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Primate Biology with Special Emphasis on Reproduction

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Introduction

The Indian subcontinent is richly endowed with a Primate fauna. The Order Primates includes the tree-shrews, the south and central American ('New World') monkeys, the 'Old World' (Africa and Asia) monkeys, the tail-less apes and man. This grouping has been made possible because there are a number of similar characters between the monkeys and apes on the one hand and man on the other; there are also important differences.

Origin and Distribution

Origin of Primates

Some 65 million years ago, the monkeys took their origin from the ancestral insectivores and branched off during successive millions of years into lorises, lemurs, tarsius, new world monkeys, old world monkeys, apes and man. The crucible of this gigantic radiation appears to have been the forests of Northern Hemisphere. From there they migrated through the Bering Strait land bridge into North America on the one hand and on the other into Eurasia. Thereafter the evolution of the Primates in the two land masses was independent. There was also a further movement of the two stocks to the south; the North American Primates extended into South America which became their permanent abode while the Eurasian branch moved to their ultimate habitats in Africa, South Asia and East Indies. With regard to India, Kurup (1974) described that there was a faunal flow from the Indo-chinese and Palaearctic-Ethiopian regions into peninsular India. The flow from the Indo-chinese region was greater than that from other western regions. In this connetion, it may be interesting to mention that we find one species of macaque in north Africa (the tail-less 'Barbary ape') and it is the only Primate common to Africa and India. It is the only free-living monkey in Europe; it is likely that it was introduced there, probably in 1704. The highest latitude to which the nonhuman primates have extended is 41°21′ north in Honshu island in Japan.

Systematics

(*a*) *Prosimii*

There are 192 living taxa in the whole world excluding man. The Order Primates is divided into suborders—Prosimii and Anthropoidea. Tupaiidae, one of the families of Prosimii, occupies the lowest rung of the geneological tree and comprises the treeshrews. This group is considered to be similar to the ancestral mammalian stock.

These animals (*Tupaia*) are least monkey-like; they look more like other insectivores with longish snouts and claws on all the digits. From the palaeontological point of view, Von Valen (1965) stated that the tupaiid-primate relationship is "possible but unlikely". However, serological studies (Goodman 1962) are in favour of associating the tree-shrews with Primates. In India, *Tupaia* has been described north of river Ganga and one species occurs in Nicobar Islands. In south India, we have a squirrel-like tree-shrew *Anathana* with dentition very much unlike a rodent.

Of the Prosimii, we have two genera, *Loris* and *Nycticebus* both coming under the infraorder Lorisiformes. Both are shy animals taking only nocturnal sorties from their hideout in trees in search of food. The slender loris, *Loris tardigradus* occurs in parts of Karnataka and Tamil Nadu and extends northward in the Nallamalai range in the eastern ghats (Andhra Pradesh) (Kurup 1974). *Loris* has prominent eyes, helpful during nights, and is tail-less. They live during the day concealed among branches and in the hollows of trees squatting with the head lodged in between the hind limbs. Johnson (1982) recorded that in Mundanthurai sanctuary (Tamil Nadu), loris moves during day for feeding, etc. The rolled up posture of *Loris* hinders blood flow to the extremities. To obviate the ischaemia thus caused, the large femoral arteries break up into plexuses at the joints so that circulation is ensured in a few of these at least. Urine marking by rhythmic micturation or smearing hand and feet while walking is a common behavioural pattern in prosimians. In both *Loris* and *Nycticebus*, the second toe carries a claw used for preening the hair and is described as the toilet-claw; the other digits carry nails. The incisors present a comb-like appearance also used in combing the hair. The Assamese slow lorises (*Nycticebus coucang*; *Nycticebus pygmeus*) are of a bigger build and exhibit a short tail. They are also night prowlers like their south Indian congener. *Nycticebus* breeds right through the year while in *Loris* it is restricted to two seasons in a year. In *Nycticebus* gestation is of 193 days (Manley 1966, 1967) while in *Loris* it is 140–174 days (Nicholls 1939). We have very commonly seen twins being born of *L. tardigradus*. In our colony of the 81 gravid loris uteri examined, 43% had single embryos while 54% contained twins (Ramaswami & Anand Kumar 1965). Nicholls (1939) and Manley (1966) also described that a litter consisted of two normally, while Hill (1942) described more commonly birth of a singleton.

