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Author(s): William O. Wirtz, II

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GROWTH AND DEVELOPMENT OF *RATTUS EXULANS*

WILLIAM O. WIRTZ, II

ABSTRACT.—Growth and development were studied in the Polynesian rat, *Rattus exulans*, at Kure Atoll, Hawaii, and in the laboratory. Reproduction is seasonal on Kure, mean litter size is 4.07 in the field and 3.97 in the laboratory, and sex ratios of litters are equal. Gestation is 19 to 21 days in the laboratory, and post-partum estrus occurs. Growth in weight and linear dimensions is most rapid in the first 4 weeks. Sight and hearing are present by the end of the second week, and weaning occurs by the end of the fourth. Sexual dimorphism in weight and linear dimensions results from the continued growth of males after the twelfth week and a reduction of growth rates in females. Captives grow heavier and larger than wild animals, possibly as a result of nutritional differences. Animals from Kure are significantly larger than those from the Carolines and Malaya. The relationship between adrenal weight and age appears to be linear for the first 110 days, and correlation is strongest between adrenal weight and body length. Spleens are relatively larger in young animals, probably as a result of the importance of this organ in prenatal hemopoiesis.

The Polynesian rat, *Rattus exulans*, is distributed over most of the central and western Pacific region from the Asiatic mainland east to Hawaii and south to New Zealand. From October 1963 through August 1965, ecological studies were conducted on a population of this species on Kure Atoll, at the distal end of the Northwestern Hawaiian Islands, under the aegis of the Pacific Ocean Biological Survey Program (Wirtz, 1972). During the course of this study and subsequent work on a laboratory colony from the island, data were collected on the growth and development of the species as typified by individuals in the population studied.

In spite of the widespread distribution of numerous species of *Rattus*, relatively few studies have described growth and development. Storer *et al.* (1962) provided some information on the growth of *Rattus exulans*; Taylor (1961) detailed the reproductive biology of *R. assimilis* in Australia and the laboratory; Calhoun (1962) discussed the growth of wild *R. norvegicus*, and Ferry (1913) and King (1923) the laboratory variety of this species; and Kelway and Thompson (1957), Ecke (1955), Gomez (1960), and Storer *et al.* (1962) mentioned facts about growth of *R. rattus*. Data are presented here for *R. exulans* and compared with those available for other species of the genus.

MATERIALS AND METHODS

All litters used in this study were conceived in the wild and born in captivity or conceived and born to wild animals that had been kept in the laboratory for less than a year. Additional behavioral observations were obtained on subsequent captive generations. Thirteen litters totaling 47 individuals were studied in detail. All data obtained from wild-conceived animals were recorded at Kure Atoll; the remainder were obtained from the colony first housed in Washington, D. C., and later moved to Cornell University.

Cage facilities at Kure Atoll consisted of wooden pens with hardware cloth covers. The colony on the mainland was maintained in hardware cloth cages, one and two cubic feet, with solid bottoms. Animals were maintained on natural light cycles on Kure and in Washington, but were moved to a 12-12 artificial cycle at Cornell. Wood shavings, laboratory rat chow supplemented with greens, and water were freely provided, and nest boxes were provided for pregnant females and their subsequent litters.

Weights and measurements were taken on anesthetized animals. The species is tolerant of ether, but several young were lost with the use of chloroform. Molt patterns were followed on animals whose entire pelage had been dyed with Nyanzol A; no adverse effects were observed.

Preserved adrenals and spleens were carefully blotted dry and cleaned of fascia before weighing to the nearest 0.1 milligram on a torsion balance. Weights of paired adrenals were compared with age in known-age rats, and with body length and body weight in all individuals.

RESULTS AND DISCUSSION

Breeding Season

Reproductive details of the wild population have been described elsewhere (Wirtz, 1972). In contrast with data recorded elsewhere within its geographic range (Harrison, 1952; Nicholson and Warner, 1953; Storer *et al.*, 1962; Watson, 1956), the species is seasonal on Kure, reproduction occurring from January through September, with most litters being produced from March through August. The laboratory colony maintained its wild cycle through the first winter in Washington, but litters conceived under the artificial lighting regime at Cornell were born in all months of the year.

Litter Size and Sex Ratio

Wild females have one, rarely two, litters per year on Kure (Wirtz, 1972). Mean litter size in the Kure population, based on combined autopsy data, is 4.07, whereas mean litter size of 59 litters born in captivity is 3.97. Sex ratios in litters born in captivity are equal, litters being composed of a mean number of 1.91 males and 1.94 females.

