～4	Wild type	34	19	9	10
		Albino	33	23	12	11
	YsII. Albino, Nos. 1～4	Wild type	66	42	20	22
Tj. Hetero, Nos. 6, 7	Kk. Albino, No. 2	Wild type	86	84	0	84
My. Albino, Nos. 1, 2	Md. Albino, No. 1	Wild type	13	13	6	7
My. Hetero, No. 4	YsI. Albino, Nos. 1, 2	Wild type	52	36	17	19
	YsII. Albino, Nos. 1, 2	Wild type	31	21	11	10
My. Hetero, Nos. 5～8	YmI. Albino, No. 2	Albino	432	40 (+121)	2 (+7)	38 (+114)
My. Hetero, No. 4	Kk. Hetero, Nos. 1, 2	Wild type	52	25	12	13
		Albino	19	16	7	9
YsI. Albino, No. 1	YsII. Albino, No. 1	Wild type	7	7	3	4
	Kk. Hetero, No. 1	Wild type	13	9	5	4
YsI. Albino, Nos. 3～5	Sj. Albino, No. 1	Albino	160	54	28	26
YsI. Albino, Nos. 6, 7	YmII. C-Albino, No. 1	C-Albino	23	20	13	7
		Albino	20	17	9	8
YsI. Hetero, No. 5	Nm. B-Albino, No. 1	Wild type	135	34	14	20
		Albino	82	21	11	10
		B-Albino	106	30	17	13
YsII. Albino, No. 3	Kk. Albino, No. 2	Wild type	1	1	0	1
YsII. Albino, Nos. 4, 5	YmII. C-Albino, No. 1	Wild type	112	64	24	40
Md. Hetero, Nos. 3, 4	YsI. Albino, Nos. 1, 2	Wild type	23	22	12	10
Md. Hetero, Nos. 2～4	YsII. Albino, Nos. 1～3	Wild type	36	31	13	18
		Albino	31	29	15	14
Md. Hetero, Nos. 3, 4	Kk. Hetero, No. 1	Wild type	12	12	5	7
Kk. Albino, Nos. 2～6	YmI. Albino, No. 2	Albino	465	34 (+9)	0	34 (+9)
	YmII. Albino, No. 1	Wild type	54	31	15	16
Nm. B-Albino, No. 1	YmI. Albino, No. 1	Wild type	15	7	0	7
	Sj. Albino, No. 1	Albino	12	10	4	6
		B-Albino	17	14	6	8
	Tj. Albino, No. 4	Albino	5	4	1	3
		B-Albino	11	10	9	1
	YsII. Albino, No. 5	Wild type	12	9	4	5
Nm. B-Albino, Nos. 2, 3	YmII. C-Albino, No. 1	Albino	54	42	22	20
		B-Albino	64	41	21	20
		C-Albino	60	38	22	16
		BC-Albino	55	44	23	21
YmII. C-Albino, No. 1, 2	YsI. Albino, No. 6	Albino	13	10	5	5
		C-Albino	15	14	7	7
	YsII. Albino, No. 6	Wild type	29	25	13	12
	Kk. Albino, No. 3	Wild type	36	31	16	15
	YmI. Albino, No. 2	Wild type	34	22 (+5)	1	21 (+5)

No. of frogs	No. of raised frogs	Sex of mature frogs		
		Total	♀	♂
374	60	32	0	32
104	50	27 (+23)	10 (+4)	17 (+19)
94	75	51 (+24)	0 (+2)	51 (+22)
10	10	10	5	5
15	15	13	6	7
40	40	40	22	18

3. Tojo (TJ) stock

Six kinds of matings, between 4 female albinos and a male albino, between a female albino and a normal male from the field, between 2 heterozygous females and 2 male albinos, between 5 heterozygous females and 5 heterozygous males, between 3 heterozygous females and 2 normal males from the field, and between 7 normal females from the field and 3 male albinos, produced 1421 frogs (Table 23). Of these frogs, 555 were continuously reared. As a result, 469 of them matured; 240 (51%) were females and 229 were males. From control matings between 7 normal females and 3 normal males from the field, 111 mature frogs were produced; 56 (50%) were females and 55 were males.

A male albino (No. 4) of the TJ stock produced 16 albino frogs by mating with a female albino of the NM stock. Of these offspring, 14 matured sexually; ten were females and four were males (Table 24).

4. Midori (MD) stock

From 4 kinds of matings, between 5 normal females from the field and 3 male albinos, between a normal female from the field and 2 heterozygous males, between a heterozygous female and 2 heterozygous males, and between a heterozygous female and a normal male from the field, 484 frogs in total were produced (Table 23). Although 299 frogs were continuously reared, 252 of them matured. Among the mature frogs there were 128 (51%) females and 124 were males. Of 41 frogs produced from a control mating between a female and a male collected from the field, 36 matured; 17 were females and 19 were males. On the other hand, 13 wild-type frogs were produced from matings between 2 female albinos of the MY stock and a male albino of the MD stock (Table 24). All these frogs matured sexually; six were females and seven were males.

5. Yasuura I (YsI) stock

From 4 kinds of matings, between a female albino and a male albino, between a female albino and a heterozygous male, between 3 heterozygous females and 3 heterozygous males, and between 4 normal females from the field and 2 male albinos, 613 frogs were produced (Table 23). Although 210 of them were continuously reared, 138 attained sexual maturity; 71 (51%) were females and

67 were males. From 3 control matings between 3 normal females and 2 normal males collected from the field, 91 frogs were produced. Fifty of them were continuously reared. As a result, 34 matured; 18 (53%) were females and 16 were males.

Matings between 6 heterozygous females of the TJ, MD and MY stocks and 2 or 4 male albinos of the YsI stock produced 142 frogs, of which 100 matured (Table 24). Of the latter, 50 were females and 50 were males.

6. Yasuura II (YsII) stock

Among the albinos collected in 1972 and 1973 from place D in Yasuura, Hiroshima Prefecture, males were far more numerous than females, that is, 26 of 31 mature frogs were males. From 5 kinds of matings, between a female and a male albino, between a female albino and a normal male from the field, between 3 heterozygous females and 2 male albinos, between a heterozygous female and a heterozygous male, and between 5 normal females from the field and 5 male albinos, 796 frogs were produced (Table 23). Of these frogs, 253 were continuously reared. As a result, 166 matured sexually; 92 (55%) were females and 74 were males.

From 5 male albinos of the YsII stock, 183 frogs were produced by mating with 7 heterozygous females of the TJ, MD and MY stock, and 2 female albinos of the YsI and NM stock (Table 24). Of these frogs, 139 matured sexually; 66 (47%) were females and 73 were males.

7. Niimi (NM) stock

Three kinds of matings, between a female and a male albino, between a female albino and a normal male and between 3 normal females and a male albino produced 257 frogs. Although 136 frogs were continuously reared, 106 of them matured sexually (Table 23). Of these mature frogs, 62 (58%) were females and 44 were males. From 3 control matings between 3 normal females and a normal male collected from the field, 22 frogs were produced. Twenty-one of these frogs matured; ten were females and 11 were males.

The larger number of females obtained from the experimental matings is attributable to that obtained from the mating of a male albino with a female albino or normal females. Among the mature frogs produced from this male albino there were 56 (60%) females and 37 males. However, the same male produced 44 (48%) mature females and 47 mature males by mating with 3 albino females of the TJ stock and a heterozygous female of the YsI stock (Table 24).

8. Saijo (SJ) stock

A male albino produced 255 frogs by mating with 2 normal females from the field. Although 60 of these frogs were continuously reared after metamorphosis, 55 matured; 32 (58%) were females and 23 were males (Table 23). When this male albino was mated with 7 albino females of the TJ, YsI and NM stocks, 345 frogs were produced (Table 24). Of these frogs, 149 were continuously reared,

and 128 attained sexual maturity; 68 (53%) were females and 60 were males.

9. Yamaguchi I (YmI) stock

From matings between a male albino (No. 1) and 3 normal females from the field, 374 frogs were produced (Table 23). Of these frogs, 60 were continuously reared, and only 32 matured sexually, all of them were males. When this male albino was mated with 4 female albinos of the Tj and Nm stocks, 278 frogs were produced. Of these frogs, 65 were continuously reared. As a result, only 30 frogs matured sexually. All the mature frogs were also males (Table 24). Accordingly, it was very probable that the male albino was YY in sex-chromosome constitution.

Although 198 metamorphosed frogs were produced from matings between another male albino (No. 2) and two normal females from the field, 125 of them were continuously reared. Eleven frogs died within two weeks after metamorphosis and 36 others were killed to examine their sex. Of a total of 47 frogs, 6 (13%) were females with underdeveloped ovaries and 41 were males. At the sexually mature stage, only 10 (13%) of 78 frogs were females, while 68 were males. In the total of mature and immature frogs, there were 16 (13%) females and 109 males among 125 frogs. It was noteworthy that all the 51 mature frogs produced from a mating between one (No. 25) of the two normal females and the male albino were males (Table 23).

From 3 kinds of matings between the male albino (No. 2) and 4 heterozygous females of the My stock, two female albinos of the YmII stock and 5 female albinos of the Kk stock, 931 frogs were produced (Table 24). The sex of 135 of these frogs was examined within 2 months after metamorphosis; 7 were females with underdeveloped ovaries and 128 were males. The sex of 96 other frogs was examined at the sexually mature stage. As a result, 3 were females and 93 were males.

On the basis of the sex of these offspring, it was presumed that the male albino was YY and that the female offspring were sex-reversed genetic males (XY).

10. Yamaguchi II (YmII) stock

Two female colored albinos produced 25 frogs by mating with a normal male from the field. Twenty-three of the latter matured; 11 of them were females and 12 were males (Table 23). From 2 male colored albinos, 40 frogs were produced by mating with 2 normal females from the field. All of them attained sexual maturity; 22 were females and 18 were males.

The two female colored albinos produced 28 colored or red-eyed albino frogs by mating with a male albino of the YsI stock belonging to the same group. Of these frogs, 24 matured sexually; 12 were females and 12 were males. From matings between the same two females and 2 male albinos of the Kk and YsII stocks 65 wild-type frogs were produced. Fifty-six of them matured sexually; 29 were females and 27 were males (Table 24). When these two female colored albinos were mated with a male albino of the YmI stock, 34 frogs were produced.

Twenty-two of these matured sexually and it was found that only one frog was a female and the other 21 were males. This male albino was that previously presumed to be YY. The single female offspring was considered to be a sex-reversed genetic male (XY).

A male colored albino was mated with 4 kinds of female albinos belonging to the YsI, YsII, Kk and Nm stocks (Table 24). From 2 female albinos of the YsI stock, 2 female albinos of the YsII, 5 female albinos of the Kk and 2 female black-eyed albinos, 442 frogs in total were produced. Of these frogs, 297 matured sexually; 149 (50%) were females and 148 were males.

IV. Electron-microscopical structure

Japanese tree-frogs in the field are usually green or yellowish green in ground color of the dorsal surface (Plate I, 1). However, their colors change strikingly into gray, grayish brown or dark brown according to their environment. Differing from the normal tree-frogs, albinos are always whitish, although their colors change from white tinged with greenish yellow into light brownish gray. There is generally a difference in tinge of whiteness between different groups of albinos. The three groups also differ from one another in color of the pupil.

The albinos of the first group except the YmII and Sj stocks are usually more yellowish than those of the other groups in color of the dorsal surface. The albinos of the YmII stock (Plate I, 2) become nearly wild-type frogs with growth after metamorphosis and change their color as the latter do. Those of the Sj stock (Plate II, 7) are usually somewhat greenish, being similar to the albinos of the second group in color of the dorsal surface. The pupil of the eye is pink in the albinos of the stocks other than the YmII as well as of a part of the Nm stock. The albinos of the YmII stock have black pupils which are nearly the same as those of wild-type frogs. Among albinos of the Nm stock there are two kinds of individuals, black-eyed and red-eyed (Plate I, 3, 4). The pupils of the black-eyed albinos are reddish black, while those of the red-eyed albinos are pink. The albinos of the second group including the Md and YsII stocks (Plate II, 8, 9) are usually more greenish than those of the other groups in color of the dorsal surface. Their pupils are dark red. The albinos of the third group consisting of the YmI, Kk and My stocks (Plate II, 10~12) are very similar to those of the Tj, YsI and Nm stocks (Plate I, 3~6) of the first group in color of the dorsal surface, although they are usually less yellowish than the latter. Their pupils are red which is somewhat deeper than the pupil colors of albinos in the Sj, Tj, YsI and a part of Nm stocks of the first group.