In *Loris*, the well developed scrotum regresses during the non-breeding season and does not contain the testes as these are active throughout the year and it is not necessary for the testes to reside in the scrotum to be actively elaborating sperm (Ramaswami & Anand Kumar 1965).

Parturition in *Loris* has also been studied by Kadam and Swayamprabha (1980). They found that breech and head presentation to be common. It takes about 4 min for the fetus to be expelled. Placenta comes out later and is devoured by the mother.

The mother-infant relationship in *Loris* has been described by Swayamprabha and Kadam (1980). There does not appear to be any mutual recognition between mother and infant. Any lactating mother accepts alien babies. Maternal interest declines and is lost after fifteen months post-delivery. In the langur *Presbytis entellus* an infant which is with another female can recognize within two months its mother from a distance of 6 m (Chance 1971).

In an experimental study (Manjula & Kadam 1983) of the ligation of efferent ducts of the loris testis for 15 days, the testis of

ligated animals showed an increase in weight and also diameter of the seminiferous tubules. The size of the Leydig cells and probably the out-put of androgens, and consequently secretary activity of the accessory glands was reduced. Citric acid and fructose was reduced. No account is available of the fate of the contralateral testis whose efferent ductules were not ligated.

Manjula and Kadam (1983) have made certain biochemical studies using castrate lorises, particularly the effect of testosterone propionate, 5-α dihydrotestosterone on sialic acid concentration in the epididymis and other accessory glands. The caput and cauda epididymides lost weight as also other accessory glands fifteen days post-castration. With a single injection of 250μg of testosterone propionate, the epididymis regained its original control levels. The caput epididymis regained its original control weight with only 50 μg of 5-alpha DHT; the cauda epididymis did not regain its weight. The authors therefore conclude that sialic acid in the epididymis is androgen dependent.

Rajalakshmi (1985) argues that since the level of sialic acid decreases on the entry of spermatozoa into the epididymis, the sialoproteins may play a role in sperm maturation. Prasad and Rajalakshmi (1976) also pointed out the decrease of sialic acids bound to spermatozoa during their passage from caput to cauda epididymides. She also referred to work which stated that epididymal proteins played a role in the maturation of human spermatozoa.

Whether sialic acid concentration is androgen-dependent or not has become a controversial topic. Bose and Kar (1968) studying the sialic acid concentration in male rhesus monkey reproductive organs came to the conclusion that it was not androgen-dependent. Using the Hanuman langur as the experimental animal, it was found (Ramaswami 1975) that in castrated Hanuman langurs, injection of testosterone propionate did not affect the sialic acid concentration in the epididymides, vas deferens, seminal vesicles and prostate. This subject may have to be re-examined taking the two genera of monkeys from different geographical areas.

Butler (1960) described the breeding cycle of another prosimian *Galago* of Sudan. The oestrous cycle lasts for 4–6 weeks recurring throughout the year. Probably it exhibits a post-partum oestrus. In mid-December there is intense sexual activity in these animals in Nuba mountains where they live. During oestrus, the vaginal cytology shows sequential changes. The corpus luteum is pedunculated, resembling that in *Loris* where it is extra-ovarian; a similar corpus luteum is also found in totally unrelated genera like *Elephantulus* and *Rhinopoma*. In *Galago*, twin pregnancies were not common.

We have unfortunately no breeding colony of these, so far in India, it may not be difficult to establish one in Assam or Bengal. A breeding colony of its relative, the Malagasy lemur is working very well in North Carolina, USA.

