was increased, but the frequency and length of bursts were hardly affected.

Smith and Smith suggested that the process defining burst length and frequency was a gate, switching a cell on to standard activity; there is evidence for this in their paper. It is likely that the frequency of firing within bursts is either an intrinsic property of the cell itself or some index of activity in the network to which the cell belongs. Although the latter seems more likely it is not necessary to distinguish between the two possibilities here—the important fact is that a generally stable property of a cortical cell has been changed. Similar long-term changes have been reported by other workers (*11*). The general feature of these results is that maintained increases in firing rate of cortical cells throughout the cortex, in both rats and cats, have been produced by strong physiological or electrical stimulation. The stimulation must either be very intense or be continued for several minutes. For example, Bindman *et al.* found that, to produce a maintained increase in firing rate by passing a current of 0.5 μa/mm^2 of cortical surface through the cortex it was necessary to polarize for at least 5 minutes. One of their figures (*11*, fig. 4) shows striking similarities to our Figs. 3 and 4. Further, peak activity was not reached until about 5 minutes after the start of polarization. Gartside and Lippold (*12*), using electrical stimulation of the rat's forepaw to excite cells in the appropriate sensory receiving area of the cortex, have shown the same effect. Stimulation must last for at least 5 minutes from the start of an increase in cortical activity, and peak activity is not reached for at least 5 minutes. The similarities among the results produced by different forms of stimulation in different parts of the cortex in different animals suggest that prolonged excitation depends on a fundamental property of the cortex.

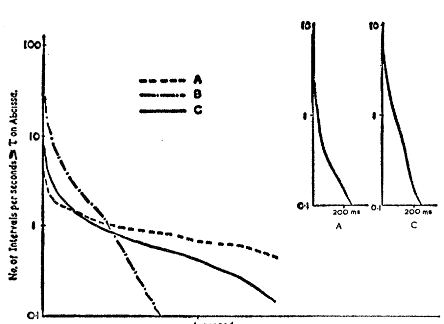

Fig. 5. Interval histograms taken over periods shown on Fig. 3. Inset shows the permanent increase in the number of short intervals; this increase accounts for the increase in firing rate maintained after an intense light flash.

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Marmosets (Hapiladae): Breeding Seasons, Twinning, and Sex of Offspring

Abstract. *Our records on marmosets, primarily* Oedipomidas oedipus, *plus data from the literature, confirm that these animals customarily have twins. Demonstrated chimerism for several tissues is significant, for virtually all twins are of biovular origin. Furthermore, a single birth may often be a survivor of twins. Births occur during any month, but springtime appears to be the most common period. An average interval of 240 days between births predicts the production level of a captive colony. A gestation period of about 140 days appears to be a valid estimate.*

We are aware of several serious efforts to breed and use marmosets in the laboratory. The small size, low cost, and relative availability of these animals are only some of the reasons that make their use desirable. In comparison with higher primates, marmosets have a high production rate (three to four young per year) and short generation time (1 to 2 years). The fact that marmosets not only give birth to twins but that these twins are chimeric for blood, splenic tissue, lymph node (*1*), bone marrow (*1–3*), and testicular tissue (*4*) suggests their use as unique models for studies of tissue immunity. Also, an enzymatic function of the placenta (*5*) which appears to prevent free-martinism has been reported in these animals; their twins are characterized by extensive anastomotic connections via their placentae (*6*).

About three-fourths of all marmosets born in captivity are multiple births, presumably chimeric. Since the percentage of twins which are heterosexual is high, the sex chromosomes provide a useful and unique autosomal tag. The number of offspring born as singletons does not mean, however, that marmosets are unlikely to carry cellular contributions from undetected, resorbed twins. In fact, Wislocki (*6*) has reported a well-developed embryo beside a dead, macerated one, and in both our laboratory and that of Gengozian (*7*) similar observations have been made. It is sometimes unfortunate that each individual marmoset must be suspected of being phenotypically (and, perhaps, genotypically) contaminated, for studies of blood groups and other characters are made much more difficult.

Our data have come from a breeding colony of marmosets, all but two pairs of which were *Oedipomidas oedipus*. The others were one pair of *Tamarinus mystax* (two pregnancies) and one pair of *T. nigricollis* (five pregnancies). Although we have maintained a colony for nearly 5 years, breeding has taken place over the past 2½ years; 30 females have been pregnant 65 times. Ten of these females died for a variety of reasons, some intentional; thus the opportunity for multiple pregnancies did not come to all females. Twelve females have been pregnant once; 7, twice; 6, three times; 4, four times; and 1, five times.