Reproductive Behavior

Captives showed varying degrees of tolerance toward each other. Some pairings led to immediate and continual fighting while others produced several litters, and a few females even tolerated the male in the cage during parturition and lactation. Usually pregnant females harassed the male, biting him about the tail and rump, until his distress was noted and he was removed from the cage.

Copulation was observed on numerous occasions, both among pairs and in holding cages. In the latter situation an estrus female would permit mountings by several males, frequently in close succession. In cages with an established hierarchy only high-ranking males copulated successfully.

Pre-copulatory behavior includes superficial grooming of the head and shoulders and licking of the perineal region of the female by the male. Non-

estrus females flee these advances or turn in antagonism toward the male. Receptive females assume a position of lordosis, back depressed with head and pelvis elevated, hind legs straightened to the rear, and tail cocked to one side. The physiological state of the female apparently conditions her response to the male, and once receptivity is indicated little further grooming or licking is initiated by the male.

During copulation the male grasps the female just behind the rib cage with his forepaws. Biting or grooming of the female by a mounted male was not observed. Males sometimes paw at the female's sides with a hind foot while mounting. Periods of intromission are brief (5 to 10 seconds), and there is little movement of either partner at this time. The animals separate following ejaculation and the male cleans his genitalia and sometimes grooms his entire body. Females only occasionally clean or groom. Longer (1 to 2 minutes) periods of grooming are frequently interspersed between repeated bouts of copulation.

Gestation, Parturition, and Post-partum Estrus

The gestation period, based on laboratory records, is between 19 and 21 days. These values were obtained by recording the number of days between introduction of a male and birth of a litter, and in a few instances between observed copulation and birth of a litter.

Parturition was observed on two occasions, but details of birth were recorded only once. A litter of four was born between 1500 and 1538 on 5 March 1966. No young were present at 1500 and the third had just been born at 1520, when the female was observed eating its placenta. At 1534 the female went to another corner of the cage from that in which the three young were located, perhaps in response to the presence of the observer. She began arching her back, first toward one side and then toward the other, and turning her head first to one side and then to the other, reaching toward her inguinal region. There was a prominent contraction of both her sides just before the appearance of the neonate, and she assisted with her mouth in the delivery. The entire process, from when she first started turning toward her inguinal region to the presence of the young on the floor of the cage, took only 4 minutes. She then began to eat the placenta, but stopped before finishing. She had not completely consumed the placentae from the third and fourth young in the next half hour, but had moved the fourth young into the nest with the others.

Four females had a second litter within 24 days of the first when males remained in the cage with the female and young. One of these females conceived the second litter even though the male was removed from the cage within 24 hours of parturition.

The gestation period varies from 21 to 27 days in those species of *Rattus* that have been studied, with a mean for albino *R. norvegicus* of 22 days and *R. assimilis* of 22.8 days (Asdell, 1964; Taylor, 1961). Female *R. exulans* having a second litter within 24 days of the first support the observation of Svihla

(1936) that post-partum estrus occurs in this species. That more records of successive litters were not obtained is certainly due to the practice of removing males from the cage prior to parturition. In spite of the occurrence of post-partum estrus in captives, few females bred more than once in a season on Kure Atoll (Wirtz, 1972). The gestation period is apparently not lengthened to any great extent by the presence of a nursing litter as has been reported for *R. assimilis* (Taylor, 1961).

Parental Care

Nest building can be elicited in adults of both sexes if sheets of newspaper or paper towel are provided. Nests built from these materials varied from platforms to cups to hollow spheres. A few spherical nests of shredded grasses and leaves were found in the wild. Extra nesting material usually was not provided, and most females mounded shavings into a cup-shaped nest, usually in the nest box. Occasionally a female ignored the nest box and mounded shavings into a pile up to 25 centimeters in diameter at one side of the cage.

Small young normally were covered by the female as they nursed; larger young often lay to one side. Young dislodged from a teat when a female fled the nest at a disturbance were retrieved as soon as the disturbance had passed. Larger young would attempt to maintain their hold on a teat and run to one side of the female as she left the nest. Young were carried in the teeth by the loose skin over the shoulder, on the side, or of the venter. Small young, normally carried by the venter, would curl about the female's muzzle. Young carried by the side usually curled their limbs and tail, whereas larger young, grasped by the skin of the shoulder, were dragged.

Males that were tolerated by females with litters played little role in care of the young. A few males were tolerated in the nesting area, but most built small sleeping nests in another corner of the cage. Some females persistently destroyed their newborn litters, but this behavior is probably a consequence of captivity.