The dorsal skin, the pigment epithelium of the retina and the choroid of the eye were examined under an electron microscope to elucidate abnormal production of melanosomes in the albinos of the 10 stocks divided into three groups.

1. Tree-frogs of the wild type

a. Dermal melanophores

In the dorsal skin of a normal tree-frog collected from the field, there are three

kinds of dermal chromatophores, xanthophores, iridophores and melanophores (Plate III, 13). These dermal chromatophores are nearly the same as those of *Hyla cinerea* (BAGNARA, TAYLOR and HADLEY, 1968) in arrangement as well as in ultramicroscopical structure. The melanophores are the deepest in location and have many long processes. Each melanophore is filled with completed melanosomes which are shape like elongated ellipsoids. They are about 0.3~0.4 μ in the diameter of transverse section. Each of the completed melanosomes is homogeneous and reveals no inner structure. Premelanosomes are scarce in the dermal melanophores (Plate III, 14).

b. Pigment cells in the eye

The pigment epithelial cells of the retina are abundantly provided with completed melanosomes which are similar to those of the dermal melanophores in shape and about 0.4~0.6 μ in the diameter of transverse section (Plate IX, 31, 32). The melanophores in the choroid are also filled with completed melanosomes which are somewhat different from those of the retina in shape (Plate IX, 33). These melanosomes are rather roundish, although they are about 0.4~0.6 μ in the diameter of transverse section.

2. Albinos of the first group

a. Dermal melanophores

Both xanthophores and iridiphores in the albinos of the TJ, YsI, SJ, NM and YmII stocks belonging to the first group are the same as those of wild-type tree-frogs in microstructure. In contrast with these chromatophores, dermal melanophores are quite different from those of wild-type tree-frogs in structure. Except the colored albinos of the YmII stock, the dermal melanophores have no completed melanosomes, although they contain colorless premelanosomes. These premelanosomes are not only fewer than the melanosomes found in the dermal melanophores of wild-type tree-frogs, but remarkably smaller than the latter. They are elongated ellipsoids, being about 0.2 μ in the diameter of transverse section. In each premelanosome, several spiral threads are arranged almost parallel to its long axis.

The albinos of the TJ stock (Plate IV, 16, 17) differ distinctly from those of the YsI, SJ and NM stocks (Plates III, 15, IV, 18 and V, 19~21) in the scarcity and smallness of premelanosomes. The colored albinos of the YmII stock (Plate VI, 22, 23) have a small number of incomplete melanosomes in addition to many premelanosomes. The incomplete melanosomes differ from completed melanosomes in size and structure; each of them is somewhat smaller and surrounded with a clear limiting membrance. Strange to say, the dermal melanophores of the albinos of the TJ and NM stocks contain a few reflecting platelets in addition to premelanosomes.

b. Pigment cells in the eye

In the albinos of the TJ, YsI and SJ stocks, as well as the red-eyed albinos of

the NM stock, the pigment epithelial cells of the retina as well as the melanophores in the choroid have no completed melanosomes. However, a few small colorless premelanosomes are found in these pigment cells, as those in the dermal melanophores. They are nearly the same as the latter in shape and inner structure, although they are slightly larger (Plates X, 37~42, XI, 46~48 and XII, 49~51).

The black-eyed albinos of the NM stock are characteristic of existence of completed melanosomes in the pigment epithelial cells of the retina, and of nonexistence of such melanosomes in the melanophores in the choroid. The pigment epithelial cells of the retina contain numerous completed melanosomes that are the same as those of wild-type tree-frogs in size and shape as well as in amount. Premelanosomes are scarce in these pigment epithelial cells of the retina. In contrast to the retina, the melanophores in the choroid contain a few small colorless premelanosomes that are very similar to those of dermal melanophores in shape and inner structure (Plate XI, 43~45). The colored albinos of the YMII stock have a small number of incomplete melanosomes in addition to many premelanosomes in the choroidal melanophores as well as in the pigment epithelial cells of the retina (Plate IX, 34~36).

3. Albinos of the second group

a. Dermal melanophores

Xanthophores and iridophores in the albinos of the YsII and MD stocks do not differ from those of albinos belonging to the first group as well as from those of wild-type tree-frogs (Plate VII, 25). Melanophores are very abnormal in structure; they contain colorless premelanosomes in place of completed melanosomes. The premelanosomes are far more numerous than those of albinos belonging to the first group. They are very similar to the latter in size and shape, or rather a little more slender, although they are nearly the same in inner structure. They appear to be almost equal in density to the melanosomes in dermal melanophores of wild-type tree-frogs.

There are no distinct differences between the albinos of the YsII stock and those of the MD stock in the density, size, shape and inner structure of premelanosomes (Plate VII, 25~27).

b. Pigment cells in the eye

No completed melanosomes are found in the pigment epithelial cells of the retina as well as in the melanophores of the choroid. These pigment cells contain small colorless premelanosomes alone. The premelanosomes do not distinctly differ from those contained in dermal melanophores in minute structure. They are slightly thicker and more numerous than those in the eyes of albinos belonging to the first group. While the premelanosomes in the retina are elongated ellipsoids, those in the choroid are rather roundish (Plate XIII, 55~60).

4. Albinos of the third group

a. Dermal melanophores

The albinos of the third group consisting of the Kk, My and YmI stocks are the same as those of the first and second groups in abnormal structure of dermal melanophores, as well as in the normality of xanthophores and iridophores. There are no completed melanosomes in the melanophores; the latter contain colorless premelanosomes alone. The premelanosomes in each melanophore are remarkably different from those of the first and the second groups in various respects.

It is noteworthy that the three kinds of albinos, the Kk, My and YmI stocks, differ distinctly from one another in the number, size, shape and minute structure of premelanosomes contained in each melanophore. The premelanosomes of the Kk stock (Plate VIII, 30) are more numerous than those of the YsI stock and nearly similar in number to those of the YsII. However, each of them is rather spherical and very large, being about 0.5 μ in the diameter of transverse section. The body of each premelanosome is surrounded with a limiting membrane and becomes dark by staining with uranyl acetate and lead citrate, without revealing clear spiral threads. The premelanosomes of the My stock (Plate VI, 24) are far fewer than those of the Kk and YmI stocks. Although each of them is somewhat similar to that of the YsI or YsII stock in size and inner structure, it is remarkably long and narrow. A few reflecting platelets are contained in addition to premelanosomes in the melanophores of the My and YmI stocks. The premelanosomes of the YmI stock (Plate VIII, 28, 29) are found in a high density in each melanophore. They are full of variety, although there are no large premelanosomes such as found in the melanophores of the Kk stock. Some of them are similar to those of the YsII stock in size, shape and minute structure, while the others are peculiar in these respects.

b. Pigment cells in the eye

The pigment epithelial cells of the retina as well as the melanophores of the choroid in the albinos of the third group contain premelanosomes alone which are similar to those of the dermal melanophores in inner structure. While the premelanosomes in the My stock (Plate XIV, 61~63) are small and usually elongated ellipsoids, those in the Kk stock (Plate XII, 52~54) are large and roundish, being about 0.4 μ in the diameter of transverse section. As observed in dermal melanophores, the premelanosomes in the pigment cells of the eye show no distinct spiral structure. The pigment epithelial cells of the retina and the choroidal melanophores in the eyes of albinos of the YmI stock contain premelanosomes alone which are similar to those of the YsII stock or peculiar to the YmI stock in number, size, shape and minute structure (Plate XIV, 64~66).

DISCUSSION

The fact that albinism is due to a recessive gene in the homozygous condition is a matter of common knowledge in vertebrates including human beings. This was ascertained in amphibians by several investigators, although their experiments were of a small scale. The existence of such a single recessive gene underlying albinism was presumed for the first time in *Rana temporaria* by EALES (1933) and SMALLCOMBE (1949) and in parthenogenetically developed *Rana nigromaculata* by TOKUNAGA (1949). During the last ten years this was ascertained in *Rana pipiens* by BROWDER (1967, '72) and GILL (SMITH-GILL), RICHARDS and NACE (1970, '72), in axolotl by HUMPHREY (1976) and BENJAMIN (1970), in *Hyla arborea japonica* by DAITO (1968) and in *Xenopus laevis* by HOPERSKAYA (1975).

The results of the authors' crossing experiments performed among ten stocks of albino *Hyla arborea japonica* collected from an area surrounding Hiroshima are schematically shown in Figure 2. From these results it is clear that there are three albino groups which are due to three different recessive genes, *f*, *s* and *t*, and, moreover, that the Niimi and Yamaguchi II stocks of the first group differed from the others in that they have dominant *B* and *C* genes linked with their recessive *f* gene, respectively. As far as we know, the fact that albinism is brought about independently by each of two or more kinds of recessive genes has not been known in the other vertebrates including human beings. In anurans, this seems rather to be a matter of usual occurrence; we observed four kinds of albinos due to different recessive genes in the Japanese pond frog species, *Rana nigromaculata* (NISHIOKA and UEDA, unpublished). Multiple alleles of an albino gene have been well known in human beings and in various mammals, such as guinea pigs, rabbits, mice, dogs and cats. Although the albino *Hyla arborea japonica* belonging to the same group are very similar to one another in appearance, except the two strains with the *B* and *C* genes, some stocks differ from one another in the minute structures of dermal melanophores of albinos. The albinos of the TJ stock of the first group are different in detail from those of the YsI, SJ and NM stocks in this respect, while the latter three are very similar to one another. Accordingly, the TJ stock and the others seem to be different albino strains controlled by multiple alleles of the *f* gene. The YMII stock is a special strain having the dominant *C* gene linked with the recessive *f*. As albino frogs with the *f* gene alone have not yet been obtained, nothing is known about the effect of this gene upon the minute structure of dermal melanophores in this stock. The albinos of the YsII and MD stocks of the second group seems to belong to the same strain controlled by the *s* gene. In the third group, the albinos of the KK, MY and YMI stocks differ distinctly from one another in number, size and shape of premelanosomes contained in each melanophore. On the basis of these differences, it is presumed that the three stocks are three strains controlled by multiple alleles of the *t* gene. Genetic analyses of these presumptive alleles of the *f* and *t* genes will be carried out in the near future.

Hyla arborea japonica has 12 pairs of chromosomes (IRIKI, 1930; YOSHIDA, 1957; MATSUDA, 1963; SETO, 1964). The sex chromosomes were not always identified by these authors, although their existence can not be doubted on the basis of the results of the authors' crossing experiments. From a morphological point of view, YOSHIDA and MATSUDA recognized X and Y chromosomes in the male karyotype, while IRIKI (1930, '32) considered that the male was of XX-type, as the two sex chromosomes were identical in size, shape and behavior. Differing from these authors, SETO could not identify the sex chromosomes in the karyotypes obtained from adult male and female tissues both *in vivo* and *in vitro*. The chromosome pairs in which the *f*, *s* and *t* genes are located are yet unknown. It is also undetermined whether they are located in different chromosome pairs or at different loci of the same chromosome pair, although it is clear that they are in the autosomes. Each of the dominant *B* and *C* genes is of course located in the same chromosome as that of the recessive *f* gene.

It is generally believed that melanin is produced through a chain of reactions beginning with phenylalanine. Several enzymes acting under genetic control are involved one by one in the various steps of oxidation. Albinism is usually caused by block of a ring of the chain; the albino gene in mammals is considered to give rise in the homozygous form to the lack or inactivity of tyrosinase which catalyzes the oxidation of tyrosine to 3, 4-dihydroxyphenylalanine (dopa), and of dopa to dopa quinone (FOSTER, 1961, '65). According to BENJAMIN (1970), albinism in the axolotl also appeared due to an alteration of tyrosinase such that it is rendered inactive, as tyrosinase activity was absent in extracts of albino embryos, larvae, or skin. On the other hand, RITTENHOUSE (1968) observed that melanophores in the skin of albino mice contained a mixture of unmelanized granules, multivesicular bodies and bodies having an appearance intermediate between multivesicular bodies and melanin granules. In this respect, Mexican albino *Rana pipiens* examined by SMITH-GILL, RICHARDS and NACE (1970, '72) were similar to the albino mice, as their skin had a normal number of melanophores with numerous unmelanized melanosomes. However, they differed distinctly from albinos in mammals as well as from albino axolotls in that their melanophores had both tyrosinase and dopa oxidase activity.