(*b*) Old World Monkeys (Anthropoidea)

Geographical distribution

We have a large number of Old World monkeys and only one ape (the lesser ape or gibbon) represented in India. All the Old World (Africa and Asia) monkeys come under the second suborder Anthropoidea, of which the family Cercopithecoidea comprises the largest number of taxa. One of the species of *Macaca* viz., *Macaca mulatta* (the rhesus monkey)* is more widely distributed; it is

*The common names of the macaque species are as follows, given in an alphabetical order: Assamese macaque = *Macaca assamensis;* Barbary ape = *M. sylvanus;* Bonnet monkey = *M. radiata;* Celebus or moor macaque = *Macaca maurua;* Crabeating macaque = *M. fascicularis;* Formosan rock macaque = *M. cyclopis;* Japanese macaque = *M. fuscata;* Liontailed macaque = *M. silenus;* Pigtailed macaque = *M. nemestrina;* Rhesus macaque = *M. mulatta;* Stumptailed macaque = *M. arctoides;* Toque macaque = *M. sinica*

found north of the river Godavari and the bonnet (*Macaca radiata*) to its south is no longer tenable. There is considerable extension of the bonnet monkeys into the north of the river and the rhesus to the south of the same. The subspecies *M. m. villosa* is found in south Kashmir, upper Punjab and northern Uttar Pradesh. This subspecies was exported in large numbers and its natural habitat was also denuded so the population growth was unwittingly checkmated. Later the export quota was reduced to 20,000 and now, even this is stopped.

Macaca species

The reproductive biology of the rhesus and the bonnet monkeys has been studied in great detail.

The differences between the macaques and human in reproduction (Dukelow 1975) are:

Macaques are (*i*) seasonal breeders, (*ii*) gestation is shorter in them, (*iii*) there is difference in depth of embryonic implantation in them, (*iv*) monkeys have a bidiscoidal placentation, (*v*) macaques experience a short labour, (*vi*) twinning is less frequent, and (*vii*) there are differences in oestrogen metabolism as compared to the human.

The rhesus is considered to be a seasonal breeder Anand Kumar et al. (1980) though Krishnan (1972) and Prater (1965) believe they are not so. In the bonnet monkey there is no well-defined breeding season, November to January is the peak mating period; however, Eckstein and Kelley (1966) reported that in small-caged colonies, breeding occurs all the year round. In Cayo Santiago, there is no seasonality in breeding of *M. mulatta* and Carpenter (1942) stated that births occurred during June to August.

In the rhesus monkeys, consort pairs are not uncommon while in the bonnets they are absent.

In the rhesus monkey, usually one young is born at a time; van Wagenen (1972) recorded that out of 580 pregnancies, three were twins. The placenta may be bidiscoidal in more number of cases while in others it is a single disc.

In the rhesus monkey, the oestrous cycle is of 28 days duration. Females mature earlier (3.5 years) than males (4.5 years). Gestation is of 165–168 days duration (Hartman 1932, van Wagenen 1972). Anand Kumar et al. (1980) after mating 23 adult female rhesus monkeys and examining vaginal swabs for sperm found that the gestation time was 165 days thus confirming previous records. Their laparoscopic studies also revealed that out of a total of 102 female monkeys with a cycle length of 23–31 days, only 76 ovulated; the side of ovulation is not indicated. They pointed out that there are differences in the timing of seasonal changes and in the amount of ovulatory and anovulatory cycles and also the period of the year when the largest number of normal menstrual cycles occur. Wallach et al. (1973) studying the rhesus females reported that the right ovary ovulated in the majority of cases.