Morphological and Behavioral Development

Neonates are bright pink, perhaps due to peripheral vasodilation occurring during parturition, which fades within a few hours of birth. The eyes and external auditory meatuses are sealed and the pinnae are folded ventrad from the point of their dorsal attachment to the skin of the head. There are extremely fine hairs scattered over most of the body, but with the exception of the mystacial vibrissae, which are 5 to 6 millimeters long at birth, body hairs are visible only under a dissecting microscope. The dorsum, tail, pinnae, and plantar tubercles are slightly pigmented, and a slight amount of pigment is present in the scrotum of males. The skin of the sides and venter is translucent to the extent that the outline of major organs, such as stomach and liver, are distinguishable through it. No teeth are erupted. A slight lump and scab are present at the umbilical attachment. There is little coordinated body movement, and faint cries may be made in response to physical disturbance.

The pinnae unfold by the end of the second day. Fine hairs are visible to the unaided eye on the dorsum and underside of the neck, though not on the rest of the venter, by the end of the third day. The dorsum, tail and pinnae are more darkly pigmented than at birth, due to the presence of pigment in developing hair follicles, and pigment spots have developed at the ankles. The mystacial vibrissae are 6 to 7 millimeters long by the fifth day, the scab at the umbilicus has darkened, muscular coordination is slightly improved, and the animal is able to crawl feebly and right itself when turned on its back. Incisors may be visible, though frequently they are not distinguishable until the seventh day. The skin of the dorsum exhibits greater hair follicle activity, and thus appears darker, by the end of the first week, and the organs are less visible through the body walls. The dorsal pelage is obvious, but white ventral hairs are not yet noticeable to the unaided eye. Mystacial vibrissae are 9 millimeters long, pigment spots develop at the wrist, and those at the ankle increase in size. Teats are visible on females, a small scab remains at the umbilicus, and the young crawl easily with a spraddle-legged stance.

During the second week white ventral pelage appears, the brown pelage of the dorsum develops into a solid coat, and guard hairs are distinguishable among the finer body hairs. Mystacial vibrissae reach 17 millimeters, and the pigment deposits of the pinnae, tail, wrists, ankles and plantar tubercles darken. Incisors erupt between the seventh and ninth days, with the lowers usually being slightly ahead of the uppers. By the end of the second week the lower incisors are 1 millimeter long and the uppers 0.5 millimeter. Molars occasionally erupt as early as the thirteenth day, but usually not until the middle of the third week. The young jump in response to squeaking by the observer after the thirteenth day, though some individuals respond as early as the tenth. The eyes open between the twelfth and fourteenth days, usually closer to the latter. Muscular coordination improves considerably; from the spraddle-legged stance of the first week the limbs are moved under the body. Once the eyes are open juveniles leave the nest and begin climbing cage walls if disturbed. They are still dependent on the female, for they run to her and resume nursing as soon as the disturbance has ceased. Juveniles will cling to a vertical surface and will climb to 20 centimeters before losing their grip. Squeaks are lower pitched and less frequent by this age.

Growth of the juvenile pelage normally is completed during the third week, although growth of ventral pelage has been recorded on the twenty-second day. The vibrissae exceed 20 millimeters by the end of this week, the lower incisors reach a length of 2 millimeters, the uppers a length of 1 millimeter, and the molars erupt. By the end of the third week the young, weighing between 18 and 23 grams, are roaming the cage, gnawing on wood chips, and tasting solid food. Weaning begins in this week, and is definitely completed in the fourth week. Young frequently groom themselves, siblings, and adults. They will climb vertical obstacles 10 centimeters high placed in the cage. Young in this age group are trapped in the wild.