The biochemical aspects of the ten stocks of albino *Hyla arborea japonica* have scarcely been examined hitherto. However, it is quite clear that these varieties of albinos found in the single subspecies are excellent materials for clarifying the chain of chemical reactions producing melanin as well as the morphological process of melanosome formation. The steps of chemical reactions presented by LERNER (1953) as a general sequence of enzymatic oxidation of tyrosine to melanin are as follows: Tyrosine→Dopa→Dopa quinone→Leuco compound→Dopachrome→5, 6-dihydroxyindole→Indole 5, 6-quinone→Melanin. It is probable that the three albino genes, *f*, *s* and *t*, in the homozygous form block roughly three of these seven steps of chemical reactions by the lack or inactivity of the respective enzymes. Biochemical assays on the tyrosine and its derivatives as well as the tyrosinase and some other oxygenases contained in the dermal melanophores

of each kind of albinos are necessary in order to corroborate this tentative speculation.

Another interesting fact clarified by the present investigation is the discovery of YY male albinos Nos. 1 and 2 of the Kk stock and Nos. 1 and 2 of the YmI stock. While YY males were produced in a fresh-water fish species, *Oryzias latipes*, by mating between a sex-reversed genetic male (XY) and a normal male (XY) (Yamamoto, 1955), they have not yet been reported in amphibians. The male heterogamety (XY) of *Hyla arborea japonica* is confirmed by the results of the crosses between the above male albinos or their male offspring and normal females (Tables 23 and 24). The fact that the sex reversal of genetic males occurs easily by injection of estrogene in this subspecies has also been ascertained (Kawamura and Nishioka, 1977). A sex-reversed genetic male has actually been discovered among the frogs of this subspecies from the field. However, it was strange that all the male albinos belonging to two of the ten albino stocks collected from the field were of YY in sex-chromosome constitution. The albinism of each of the two stocks was due to the albino gene which was considered to be an allele of the *t*. As YY males are produced without fail from a cross between a sex-reversed genetic male (XY) and a normal male (XY), genetic males homo- or heterozygous for the *t* gene or its allele should be apt to give rise to sex reversal. The authors will confirm this assumption within the not too distant future.

SUMMARY

1. Crossing experiments were performed among ten stocks of albino tree-frogs, *Hyla arborea japonica*, collected from an area of about 6000 square kilometers surrounding Hiroshima in order to clarify the inheritance of albinism.

2. The ten stocks were sorted into three groups. The albinos in the first group consisting of the Yasuura I (YsI), Tojo (Tj), Saijo (Sj), Niimi (Nm) and Yamaguchi II (YmII) stocks are caused by the presence of the recessive first albino gene (*f*). The albinisms of the Nm stock are black-eyed by the presence of the dominant black-eyed gene (*B*) linked with the *f*, while those of the YmII stock are somewhat colored by the presence of the dominant colored gene (*C*) linked with the *f*. The albinos in the second group consisting of the Yasuura II (YsII) and Midori (Md) stocks are caused by the presence of the recessive second albino gene (*s*) in the homozygous condition. The albinos in the third group consisting of the Kake (Kk), Miyoshi (My) and Yamaguchi I (YmI) stocks are caused by the presence of the recessive third albino gene (*t*) in the homozygous condition.

The *f*, *s* and *t* genes are different from one another in locus, although they are all located in the autosomes. The hybrids of albinos belonging to different groups are of the wild type in color and pattern.

3. *Hyla arborea japonica* is of XY type in sex-determining mechanism. The albinos produced from any kind of mating in the laboratory do not usually differ in sex ratio from the wild-type frogs produced from any kind of mating.

Two albino males of each of the Kk and YmI stocks collected from the field were all YY in the sex-chromosome constitution. These YY males were considered to have been produced from crosses between sex-reversed genetic males (XY) and normal males (XY).

4. The three groups of albinos differ slightly from one another in the colors of skin and eyes. Under the electron microscope, all of them are very abnormal in structure of dermal melanophores and pigment cells of the eyes, while they are nearly normal in xanthophores and iridophores. The dermal melanophores of all the albinos have no completed melanosomes, except those of the colored albinos of the YmII stock. They contain only colorless premelanosomes. The colored albinos have a small number of incomplete melanosomes in addition to many premelanosomes in the dermal melanophores as well as in the pigment cells of the eye. The pigment epithelial cells of the retina and the melanophores in the choroid of the eyes of all the albinos have only colorless premelanosomes, except those of the black-eyed albinos of the Nm stock and of the colored albinos of the Ym II stock. The black-eyed albinos are characteristic of the existence of completed melanosomes in the pigment epithelial cells of the retina alone.

The three groups of albinos are distinctly different from one another in the number, size, shape or minute structure of premelanosomes contained in dermal melanophores and pigment cells of the eye. In the first group, the albinos of the Tj stock differ from those of the YsI, Sj and Nm stocks in the scarcity and smallness of premelanosomes. In the third group, the albinos of the three stocks, the Kk, My and YmI, differ distinctly from one another in the number, size, shape or minute structure of premelanosomes contained in dermal melanophores and pigment cells of the eye.

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LITERATURE

Bagnara, J. T., Taylor, J. D. and M. E. Hadley 1968. The dermal chromatophore unit. J. Cell Biol. **38**: 67–79.

Benjamin, C. P. 1970. The biochemical effects of the *d*, *m*, and *a* genes on pigment cell differentiation in axolotl. Develop. Biol. **23**: 62–65.

BOSCHWITZ, D. 1962. An albino specimen of *Hyla arborea savignyi* AUDOUIN.. Zool. Anz. **168**: 213–216.

BRAME, A. H., Jr. 1962. A survey of albinism in salamanders. Abhand. u. Berich. f. Natur. u. Vorgesch. **11**: 65–81.

BROWDER, L. W. 1967. Pigmentation in *Rana pipiens*. A study in developmental genetics. Ph. D. Thesis, University of Minnesota.

———— 1972. Genetic and embryological studies of albinism in *Rana pipiens*. J. Exp. Zool. **180**: 149–155.

DAITO, Y. 1968. On albinos in the tree frog, *Hyla arborea japonica* GÜNTHER. (In Japanese) Zool. Mag. (Tokyo) **77**: 92–96.

EALES, N. B. 1933. Albinism in the common frog. Nature **132**: 278–279.

FOSTER, M. 1961. Enzymatic studies of pigment-forming abilities in mouse skin. J. Exp. Zool. **117**: 211–246.

———— 1965. Mammalian pigment genetics. Advances in genetics, Acad. Press **13**: 311–339.

GILBOA, I. and H. G. DOWLING 1974. A bibliography on albinism in amphibians and reptiles. Publ. Herpetol. **6**: 3–11.

GILL, S. J., C. M. RICHARDS and G. W. NACE 1970. Biochemical and developmental studies on albinism in *Rana pipiens*. Am. Zool. **10**: 529.

———— 1972. Genetic and metabolic bases of two "albino" phenotypes in the leopard frog, *Rana pipiens*. J. Exp. Zool. **180**: 157–167.

HENSLEY, M. 1959. Albinism in North American amphibians and reptiles. Michigan State Univ. Museum, Publ. Mus. Biol. Series **1**: 133–159.

HERKNER, H. 1959. Albinismus bei Laubfroschkaulquappen. Die Aqu. Terr. Z. **12**: 126–127.

HOPERSKAYA, O. A. 1975. The development of animals homozygous for a mutation causing periodic albinism (a^p) in *Xenopus laevis*. J. Embryol. exp. Morph. **34**: 253–264.

HUMPHREY, R. R. 1967. Albino axolotls from an albino tiger salamander through hybridization. J. Hered. **58**: 95–101.

IRIKI, S. 1930. Studies on amphibian chromosomes. 1. On the chromosomes of *Hyla arborea japonica* GUENTHER. Mem. Coll. Sci. Kyoto Imp. Univ., Ser. B, **5**: 2–17.

———— 1932. Studies on amphibian chromosomes. 5. Explanation of the sex-chromosome type of *Hyla arborea japonica* from the standpoint of spiral structure. Sci. Rep. Tokyo Bunrika Daigaku, Sec. B, **1**:73–80.

JAMESON, D. L. and R. M. E. MYERS 1957. Albino Pacific tree frogs. Herpetologica **13**: 74.

KAWAMURA, T. and M. NISHIOKA 1977. Aspects of the reproductive biology of Japanese amphibian. Reproductive Biology of Amphibians, edited by D. H. TAYLOR and S. I. GUTTMAN. pp. 103–139. Plenum Press, New York and London.

LERNER, A. B. 1953. Metabolism of phenylalanine and tyrosine. Advan. Enzymol. **14**: 73–128.

MATSUDA, K. 1963. Culture techniques with some amphibian tissues and a chromosome study of the tree frog, *Hyla arborea japonica*. (In Japanese) Zool. Mag. (Tokyo) **72**: 105–109.

NISHIOKA, M. and H. UEDA 1977. An electron-microscopic study on six kinds of color variants induced by radiation in *Rana nigromaculata*. Sci. Rep. Lab. Amphibian Biol., Hiroshima Univ. **2**: 91～102

———— Genetic and morphologic studies on ten albino stocks in *Rana nigromaculata* and *Rana brevipoda*. (Unpublished)

PETROVIC, C. A. 1973. An "Albino" frog, *Eleutherodactylus planirostris* COPE. J. Herpet. **7**: 49–51.

RITTENHOUSE, E. W. 1968. Genetic effects on fine structure and development of pigment granules in mouse hair balb melanocytes. II. The *c* and *p* loci, and *ddpp* interaction. Devel. Biol. **17**: 366–381.

SAZIMA, I. 1974. An albino hylid frog, *Phrynohyas mesophaea* (HENSEL). J. Herpet. **8**: 264–265.

SETO, T. 1964. The karyotype of *Hyla arborea japonica* with some remarks on heteromorphism of the sex chromosomes. J. Fac. Sci., Hokkaido Univ., Ser. IV, Zool. **15**: 366–373.

SMALLCOMBE, W. A. 1949. Albinism in *Rana temporaria*. J. Genet. **49**: 286.

TOKUNAGA, Ch. 1949. Albino frogs produced by artificial parthenogenesis. J. Hered. **40**: 279–281.

VAN DEVENDER, T. R. 1969. A record of albinism in the Canyon tree frog, *Hyla adenicolor* COPE. Her-

petologica **25**: 69.

YAMAGUCHI, H. 1956. Albinos of *Hyla arborea japonica* GUENTHER. (In Japanese) Collecting and Breeding **18**: 356–358.

YAMAMOTO, T. 1955. Progeny of artificially induced sex-reversals of male genotype (XY) in the medaka (*Oryzias latipes*) with special reference to YY-male. Genetics **40**: 406–419.

YOSHIDA, T. H. 1957. Sex chromosomes of the tree frog, *Hyla arborea japonica*. J. Fac. Sci., Hokkaido Univ., Ser. IV, Zool. **13**: 352–358.

EXPLANATION OF PLATES

PLATE I

Albinos of four stocks belonging to the first group in *Hyla arborea japonica*. ×1.1

1. Wild-type tree-frog (♀).
2. Colored albino (♀) of the YmII stock.
3. Black-eyed albino (♀) of the Nm stock.
4. Red-eyed albino (♀) of the Nm stock.
5. Albino (♀) of the Tj stock.
6. Albino (♀) of the YsI stock.