The females of rhesus, bonnet and the Hanuman langur usually exhibit summer amenorrhea (Anand Kumar et al. 1980, Murthy et al. 1980). Rowell (1963) would not corroborate this in rhesus monkeys but pointed out that cycles were shorter in winter than in summer. However, Kaverne and Michael (1970) found that in the rhesus monkey there was a summer amenorrhea and longer cycles during June to October in a colony of monkeys in London. Jayaraman et al. (1979) failed to bring the bonnets and the Hanuman langur back into the cycle when held in the laboratory. This amenorrhea usually results when the non-human primates are caught from the wild and put into the laboratory after a period of quarantine. Injection of Organon preparation (Menstrogen) containing ethynyle oestradiol and progesterone also failed to make them

cycle regularly. As langurs are leaf-eaters, they were fed lucerne along with food pellets. Lucerne is known to possess some oestrogenic properties. When the Hanuman langurs started cycling, they were exposed to the male for mating. The authors are not clear if the lucerne added caused the Hanuman langur to menstruate.

With regard to breeding of rhesus monkeys, Vandenbergh (1973) analysed it under three heads:

(*a*) under natural conditions as in North India,
(*b*) under freer-anging colonies (Caribbean),
(*c*) under laboratory conditions.

Southwick et al. (1961) and Lindburg (1971) described that births are concentrated in late spring and early summer; September births are also taken into account but probably they represent a second peak, reproduction being bimodal (see also Prakash 1962).

In Cayo Santiago, there is mating during autumn. In the male peculiarly there is regression of the testis during the non-breeding season (Conaway & Sade 1965).

In enclosed monkey colonies, conceptions are common during November, December and January. In Wisconsin Regional Primate Centre, the fertility is high during October–February. At Davis Primate Centre, maximum births occurred during November to April. In Bionetics laboratory, in 800 monkeys that breeding was seasonal and a peak in conception was found between September and January.

In the male rhesus monkeys, spermatogenesis was maximum during autumn; the epididymis does not show any cyclical phenomena. Castrated male cares for immature monkeys; however, they prefer castrates (Wilson & Vessey 1968).

Sex skin: In the male rhesus monkey, there is an increased reddening of the sexual skin correlated with the enlargement of the testes at the height of peak copulations. Both *M. radiata* and *M. sinica* (Toque monkey) do not show sex skin activity. However, in both the species, there is a discharge of a strong smelling clear mucus from the vagina (Hill 1942). During the ovulatory cycle, there is an orderly fluctuation of physical and chemical properties of the cervical mucus which can be correlated with endogenous oestrogen levels (Ovadia et al. 1971). It is not clear what purpose this mucus serves.

In the bonnet monkey, the menstrual cycle is of 29.5 days (Murthy et al. 1980). It is a single mount species with 5–30 pelvic thrusts (Nadler & Rosenblum 1969).

Hartman (1938) stated that the gestation period was 163 days in the bonnet monkey, Rahaman and Parthasarathy (1969) put it at 5 months and Prater (1965) stated it was 6 months. Births may occur in February and March and there is no well defined season.

There is no change in volume of semen or sperm number during the year in *M. radiata* (Moudgal 1981).

In *M. fascicularis* unlike *M. mulatta* there is no anovulatory cycle (Varaudhi 1980, Anand Kumar et al. 1980) ninety per cent of the cycles are ovulatory and the ovulation takes place on the left side.

A study of the vaginal cytology of the crab-eating macaque (*Macaca fascicularis*) indicated that it was not a good test for ovulation; however, it could be used as a good criterion in distinguishing ovulatory from anovulatory cycles (Nawar & Hafez 1972).

Summer season appears to affect adversely reproduction in the rhesus monkey. In other monkeys held in captivity (*M. fascicularis, M. arctoides, M. nemestrina*) there is uninterrupted reproductive activity during the year (Dukelow 1974). He also reported (Dukelow 1977) that extensive laparoscopic examination of monkeys did not affect their ovulation, cycle-length, conception, pregnancy or lactation. It is now known that for the highest conception, there should be natural

mating, capacitation in the female tract and ovulation (Dukelow 1974).

Of the bonnets, there are two subspecies: one (*M. radiata radiata*) occurring south of Satara and river Godavari and the other (*M. radiata diluta*) is restricted to south Kerala. In certain areas where rhesus and bonnets live together, hybridization may not be ruled out.