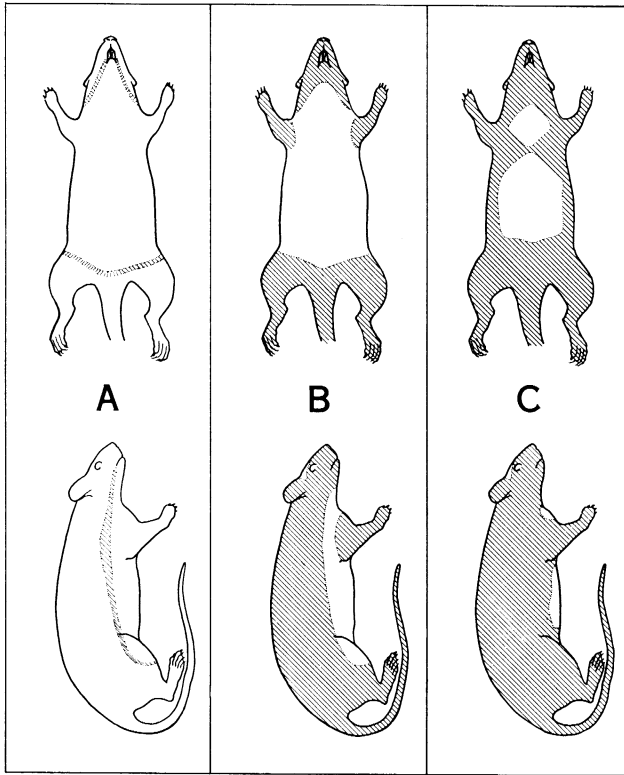


FIG. 1.—Post-juvenile molt pattern of *Rattus exulans* at 1 (A), 3 (B), and 5 (C) weeks of age. Sketches made from live animals.

Post-juvenile Molt

The juvenile pelage of *R. exulans* does not differ conspicuously from that of the adult, although it is softer and finer, and lacks the scattering of particularly heavy, pale guard hairs that characterize the adult pelage. A prolonged molt occurs in captive males between the ages of 33 and 65 days and in captive females between the ages of 28 and 66 days. This molt is regular in pattern and sequence, in sharp contrast to the spotty, irregular molts observed in adults. There is no sexual dimorphism in the pattern.

Replacement begins in lines extending from the mandibular rami over the shoulders, down the sides, and crossing the anterior surface of the thighs to join in the inguinal region (Fig. 1). One week following the first appearance of new hairs these lines have broadened in the gular region, are about 5 millimeters wide on the sides, and hair replacement is extensive in the inguinal region. By the third week replacement has spread dorsad, craniad, and caudad so that the areas of new hair are joined dorsally with the exception of crown and rump. By the end of the fourth week dorsal replacement is essentially

completed and a discontinuous patch of replacement hairs is present on the chest. In the fifth week replacement continues craniad and caudad from the chest, craniad from the inguinal region, and ventrad on the sides. Narrow areas along the mid-ventral line are last to be replaced.

Sexual Development

On Kure young rats produced in the summer breeding season do not attain sexual maturity until the following year. Animals of both sexes gain weight rapidly in late summer and females may become perforate at weights as low as 40 grams. However, these newly perforate females show no development of the reproductive tract. In males the rapid increase in weight is not accompanied by maturation of the gonads or accessory sex glands.

Slight pigment may be present in the scrotum of neonates. Pigmentation of the scrotum increases until the end of the fifth week, when it is uniformly complete on captives. The testes descend in the sixth or seventh week, are noticeably enlarged (11.5 by 7.0 millimeters) by the seventh week, and are fully enlarged (18.0 by 11.0 millimeters) by the twelfth week. Captives may become fertile as early as 63 days, and two males sired litters at 87 and 90 days.

Males of this species possess a specialized midventral glandular area (Quay and Tomich, 1963). Secretions of this gland do not vary seasonally in the wild (Wirtz, 1972), but the exact role of the gland in the biology of this species has not been ascertained. Secretions of the ventral gland in an area about 5 millimeters long just anterior to the penile opening are not visible until the ninth week or later, or about the time that the testes are fully enlarged. The area of secretion is 35 to 40 millimeters long by the twelfth to fifteenth week.

Captive females may become perforate as early as 48 days, though most do not until their eighth week. Slight enlargement of the teats was noted in one female at 89 days, but on all other females teats were recorded as undeveloped until the twentieth week. Two individuals showed bare areas around the teats at 130 and 175 days, respectively, though neither had borne a litter. One female conceived her first litter in her seventeenth week and another in her nineteenth; all other females were 30 weeks old or older before their first litters were born.