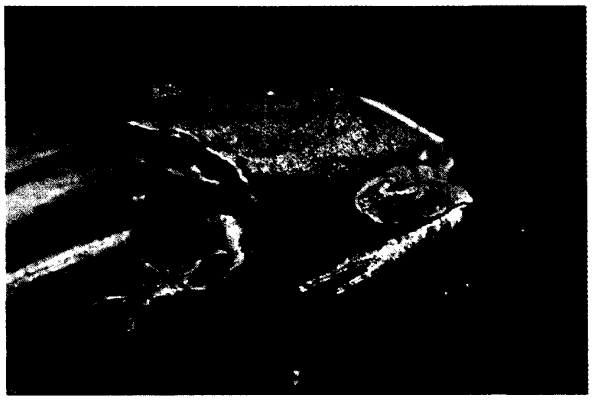

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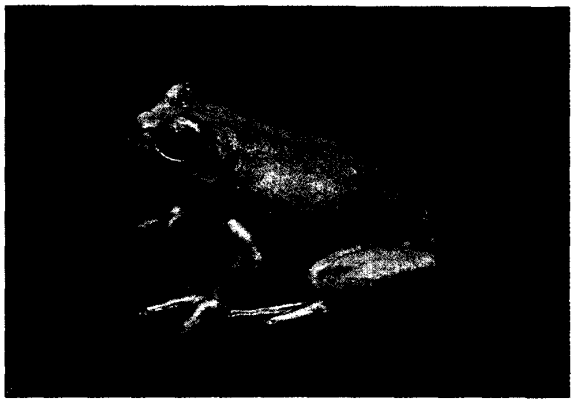
PLATE II

Albinos of six stocks belonging to the first to third groups in *Hyla arborea japonica*. ×1.1

7. Albino (♂) of the SJ stock belonging to the first group.
8. Albino (♂) of the MD stock belonging to the second group.
9. Albino (♀) of the YsII stock belonging to the second group.
10. Albino (♀) of the MY stock belonging to the third group.
11. Albino (♀) of the KK stock belonging to the third group.
12. Albino (♀) of the YMI stock belonging to the third group.

7



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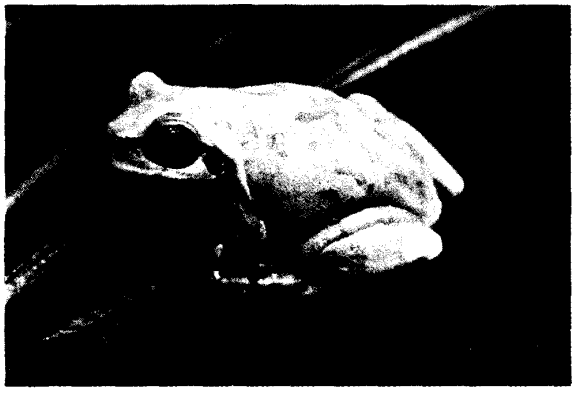

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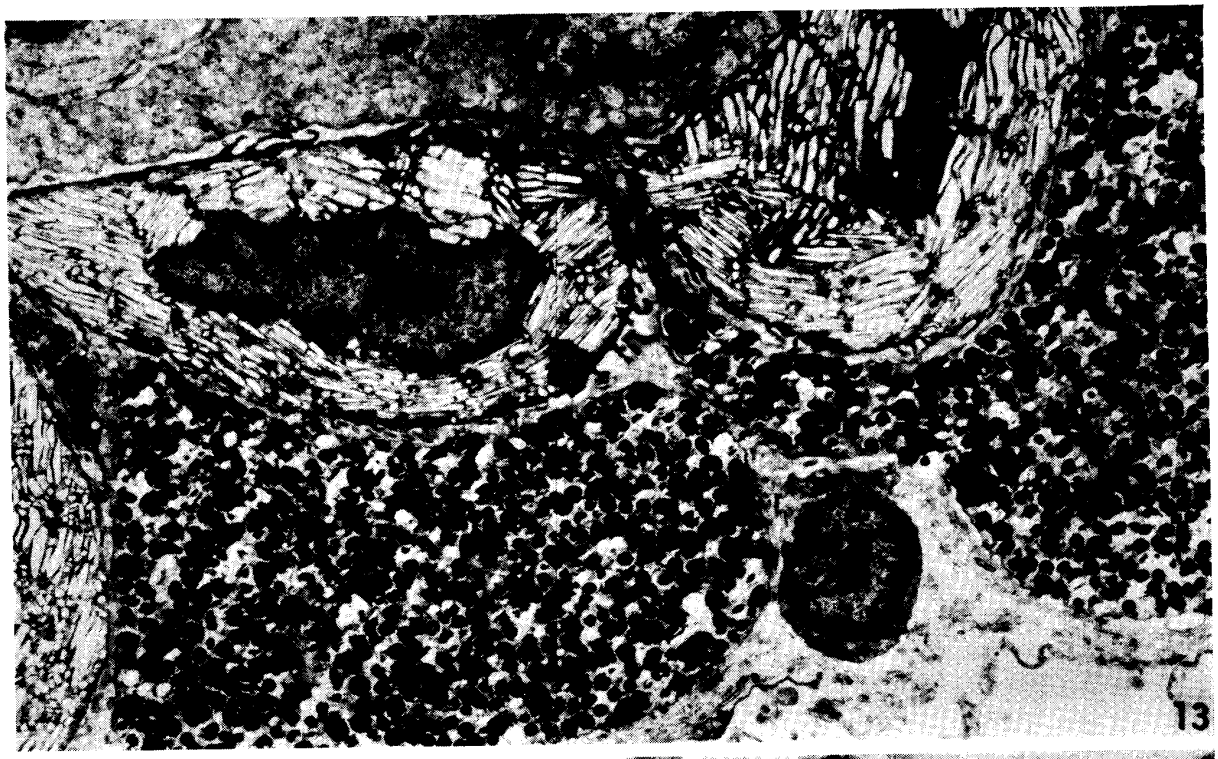
PLATE III

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, I.

13. Three kinds of chromatophores in a wild-type tree-frog. ×4000.
14. Portion of a melanophore filled with melanosomes in a wild-type tree-frog. ×22000.
15. Portion of an abnormal melanophore containing premelanosomes (arrow) in a black-eyed albino of the Nm stock belonging to the first group. ×22000.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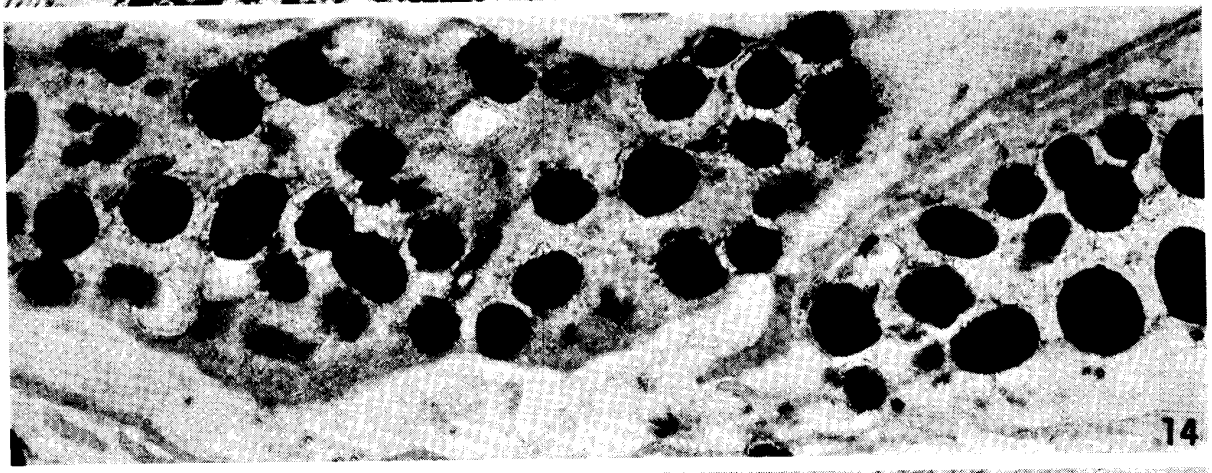
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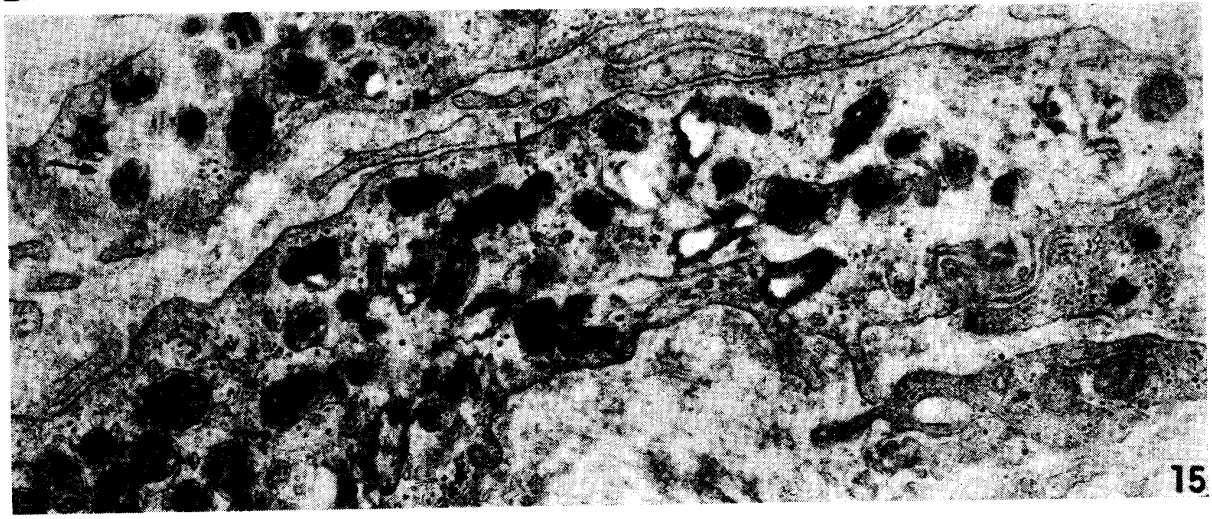
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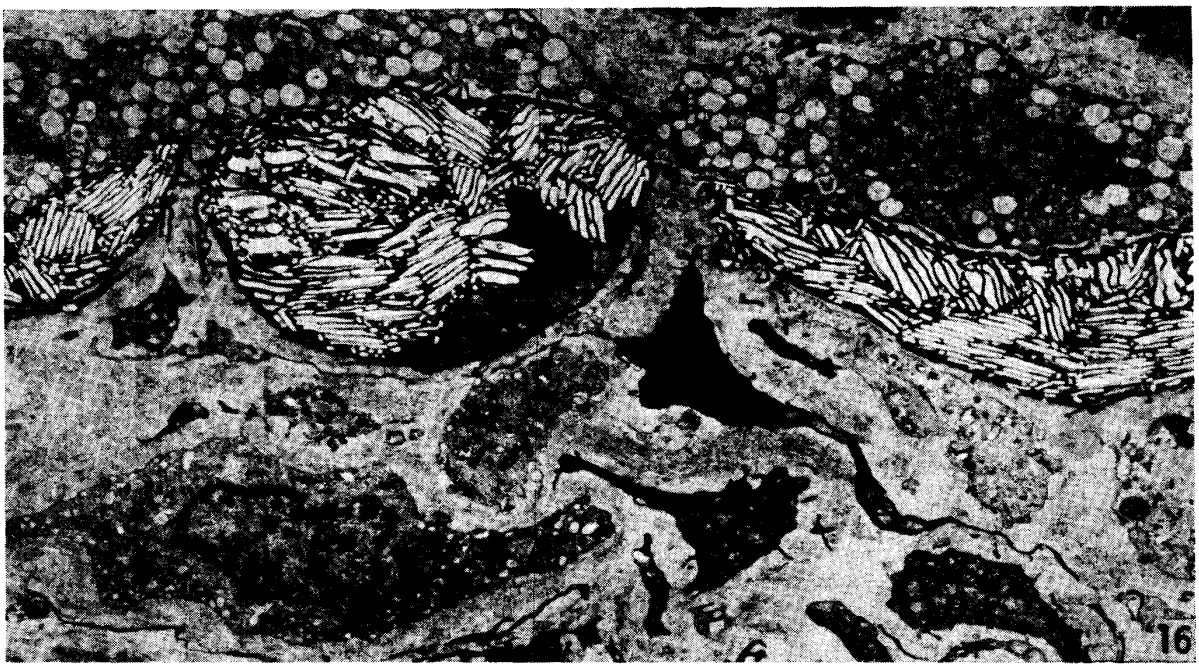
PLATE IV

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, II.