Another species (*Macaca silenus*) which is an endangered one is called the 'lion-tailed' macaque. The terminal caudal tuft of hairs is characteristic of the male and may occur rarely in the female. This caudal tuft of hairs made Pennant (1781) give it the name of lion-tailed monkey. When both lion-tailed monkey and the Nilgiri langur (*Presbytis johnii*) black in colour are sitting side by side on a tree, it is difficult to say which is which unless one is lucky to see the tail tuft of the lion-tailed monkey which is absent from the Nilgiri langur (Sugiyama 1968).

The lion-tailed monkey is called the 'Wanderoo' (Ouanderou) in Sri Lanka though Green and Minkowski (1977) stated that no lion-tailed monkey ever occurred in Sri Lanka. This black monkey is an obligate tree-top dweller of the rain forests of Kerala and Tamil Nadu. Its range also extended upto Goa. It has been observed at Nilgiri, Anaimalai and Cardamom hills and vicinity of of Periyar sanctuary, Kerala. Webb-Peploe (1947) reported that if the lion-tailed and bonnet monkeys forage in the same area, the latter would avoid the lion-tailed monkeys; if however, the langurs and bonnets come together, the macaque dominates.

Copulatory Behaviour of the Lion-tailed Monkey

Lindburg et al. (1985) give in their account the copulatory behaviour of the lion-tailed monkey. The male approaches the oestrous female and inspects the genetalia. If the female is in a sitting posture, and does not respond, the male may even lift the female up by her tail and start examining the genetalia. According to the above authors, there were 1–16 mounts with a mean of 5.1 in an ejaculatory series; Ramaswami et al. (1982) studying the lion-tailed monkey at the Ranibaugh zoo gardens, Bombay noted that there were five pelvic thrusts at each mount.

In addition, it has been pointed out by Lindburg et al. (1985) that *M. silenus* resembles *M. nemestrina* in at least two important features. They consider important the oestrous female lion-tailed and pig-tailed monkeys putting forth a "jaw thrust" signal (first noted by Kaufman & Rosenblum 1966). Tokuda et al. (1968) stated that the male pig-tail monkey's "jaw thrust" was ignored by the oestrous female for 10–30 minutes and then she presented her posterior to the male. There is no reference to the "jaw thrust" in the female pigtail monkey. The other important feature is the solicitation of the oestrous female uttering the "chu-chu" vocalization in both species. There is no reference to the vocalization in the pigtail monkey in the account of Tokuda et al. (1968). Further standing on its hind limbs and stretching out the arms and assuming a 'play-boy' stance, the oestrous lion-tailed monkey may also utter 'chu-chu' vocalization of copulation. According to Lindburg et al. (1985), the male stops its "jaw thrust" display far ahead of the fertile part of the cycle and therefore, they believe that this gesture of the male is for gaining familiarity with the female and not for mounting.

Fooden (1975) gives a figure of the sex skins of the lion-tailed and pig-tailed oestrous females and one notices that in the former the paravulval swellings are larger while in the latter, the paranal swellings are larger. He also noted that the baculum of the lion-tailed monkey resembled that in the pig-tailed one. Further during the luteal phase, the sex acts lessened in the lion-tailed monkey

(Lindburg et al. 1985) indicating the lesser influence of the hormones, particularly oestrogen, during the secretory phase.

Shideler and Lasley (1982) have compared a few Primate ovarian cycles. With regard to the lion-tailed monkey, they observe that the cycle length is 30 days. Ramaswami et al. (1982) have stated that the mode is 39 days. Asakura (1960) also studying zoo specimens stated that the cycle length in the lion-tailed monkey was 39.6 days. The follicular phase according to Shideler and Lasley (1982) is 13–14 days. There is also a tumescence of the sex skin coinciding with an oestrogen peak. When this oestrogen peak shows a nadir (see their figure 4), the detumescence starts and this coincides with ovulation. White et al. (1973) state that in *M. nemestrina*, quantitatively the tumescence of the perineum gives a more accurate indication of the phases of the menstrual cycle than does vaginal cytology. Shideler and Lasley (1982) have also confirmed the subsequent conception by using the nonhuman primate pregnancy test.