Growth

Mensural data for wild and captive-reared adults and newborn captives are presented in Table 1. Absolute growth in weight and linear dimensions plotted at weekly intervals from 0.5 to 30 weeks are given in Figs. 2 and 3, respectively. Males gain weight at an essentially linear rate until the eighteenth week, and reach 50 per cent of captive adult weight (65 per cent wild adult weight) by the eighth week. Females gain weight at a similar rate until the twelfth week, reaching 50 per cent of captive adult weight (47.4 per cent wild adult weight) in the sixth week. Linear growth in total length occurs in both sexes through about the fifth week, by which time males have reached 65.4 per cent (72.8

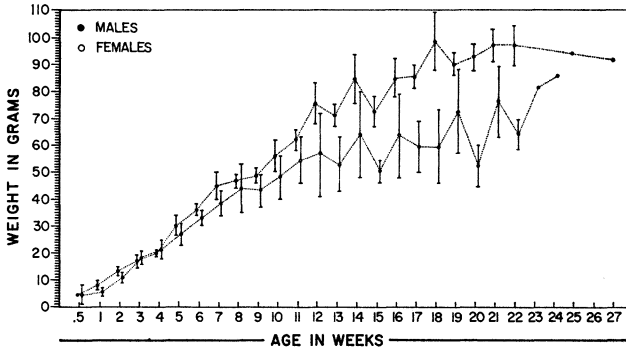


FIG. 2.—Absolute growth in weight at weekly intervals from 0.5 to 30 weeks in *Rattus exulans*. Means connected by curves, verticals indicate 95 per cent confidence intervals; points lacking confidence intervals are single values; otherwise $N = 4$ to 14 for males and $N = 3$ to 13 for females.

per cent of wild) of captive adult length and females have reached 72.0 per cent (73.8 per cent of wild) of captive adult length. From the sixth week on total length of females is significantly ($P \leq .05$) less than that of males. Body and tail length of both sexes are essentially the same at 3 to 4 days. The rate of growth of the tail exceeds that of the body so that, starting from less than 50 per cent of body length at 3 to 4 days, the tail length exceeds that of the body by the fourth week and remains thus for the remainder of life in both sexes. As with total length, by the tenth to twelfth week body and tail lengths of females are significantly ($P \leq .05$) less than those of males. Males reach 50 per cent of captive body length (58.7 per cent of wild) and 50 per cent of captive tail length (57.6 per cent of wild) by their third week. At this time females have also reached 50 per cent of captive body length (64.5 per cent of wild) and captive tail length (56.0 per cent of wild). Growth of the hind foot is essentially completed by the eighth week in both sexes, and there is

TABLE 1.—Mean weight (grams) and linear dimensions (millimeters) of wild and laboratory breeding adult male and female *Rattus exulans*, and mean weight and linear dimensions of newborn captive male and female *Rattus exulans* with per cent of mean wild adult measurement.

	Males		Females		Newborn captive			
	Wild	Lab	Wild	Lab	Male	Per cent	Female	Per cent
Weight	75.0	96.4	70.9	74.2	3.1	4.1	2.8	3.9
Total length	301.0	335.0	290.0	297.0	59.0	19.6	57.4	19.8
Body length	150.0	161.0	141.0	142.0	42.6	28.4	42.4	30.1
Tail length	151.0	173.0	150.0	155.0	16.3	10.8	15.0	10.0
Hind foot	30.2	31.0	28.5	29.5	7.8	25.8	7.4	26.0
Ear notch	21.3	20.9	20.9	20.5				
Sample size	40	14	40	12	3		7	

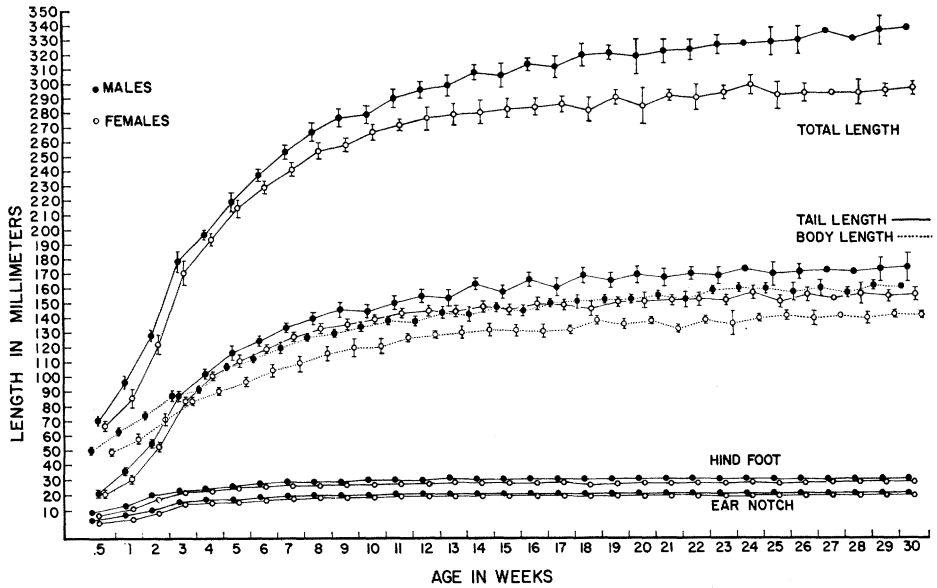


FIG. 3.—Absolute growth in linear dimensions at weekly intervals from 0.5 to 30 weeks in *Rattus exulans*. Means connected by curves, verticals indicate 95 per cent confidence intervals; points lacking confidence intervals are single values; otherwise $N = 4$ to 23 for males and $N = 4$ to 27 for females.