16. Three kinds of chromatophores in an albino of the TJ stock belonging to the first group. ×4000.
17. Portion of an abnormal melanophore containing premelanosomes (arrow) in the same albino as shown in Fig. 16. ×22000.
18. Portion of an abnormal melanophore containing premelanosomes (arrow) in a red-eyed albino of the NM stock belonging to the first group. ×22000.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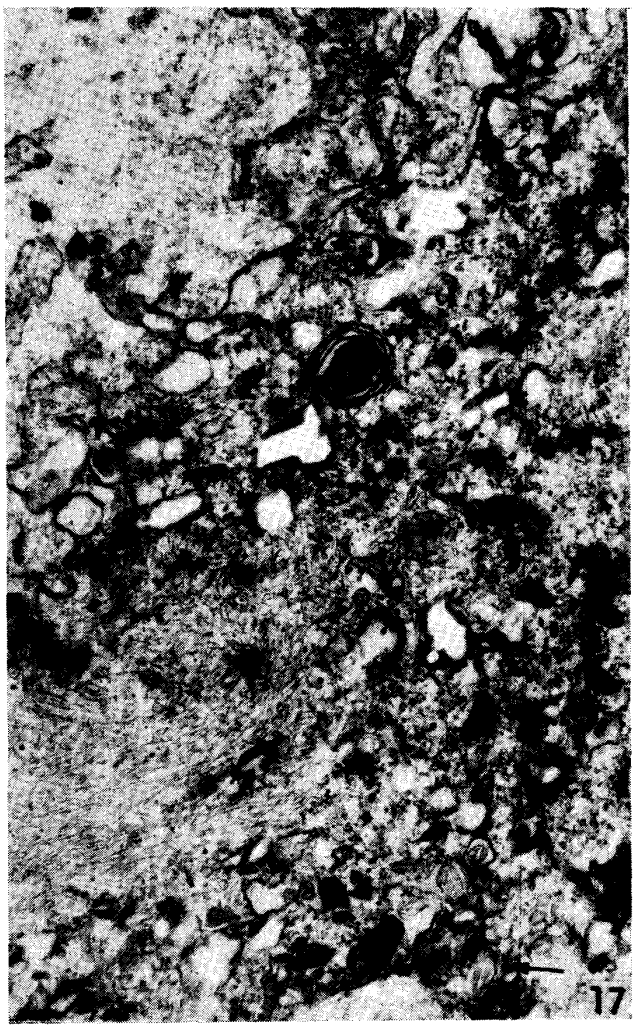
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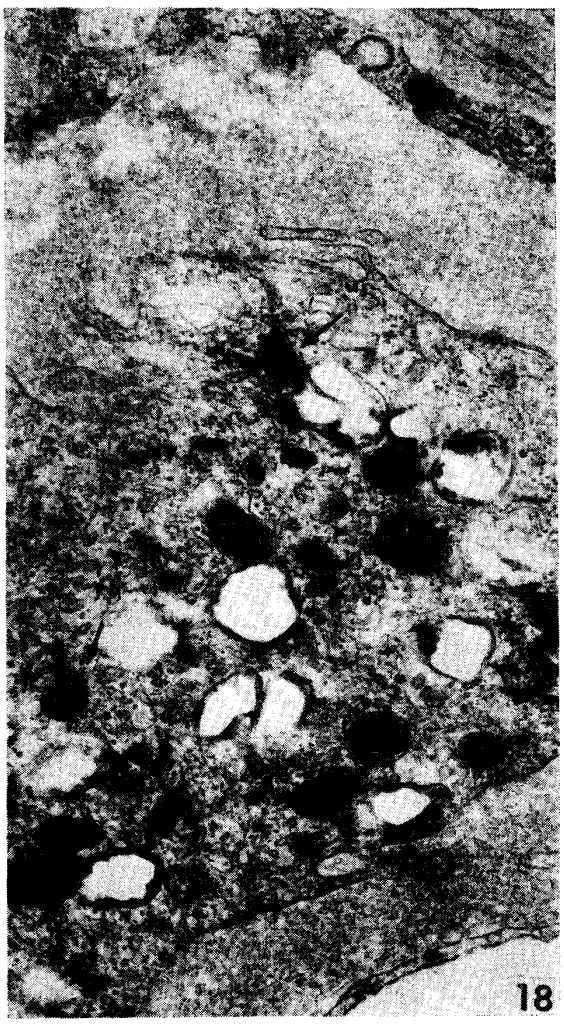
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PLATE V

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, III.

19. Three kinds of chromatophores in an albino of the SJ stock belonging to the first group. ×4000.
20. Portion of an abnormal melanophore containing premelanosomes (arrow) in the same albino as shown in Fig. 19. ×22000.
21. Portion of an abnormal melanophore containing premelanosomes (arrow) in an albino of the YsI stock belonging to the first group. ×22000.


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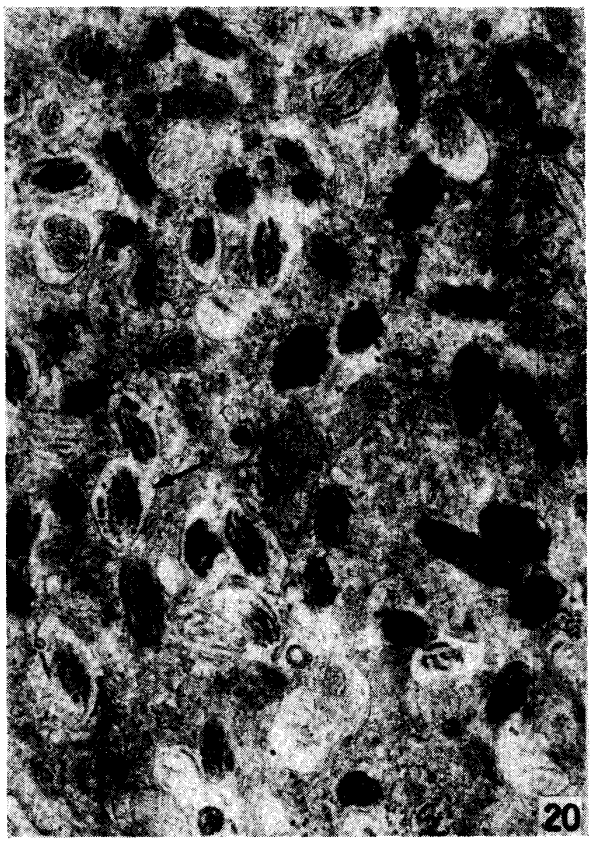
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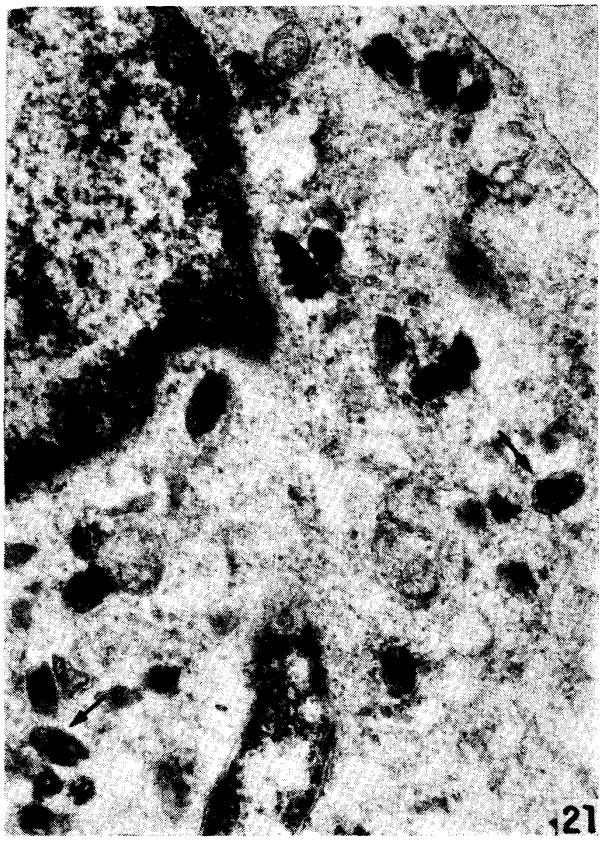
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PLATE VI

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, IV.

22. Three kinds of chromatophores in a colored albino of the YmII stock belonging to the first group. ×4000.
23. Portion of an abnormal melanophore containing a mixture of premelanosomes and abnormal melanosomes in the same albino as shown in Fig. 22. ×22000.
24. Portion of an abnormal melanophore containing premelanosomes (arrow) in an albino of the My stock belonging to the third group. ×22000.


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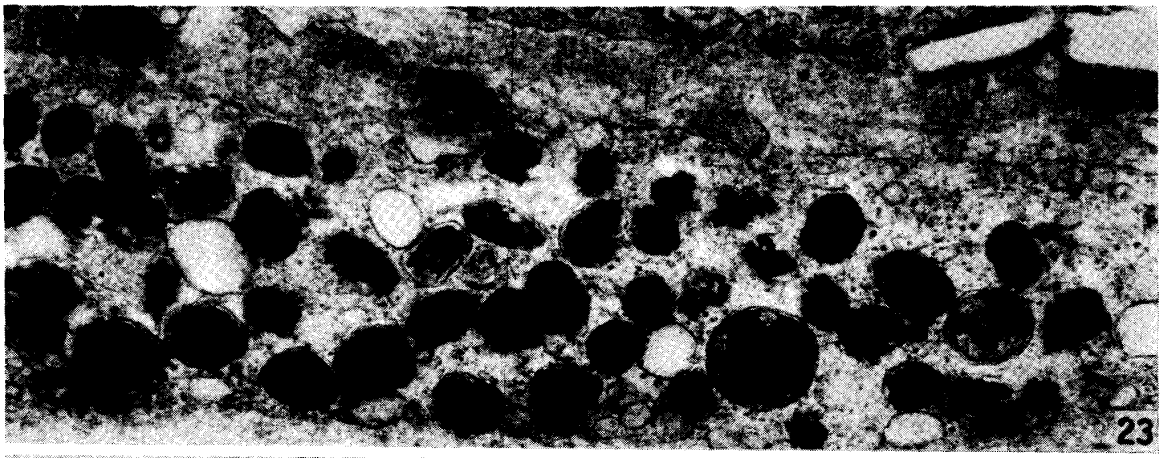
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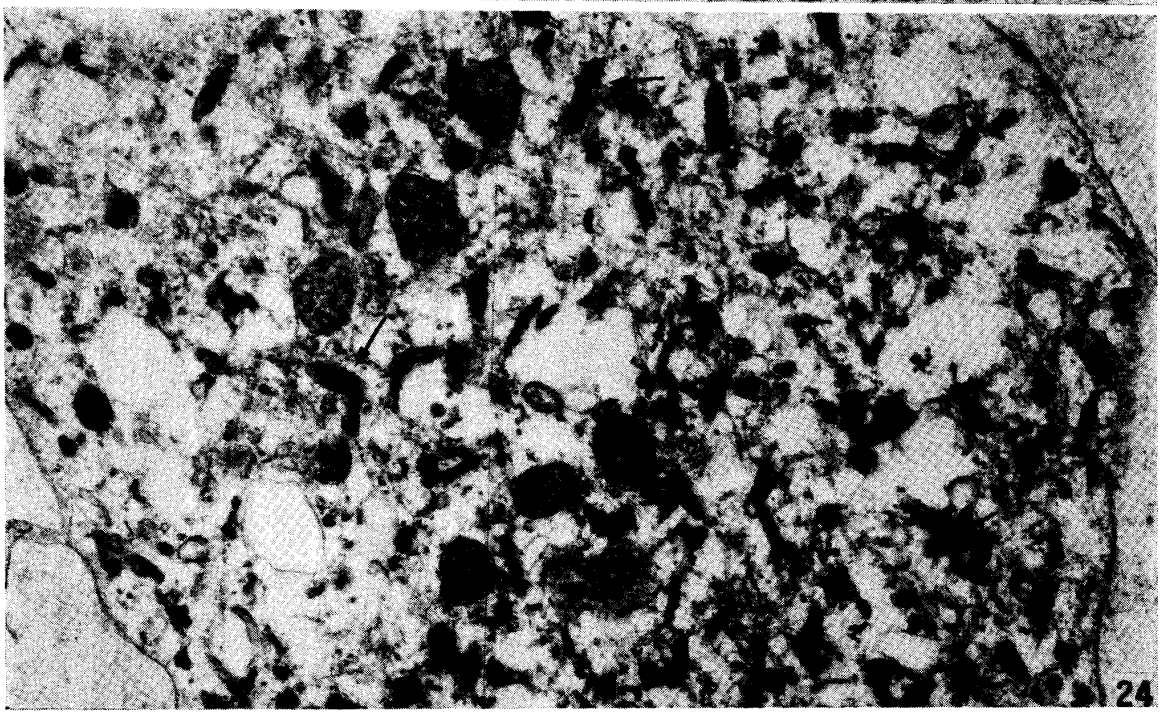
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PLATE VII

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, V.