In four instances only placentae represented the pregnancies. The remainder consisted of one case of triplets, 40 sets of twins, and 20 singletons. Not all could be sexed, for some were mutilated by cannibalism.

The care and behavior of marmosets in our colony, as well as other findings, have been reported elsewhere (*8, 9*).

Zuckerman, in 1930 (*10*), considering the possibility of a breeding season among primates, stated that little was known of breeding among South American monkeys. He cites E. M. Hume for the claim that there is a tendency for marmoset births to group toward spring and autumn. Later, Lucas *et al.* (*11*) gave the dates of 17 births of *Hapale jacchus*. These records suggested this same tendency; but, since most were from births by a single female, it is dangerous to ascribe her pattern alone to the species. Jarvis and Morris (*12*) have brought up to date the birth records of marmosets in the collections of the Zoological Society of London and gave "March to November" as a season for births of *H. jacchus*; their conclusion was based on 14 births between 1828 and 1961. Eight births among three other species were also reported. Brand (*13*) has similarly treated the experiences in the National Zoological Garden of South Africa during the period 1908–1960. His records on *H. jacchus* showed 15 births and indicated that most young were born during the spring and autumn. These, of course, were records on animals kept south of the equator.

Forty-six of the pregnancies in our colony came to full term, although some were stillbirths. Fifty-three more dates of birth were obtained from the general literature (see Table 1) and from the two recapitulations by Jarvis and Morris (*12*) and Brand (*13*). To the data on *H. jacchus* from Brand (*13*), those from Sawaya (two cases) (*14*) and Langford (one case) (*15*) were added because they also represented *H. jacchus* kept in the southern hemisphere.

When the data given in Table 1 are used to predict production in a marmoset colony, it may be assumed that births will occur during any month. During the 4 months of February through May, nearly half of the births have occurred; a tendency to group toward spring and autumn is still apparent. Yet the average of inter-

Table 1. Month of year of full-term births in marmosets. Total, 139.

Month	Brand*	Jarvis and Morris†	Literature‡	Hampton and Hampton	Total
January	0	1	1	6	8
February	2	1	6	5	14
March	3	2	5	7	17
April	2	2	10	4	18
May	2	6	1	4	13
June	0	3	4	2	9
July	2	2	4	4	12
August	0	1	8	0	9
September	3	1	4	3	11
October	4	1	5	1	11
November	0	2	3	5	10
December	0	0	2	5	7
Total	18	22	53	46	139

* Reference *13*; includes data from references *14* and *15*. † Reference *12*. ‡ See references *11*; *16–18*; *21–27*.

Table 2. Interbirth intervals for breeding females of *Oedipomidas oedipus* and *Hapale jacchus* in captivity.

Nature of interval	Observations (No.)	Interval	
		Av.	Range
	Oedipomidas oedipus		
Abortion followed by full term	8	245	189–334
Full term followed by full term	13	238	187–302
	Hapale jacchus		
Full term followed by full term	8*	162	148–190

* From Lucas *et al.* (*11*), whose data were all obtained from one female.

Table 3. Incidence of singletons, twins, triplets, and quadruplets among marmosets.

Species	Reference source	Singles	Twins	Triplets	Quadruplets
Various	(*20*)	10	46	3	
Tamarinus mystax	(*)	1	1		
T. nigricollis	(*4, 28*)	1	2		
T. nigricolliis	(*)	2	3		
Saguinus nigricollis	(*16*)		1		
Tamarinus	(*26, 29*)		4		
Oedipomidas oedipus	(*)	17	36	1	
O. oedipus	(*4*)	1	3		
Leotocebus (Oedipomidas) oedipus	(*27*)		3		
Cabuella pygmaea	(*30*)	1			
Leontocebus rosalia	(*4, 16, 17, 23*)		11	1	
Hapale jacchus	(*11, 14, 30*)	2	17	7	2
Hybrids	(*21*)		2		
Total		35	129	12	2

* Our own colony.

Table 4. Sexes of singletons, twins, and triplets of marmosets.