no significant difference between measurements of captive and wild rats. This measurement reaches 75 per cent of the adult value by the third week. The ear from notch measurement is 75 per cent of adult size by the fourth week in both sexes and 90 per cent of adult size by the eighth week. There is then slight increase in this measurement up to about the twenty-first week. As with hind foot, ear from notch measurements do not differ significantly in wild and captive animals.

Instantaneous growth rates (Simpson *et al.*, 1960) are presented in Table 2 for both sexes up through ten weeks of age. In some instances, especially after 10 weeks, mean values for a given measurement decreased from one week to the next due to variation in sample size and the fact that data from many different individuals were pooled to obtain the means, and thus meaningful K_g values could not be calculated. These data show that growth in this species is most rapid in the first 3 or 4 weeks. Weight and tail exhibit the most rapid rates of growth in the first week, and growth of the tail continues at a relatively high rate through the fourth week in both sexes. Increase in weight is variable, though greatest in the first 2 weeks in both sexes, also high in the third week for females, and high in the fifth week for males. Such variability is perhaps due to differences in lactation among different females. Both sexes show a pronounced reduction in rate of weight gain in the eighth and ninth weeks followed by a slight reacceleration in the tenth week. Once the pinnae unfold

TABLE 2.—Instantaneous growth rates of weight and linear measurements of *Rattus exulans*.

	Age interval in weeks	Weight	Growth rate, per cent per day				
			Total length	Body length	Tail length	Hind foot	Ear
Males	0- 1	13.70	7.15	5.69	11.39	7.66	—
	1- 2	6.53	3.97	2.36	5.89	4.70	6.17
	2- 3	3.86	4.70	2.24	6.71	3.07	7.07
	3- 4	2.36	1.36	.97	2.36	.42	1.74
	4- 5	6.16	1.62	1.87	1.75	1.09	.70
	5- 6	2.24	1.08	.83	.97	.83	.83
	6- 7	3.07	.83	.70	1.10	.14	.28
	7- 8	.56	.70	.83	.56	.70	.28
	8- 9	.69	.56	.42	.70	—	.28
	9-10	2.12	.14	.42	—	.28	—
Females	0- 1	10.18	5.89	4.07	10.32	6.26	—
	1- 2	9.24	4.91	2.96	7.66	5.70	7.75
	2- 3	7.66	4.81	3.97	6.53	3.97	7.33
	3- 4	2.12	1.87	.97	2.84	.56	1.36
	4- 5	2.96	1.36	.97	1.23	.97	1.23
	5- 6	3.07	.97	.56	1.10	.83	.70
	6- 7	1.87	.70	.83	.83	.28	—
	7- 8	.74	.70	.42	.70	.56	.56
	8- 9	.74	.28	.28	.28	—	—
	9-10	1.75	.42	.56	.28	.14	.28

they grow rapidly during the second and third weeks. Some of the growth indicated in the K_g value for the second week no doubt occurred late in the first week.

Both sexes show a tendency to grow larger in captivity, and males are heavier and larger in linear dimensions than females in both laboratory and wild populations. Sexual dimorphism in weight and linear dimensions results from the continued growth of males after the twelfth week and a reduction of growth rates in females. Sexual dimorphism in growth rates and absolute size has been suggested for Ponape populations of *R. exulans* by Storer *et al.* (1962), who reported that a regression of weight on body length for wild animals suggests uniform growth rates that differ between sexes, with reduced weight gain in older females. In consequence older males in the Ponape population are heavier and longer (Storer *et al.*, 1962). This paper confirms their supposition, and the limited growth data they present on *R. exulans* from Ponape fit the curves reported herein. Sexual dimorphism has also been reported for *R. assimilis* (Taylor, 1961), *R. norvegicus* (King, 1923), and *R. rattus* (Ecke, 1955). Mean weights of adult males on Kure are 19 per cent greater than those on Ponape (Storer *et al.*, 1962) and 25 per cent greater than those in Malaya (Harrison, 1951). Mean weights of adult non-pregnant females on Kure are 42 per cent greater than those on Ponape (Storer *et al.*, 1962) and 34 per cent greater than those in Malaya (Harrison, 1951).