25. Three kinds of chromatophores in an albino of the MD stock belonging to the second group. ×4000.
26. Portion of an abnormal melanophore containing premelanosomes in the same albino as shown in Fig. 25. ×22000.
27. Portion of an abnormal melanophore containing premelanosomes in an albino of the YsII stock belonging to the second group. ×22000.


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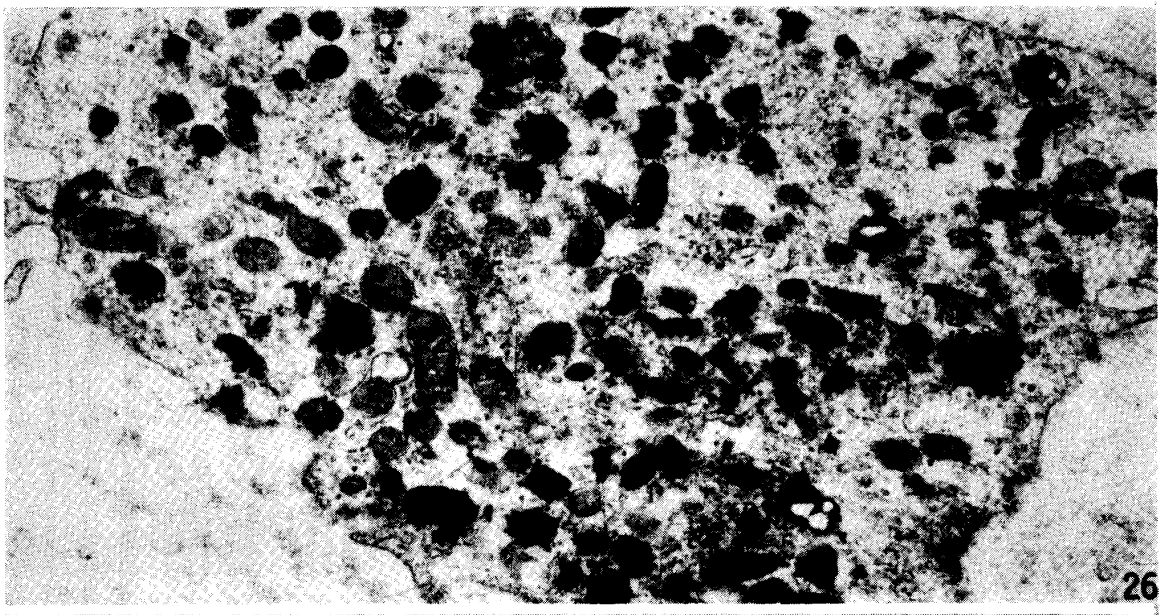
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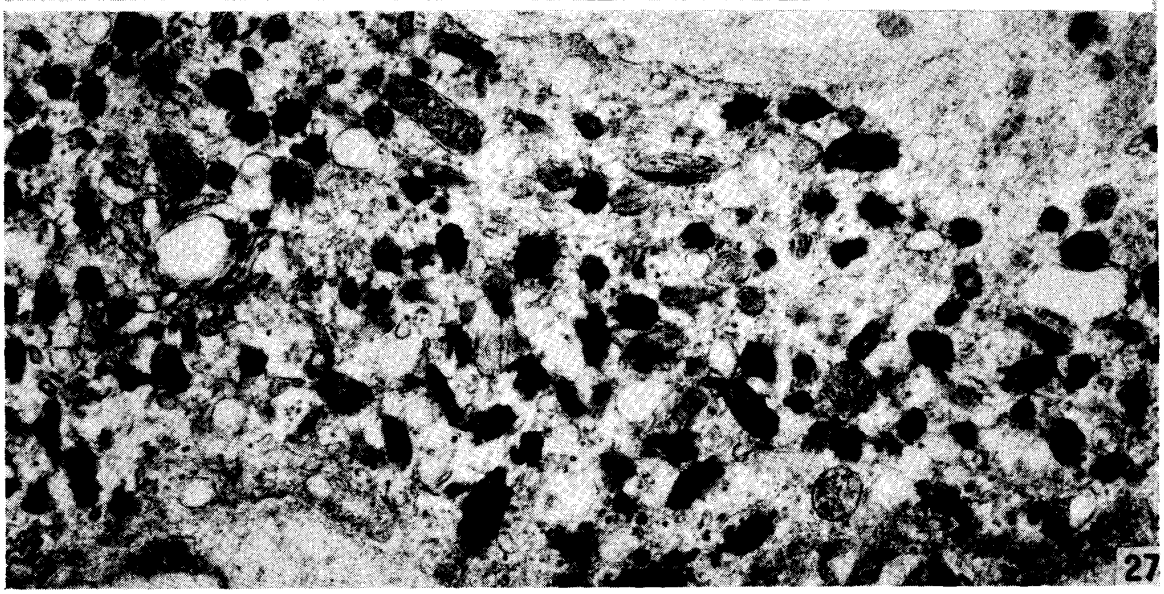
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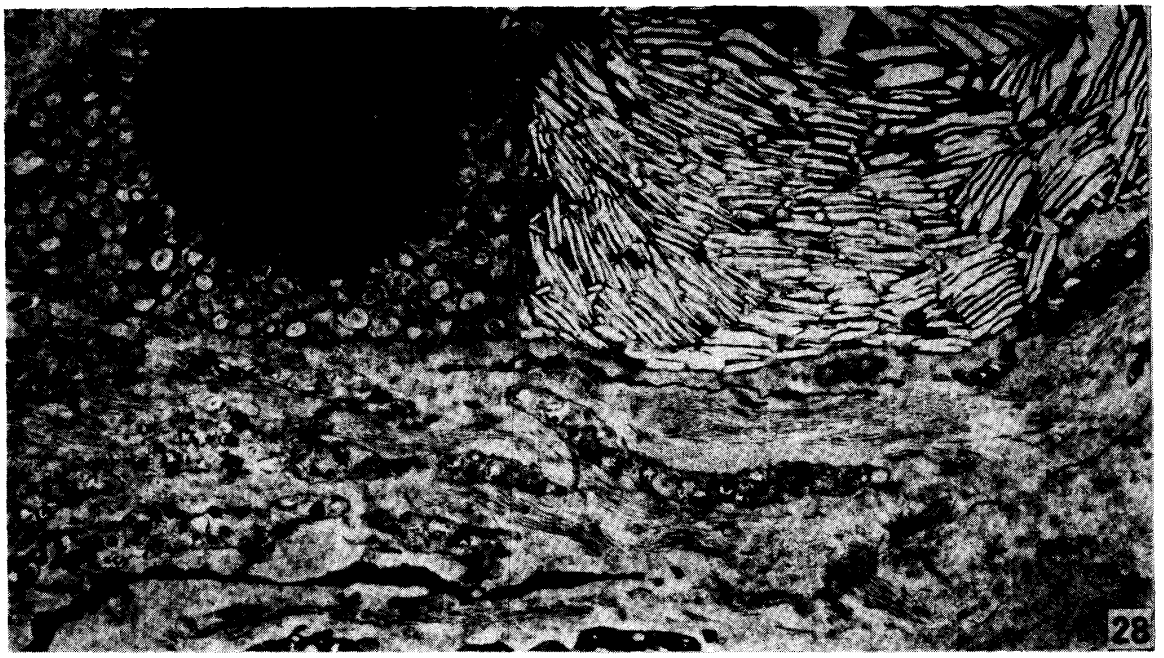
PLATE VIII

Electron microphotographs of dermal chromatophores in the dorsal skin of *Hyla arborea japonica*, VI.

28. Three kinds of chromatophores in an albino of the YMI stock belonging to the third group. ×4000.
29. Portion of an abnormal melanophore containing premelanosomes in the same albino as shown in Fig. 28. ×22000.
30. Portion of an abnormal melanophore containing premelanosomes in an albino of the KK stock belonging to the third group. ×22000.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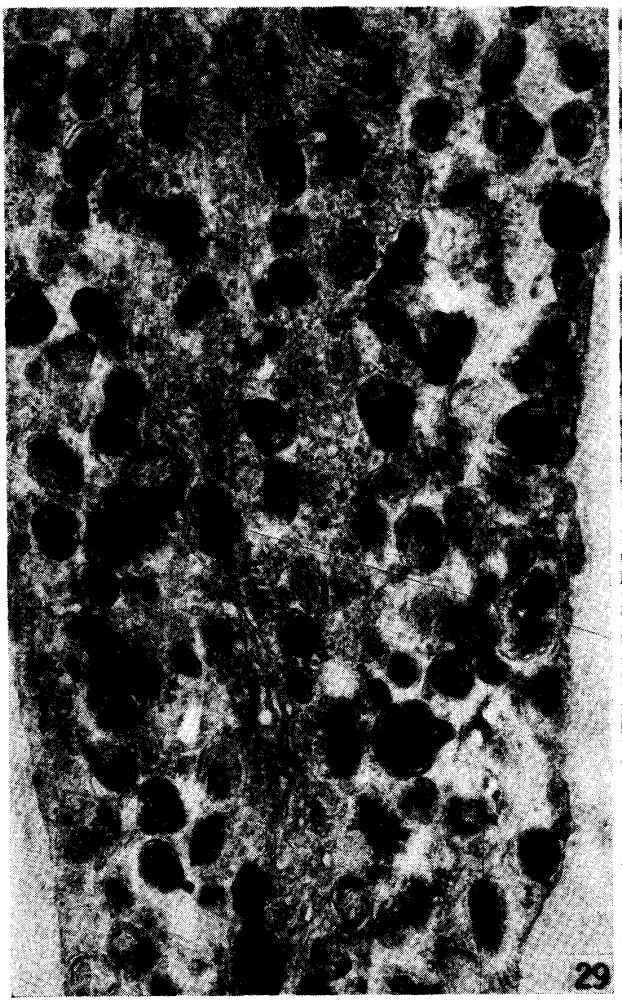
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PLATE IX

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, I.

31. Pigment epithelium and choroid of the eye of a wild-type tree-frog. ×3000.
32. Portion of the same pigment epithelium containing melanosomes as shown in Fig. 31. ×22000.
33. Portion of the same choroid containing melanosomes as shown in Fig. 31. ×22000.
34. Pigment epithelium and choroid of the eye of a colored albino of the YMII stock belonging to the first group. ×3000.
35. Portion of the same pigment epithelium containing premelanosomes as shown in Fig. 34. ×22000.
36. Portion of the same choroid containing a mixture of premelanosomes and somewhat abnormal melanosomes as shown in Fig. 34. ×22000.