Group	Source of data	Male sets	Female sets	Heterosexual sets
Twins	Literature*	8	7	12
Twins	Hampton and Hampton	9	10	18
Total		17	17	30
Triplets	Literature*			3
Triplets	Hampton and Hampton		1	
Total			1	3
Singletons	Literature*		4	
Singletons	Hampton and Hampton	8	11	
Total		8	15	

* See references *6, 11, 16, 17, 22–26, 29*.

vals between births in captive animals is not consistent with either one or two breeding periods per year.

While data from animals bred in captivity may not denote whether or not they respond to their habitat by seasonal breeding, they do provide information on the production potential such colonies may have. The shortest interbirth interval reported has been for *Leontocebus rosalia*. Rabb (*16*) gave an instance of 134 days, while Ulmer (*17*) gave intervals of 132 and 133 days from a pair observed by him. Lucas *et al.* (*11*) reported 148 days as the shortest interval between births in a female *H. jacchus*. We have noted 187 days as the shortest interval for *Oedipomidas oedipus* and 169 days for *Tamarinus nigricollis*. We have one instance of a full-term birth 153 days following placement of a pair of *Oedipomidas oedipus* together and another instance in which a female had been alone from the 162nd to the 147th day before she gave birth. The commonness of abortions and premature deliveries among captive marmosets makes the shortest intervals still subject to qualification if knowledge of "normal" gestation periods are desired. In our colony, infants much smaller than average sometimes survive. Thus we feel that 140 days should be a reasonable figure to use, assuming, perhaps, that in the shortest periods an immediate postpartum oestrus had occurred.

It is probable that an average interbirth interval is most useful as a value for those wishing to breed marmosets. To further assay data which might determine gestation period and, at least, birth frequencies, we have reviewed relevant information in Table 2. The data on *Hapale jacchus*, taken from Lucas *et al.* (*11*), came from a single female, while our data were from many females, only one of which supplied as many as four interbirth intervals.

Excepting a lapse of 535 days between its last and next-to-last pregnancies, the single female of Lucas *et al.* (*11*) showed an average interbirth interval of 162 days for eight such periods. Our data (not in Table 3) for a female *Tamarinus nigricollis* have been, in order, 187, 169, 172, and 193 days. An average period of 240 days was found for our colony of *Oediponidas oedipus*. This figure was derived from 21 intervals ranging from 187 to 334 days. The lack of a difference between those females which did not lactate (abortions followed by full-term births) and those which probably did (full term followed by full term) provides no information on whether lactation per se affects ovulation in this species.

Probably Rudolphi (*18*) was the first to show that twinning is a rule for marmosets. In 1932 Wislocki (*19*) discussed placentation of marmosets, observing that 11 of 15 cases of births known to him were twins. Later (1939) he (*6*) surveyed 40 instances of pregnancies of which 87.5 percent were twins. He concluded, from seven sets of marmoset ovaries, that double ovum twinning was the rule, since corpora lutea were found in each ovary. The finding of male, female, and heterosexual pairs in a relation of 2:2:3 among 7 sets of twins also supported biovular twinning, although he pointed out the desirability of a larger series.

Schultz (*20*) collected from the literature the records of 59 pregnancies among several species of marmosets, conclusively showing that twinning is the predominant form of birth. Further data on twinning are compiled in Table 3. Some generic names were changed by Schultz (*20*) to conform with those in general use at the time. The species listed here are the designations used by the respective sources. To the 59 cases reported by Schultz (*20*) are added 58 more cases we found in the literature. Our own colony has provided 61 more instances to bring the total to 178. Many species are represented, but a pattern representing species is not evident. It should be pointed out again that twinning may be much higher in wild marmosets (*6*).

Since the sexes of multiple births can serve effectively to ascertain the incidence of biovular pregnancies, we have compiled such data in Table 4. If all twins were biovular in origin, a relationship of one pair of males and one pair of females to two mixed pairs should apply. From the literature cited (see table), the sexes were reported in 27 cases of twins, 12 of them for *Hapale jacchus*. From our data the sexes of 37 sets of twins were known, 33 of which were *Oedipomidas oedipus*. The totals are 17 pairs of males, 17 pairs of females, and 30 mixed pairs; there are no conspicuous differences between our data on *O. oedipus* and the species reported by others. Our case of triplets was the only one out of four cases in which all were of the same sex. Other authors recorded the sex of singletons only four times, all of which were females. However, our 19 cases consisted of 8 males and 11 females. As noted in Table 3, many singletons have been reported, but the sex has often not been given.

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