Captive males also exhibit a tendency to grow significantly ($P \leq .05$) heavier and larger in linear dimensions than do wild males of the Kure population. Females show the same, but not significant, tendency. The tendency for different growth rates and absolute sizes in captivity also has been noted for other species of the genus. Field-raised *R. assimilis* grew more slowly than laboratory raised animals, the greatest disparity being in weight, but wild animals were not retarded in developmental changes such as eye and ear opening (Taylor, 1961). Albino *R. norvegicus* exhibit high rates of growth in their first 20 days, and rates taper rapidly to 120 days (Ferry, 1913), and the same type of growth is reported here for *R. exulans*. Wild *R. norvegicus* do not show the acceleration in body growth during early life that is characteristic of the albino variety (King, 1923). On the other hand, Leslie *et al.* (1952) found that laboratory-raised wild *R. norvegicus* were lighter than wild-raised animals, concluding that growth in weight and linear dimensions was influenced by environmental and nutritional conditions during the growth period. Taylor (1961) noted different rates of growth in *R. assimilis* raised by *R. assimilis* and *R. norvegicus* females, and attributed the difference to "nutritive differences." Rapid growth of *R. exulans* in the first 3 to 4 weeks also may be related to nutrition. The hypothesis has been advanced that food is a limiting factor for the Kure population (Wirtz, 1972). If this hypothesis is valid, animals from the population might be expected to grow larger and at a more rapid rate under conditions of *ad libitum* food. Captives also have heavier subcutaneous and mesenteric fat deposits than wild rats of similar linear dimensions (Wirtz, 1972).

Rattus exulans develops at a relatively more rapid rate than does *R. assimilis*, but this may be due merely to a difference in size of the adults. The period of lactation is about the same in both species, but growth rates are more rapid in *R. exulans*. *Rattus exulans* from Kure take longer to reach sexual maturity than do either *R. assimilis* (Taylor, 1961) or *R. exulans* from elsewhere in its geographic range (Harrison, 1951; Storer *et al.*, 1962).

Adrenals and Spleen

Absolute adrenal weights of 41 known-age males and 42 known-age females at ages up to 55 weeks are plotted in Fig. 4. The relationship between adrenal weight and ages appears to be linear for the first 110 days, and correlation coefficients for each sex are 0.91. The relationship between adrenal weight and body length is highly significant ($P \leq .01$), variation in length accounting for approximately 85 per cent of the variation in adrenal weight in males and 79 per cent of the variation in females (Fig. 4). The curves for each sex cross in the third week of life, that is, during the weaning period at a time rate of growth is decreasing. The adrenals of females appear to grow at a more rapid rate than those of males, but these data do not permit comparison of mass relationships.

The data presented on adrenal weight versus body length suggest that there is sexual dimorphism in the growth of this gland. At any body length, gland