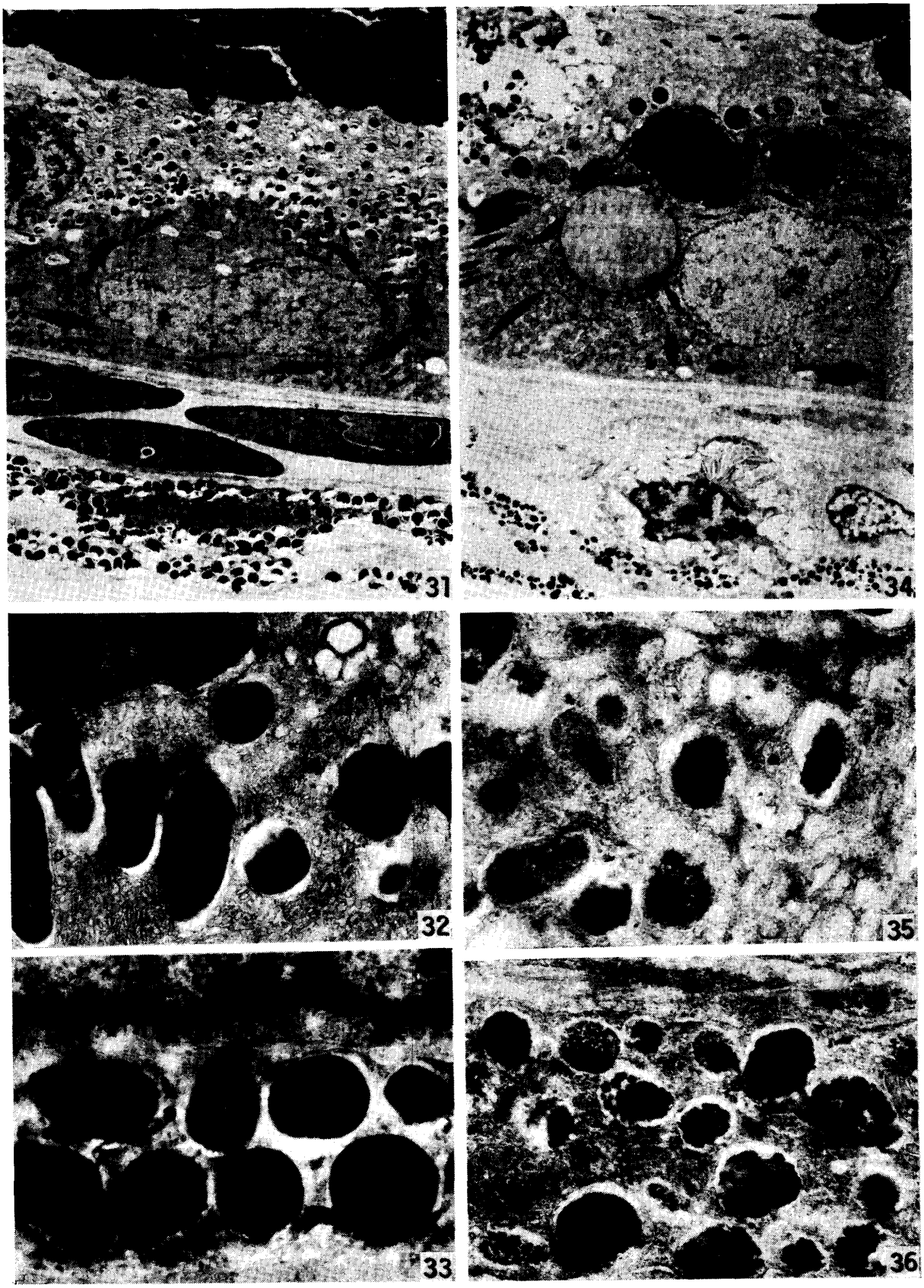
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PLATE X

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, II.

37. Pigment epithelium and choroid of the eye of an albino of the TJ stock belonging to the first group. ×3000.
38. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 37. ×22000.
39. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 37. ×22000.
40. Pigment epithelium and choroid of the eye of an albino of the YsI stock belonging to the first group. ×3000.
41. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 40. ×22000.
42. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 40. ×22000.

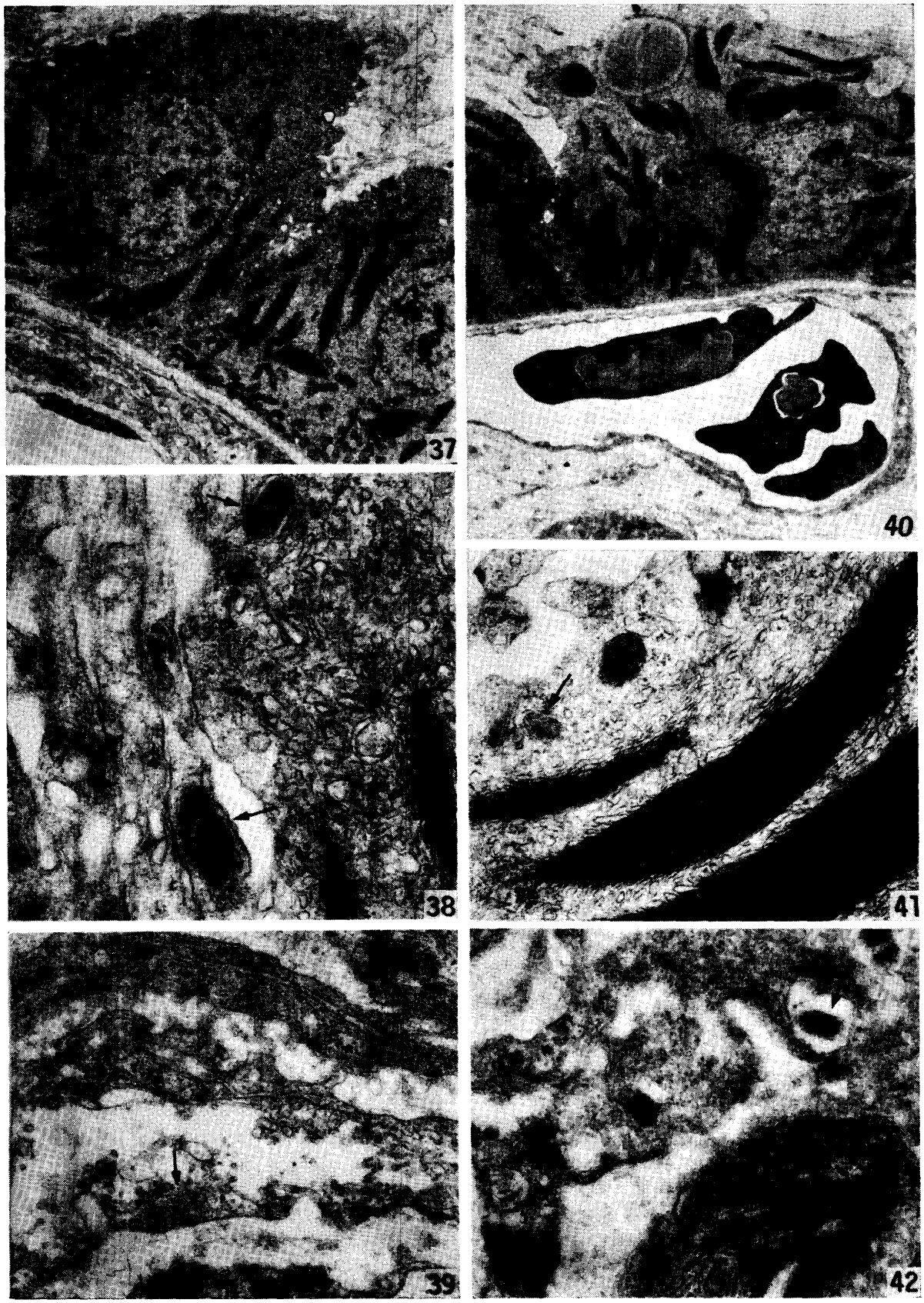
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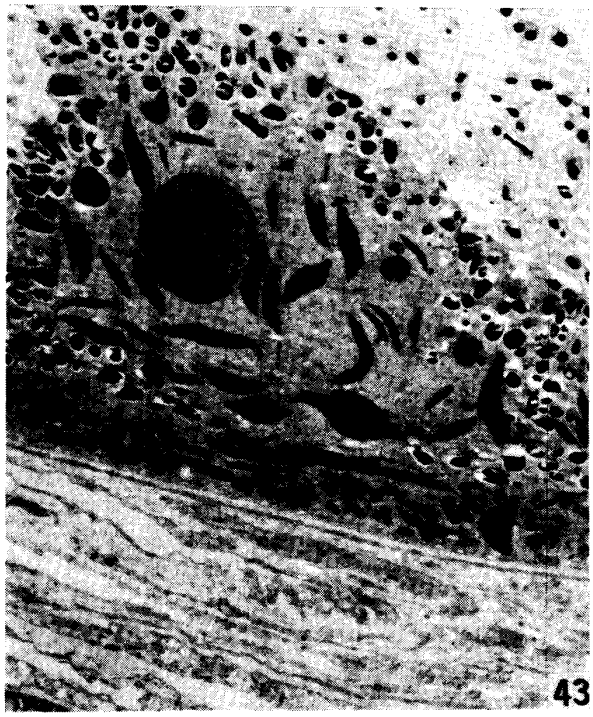
PLATE XI

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, III.

43. Pigment epithelium and choroid of the eye of a black-eyed albino of the NM stock belonging to the first group. × 3000.
44. Portion of the same pigment epithelium containing normal melanosomes as shown in Fig. 43. × 22000.
45. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 43. × 22000.
46. Pigment epithelium and choroid of the eye of a red-eyed albino of the NM stock belonging to the first group. × 3000.
47. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 46. × 22000.
48. Portion of the same choroid containig premelanosomes (arrow) as shown in Fig. 46. × 22000.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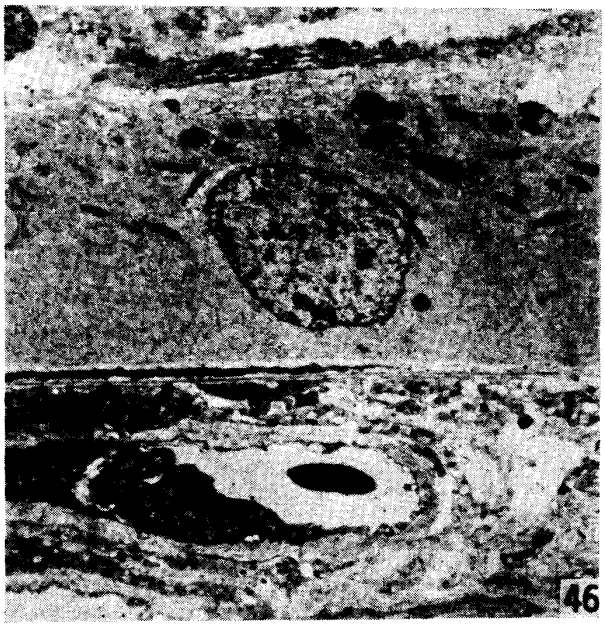
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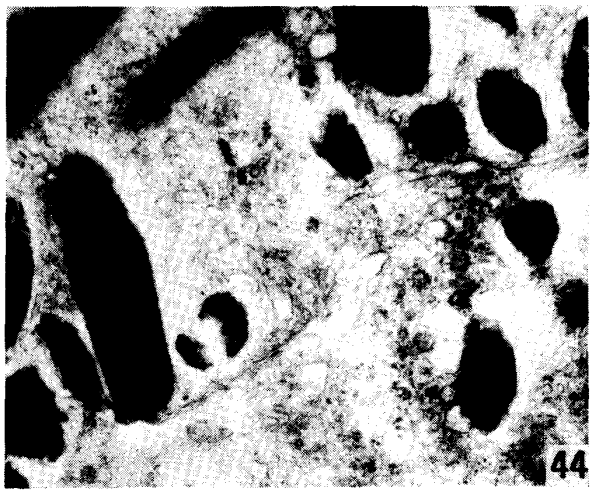
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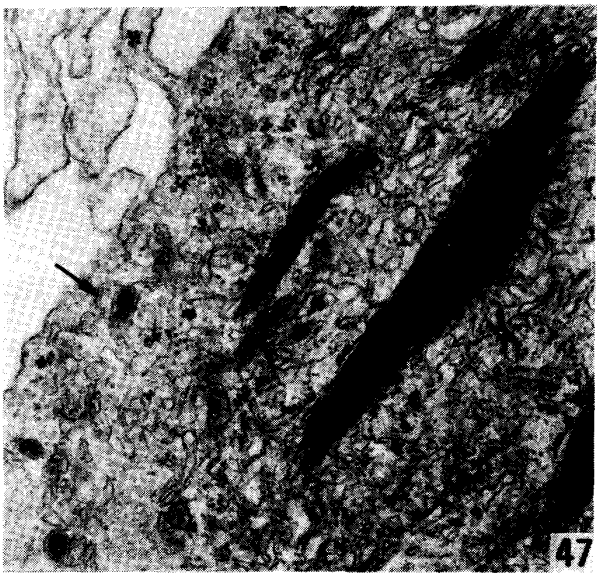
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PLATE XII

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, IV.

49. Pigment epithelium and choroid of the eye of an albino of the SJ stock belonging to the first group. ×3000.
50. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 49. ×22000.
51. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 49. ×22000.
52. Pigment epithelium and choroid of the eye of an albino of the KK stock belonging to the third group. ×3000.
53. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 52. ×22000.
54. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 52. ×22000.