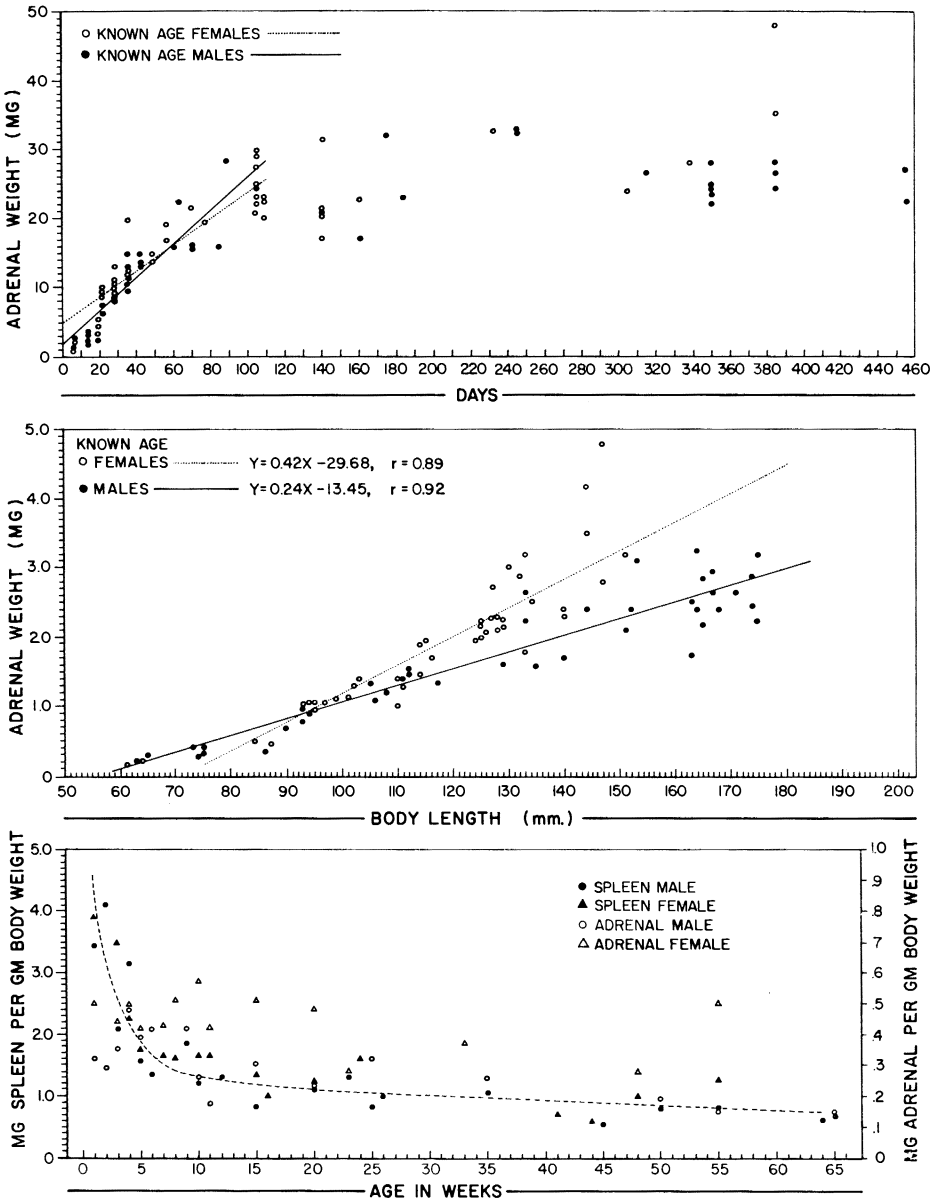


FIG. 4.—Absolute growth in adrenal weight at ages up to 55 weeks in *Rattus exulans* (top). Relationship between adrenal weight and body length in known-age *Rattus exulans* (middle). Mean milligrams adrenal gland and mean milligrams spleen per gram body weight in known-age *Rattus exulans* (bottom).

weight is generally larger for females. Correlation of gland weight and body length is significant for both sexes, and the slope of the female curve is greater. If mean milligrams adrenal gland per gram body weight is plotted against age in weeks to factor out sexual dimorphism in body weight (Fig. 4) the data suggest that relative weight of the adrenals decreases in males, while remaining constant in females. Thus the difference in slope of the curves of adrenal weight against body length should perhaps be attributed to a reduced rate of growth of the gland in males, rather than accelerated growth in females. A greater rate of increase in female adrenals after sexual maturity has been reported for *R. norvegicus* (Christian, 1967), and for *Microtus montanus* (McKeever, 1959) and *M. pennsylvanicus* (Christian and Davis, 1966).

Spleen weights are available for 43 known-age males and 45 known-age females sacrificed at ages up to 65 weeks. Comparison of absolute mass of this organ with linear measurements gives no indication of meaningful relationship. However, a plot of mean milligrams spleen per gram body weight shows that this organ is relatively larger in young animals (Fig. 4). There are 2 to 4 milligrams spleen per gram body weight in animals of both sexes less than 5 weeks of age, from 1 to 2 milligrams per gram body weight in those up to about 15 weeks, and from 0.5 to 1.5 milligrams per gram body weight in older animals.

The spleen is an important hemopoietic organ in all vertebrate embryos, producing both leucocytes and erythrocytes, whereas in the adult mammal it produces solely leucocytes, erythrocyte production being shifted primarily to the bone marrow (Romer, 1962). In addition to its role as an organ that stores erythrocytes in the adult mammal, macrophage production is important in the breakdown of spent erythrocytes and defense against bloodstream infection. The relatively large size of the spleen in juvenile *R. exulans* is probably a reflection of its importance in hemopoiesis. Extreme hypertrophy of the spleen was observed in animals with severe wounds or obvious infections in the wild population.

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Department of Zoology, Pomona College, Claremont, California 91711. Accepted 24 March 1972.