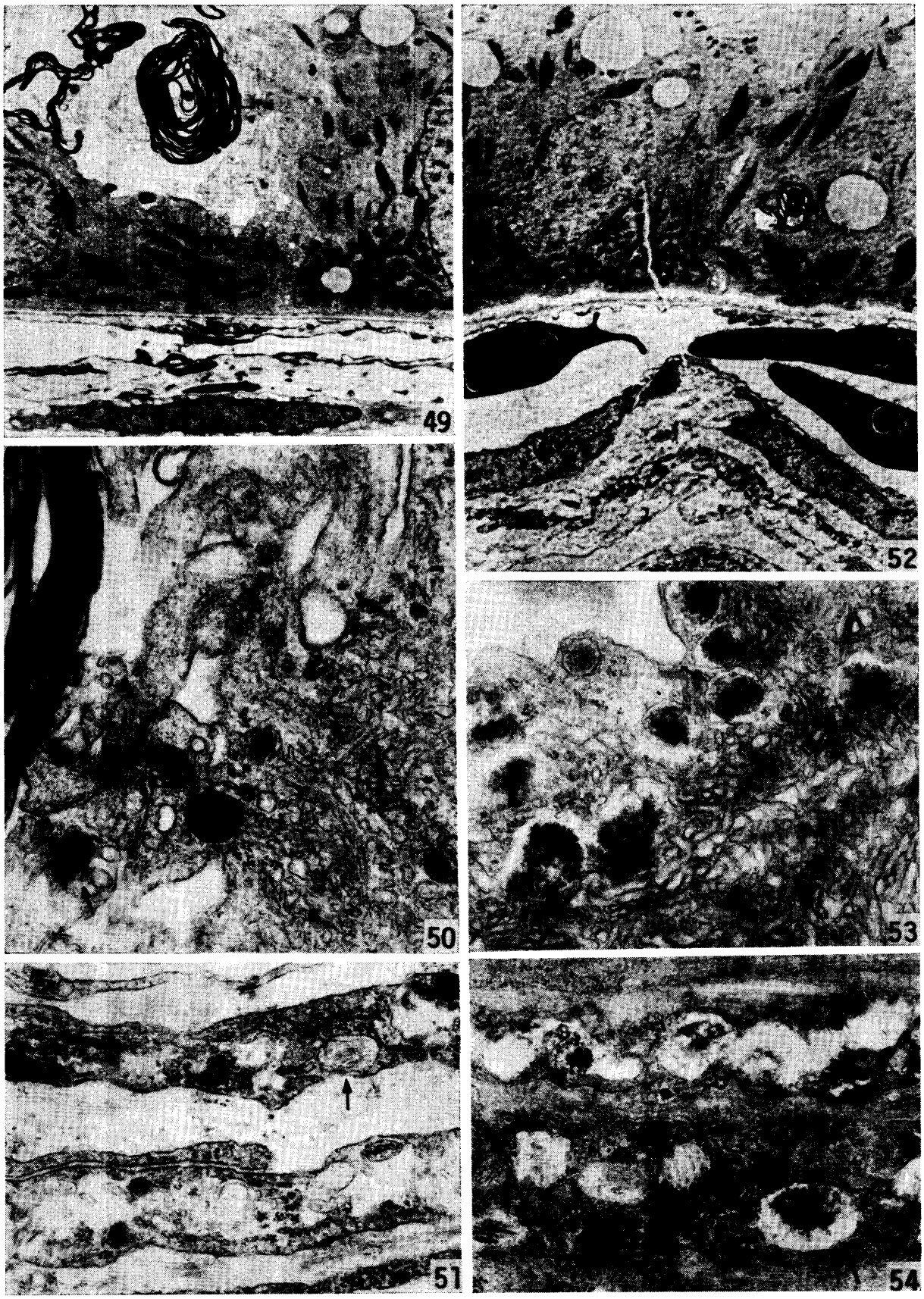
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PLATE XIII

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, V.

55. Pigment epithelium and choroid of the eye of an albino of the YsII stock belonging to the second group. ×3000.
56. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 55. ×22000.
57. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 55. ×22000.
58. Pigment epithelium and choroid of the eye of an albino of the MD stock belonging to the second group. ×3000.
59. Portion of the same pigment epithelium containing premelanosomes (arrow) as shown in Fig. 58. ×22000.
60. Portion of the same choroid containing premelanosomes (arrow) as shown in Fig. 58. ×22000.

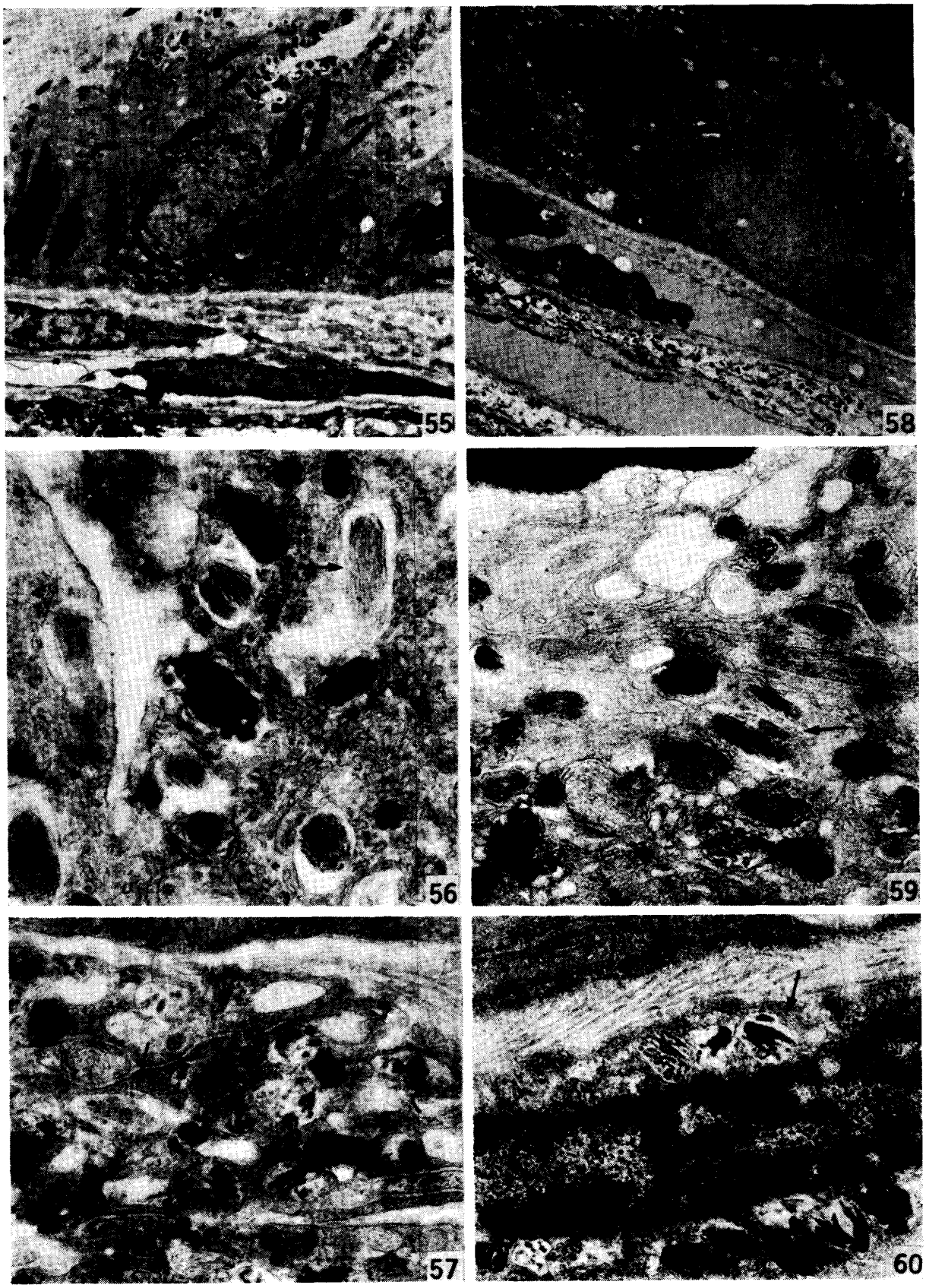
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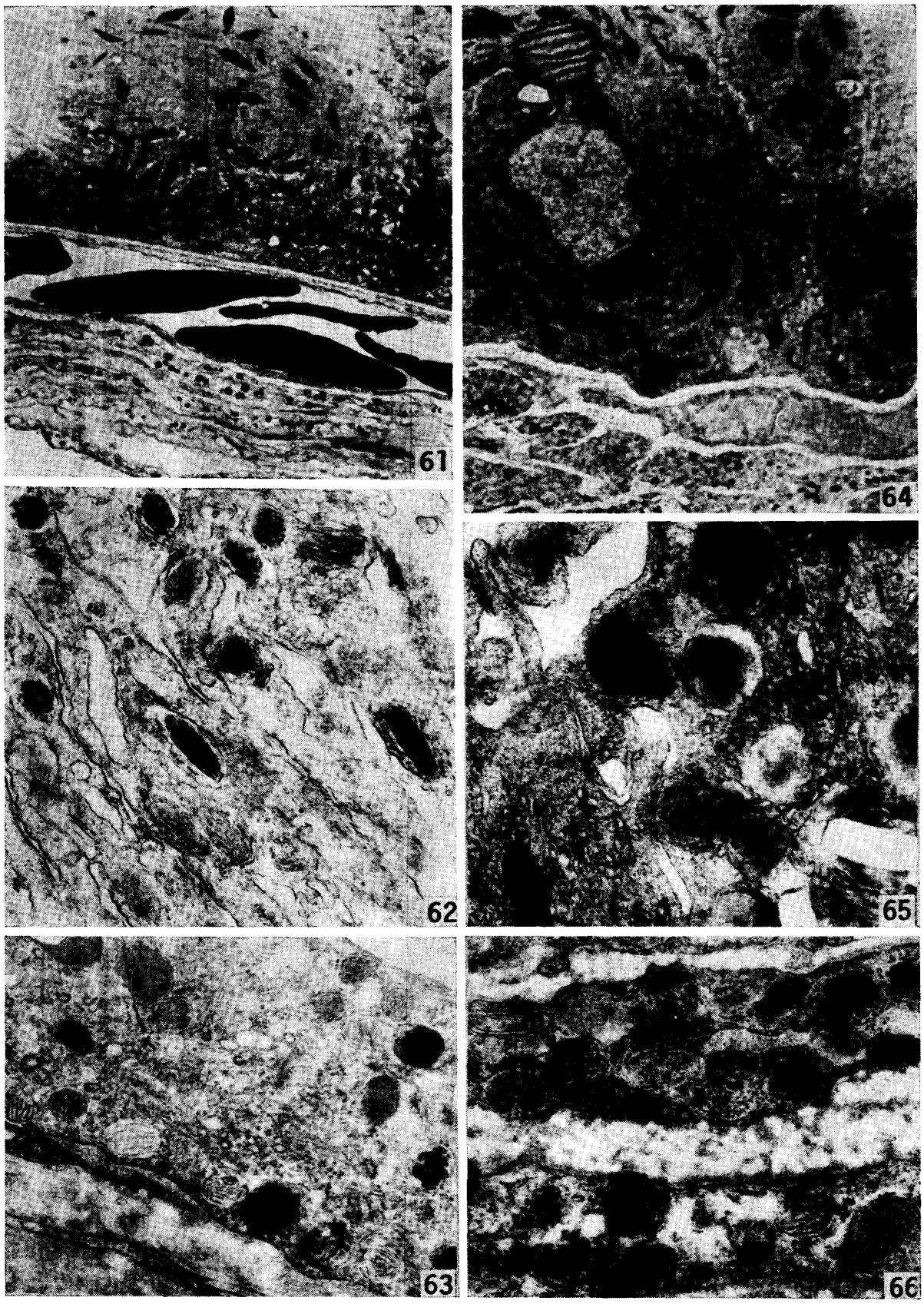
PLATE XIV

Electron microphotographs of pigment cells in the eye of *Hyla arborea japonica*, VI.

61. Pigment epithelium and choroid of the eye of an albino of the MY stock belonging to the third group. ×3000.
62. Portion of the same pigment epithelium containing premelanosomes as shown in Fig. 61. ×22000.
63. Portion of the same choroid containing premelanosomes as shown in Fig. 61. ×22000.
64. Pigment epithelium and choroid of the eye of an albino of the YMI stock belonging to the third-group. ×3000.
65. Porion of the same pigment epithelium containing premelanosomes as shown in Fig. 64. ×22000.
66. Portion of the same choroid containing premelanosomes as shown in Fig. 64. ×22000.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