The assamese macaque, *M. assamensis* is found in Assam and extends to Naga hills. There are two subspecies: one *assamese pleops* is found in Uttar Pradesh (close to the Himalayas) extending into Nepal, Sikkim and Bhutan. The other subspecies, *assamese assamensis* is found in Assam. The median parting of hair above the brows is characteristic of this species. A subspecies of the crab-eating macaque *Macaca fascicularis umbrosis* is reported from Nicobar islands. The largest number of subspecies is contained in the species *fascicularis*. The stump-tailed macaque, *M. arctoides* which is of a heavier build than rhesus or bonnet monkeys is also found in Assam. It is doubtful if the pig-tailed *M. nemestrina* occurs in the Naga hills of Assam.

The Langurs : The leaf-eating langurs have no cheekpouch and their stomach is modified to substitute the cheek-pouch physiology. These are hound-like animals and cause considerable damage to plantations where tender shoots of trees form the staple of their diet. There are some nine species described. The most ubiquitous is the Hanuman langur and this along with the other three are described below with their geographical distributions:

(*a*) The Hanuman langur (*Presbytis entellus* Dufresne): Kashmir in the north to Sri Lanka in the south.

(*b*) The capped langur (*Presbytis pileatus* Blyth): North-eastern India.

(*c*) The golden langur (*Presbytis geei* Gee (Khajuria 1956): North-Western Assam Bhutan.

(*d*) The Nilgiri langur (*Presbytis johnii* Fischer): South India.

Mohnot (1982) spent considerable time in discerning the behavioural repertoire of the Hanuman langur and similarly Poirier (1969) of the Nilgiri langur. In the Hanuman langurs, unimale bisexual groups and male bands have been studied. The latter are noticed to move in large areas. Peace seems to exist except when a female is involved. It is also noticed that the bands may split into subgroups.

In the one adult male troops of *johnii* (Poirier 1969), grooming female/female lasted very much longer than either female/male or male/male. In the unisexual groups, there is no grooming.

Infant transfer is very commonly seen in the Hanuman langurs.

A gruesome feature noticed in the Hanuman langur is infant killing; this happens even when leadership may or may not change. Very soon the female langur enters into oestrus having lost the baby (Jay 1965). In fanticide is also noticed in gorilla (Fossey 1981) and there appears to be some justification for this. The male gorilla commits infanticide by

killing another male's babies so that he can perpetuate his own lineage by breeding with the victim's mother; this outbreeding is probably nature's law.

There are two birth peaks among the Nilgiri langurs; the primary one is during May-June, and the second less important one during November-December-February (Jay 1965).

In the Hanuman langurs, copulation takes place throughout the year (Jay 1965). Copulating pairs may be disturbed by adult females or even juveniles. When a female's solicitations are ignored by a male, the female may give a slap on the male or even bite him.

The troop structure is stable in the Hanuman langur. In the south Indian and Nilgiri langurs, there is great fluidity. The feeble bond between Nilgiri langur mother and baby and the early weaning have somehow affected the socialization; the south Indian and Nilgiri langurs are less aware of the baby; this has also affected the socialization. Transfer of babies between mother and foster parent (or allo-mother) within two troops is common among colobines. What exactly the behavioural benefit is to the baby is not clear (Jay 1965).

A comparative study of the per cent testis weight of a few monkeys reveals an interesting point; (Schultz 1968, Ramakrishna & Prasad 1967, Burton in press): *Loris* resembles the cercopithecine monkeys; chimpanzee also shows a heavier testis per cent weight than other apes (Schultz 1968, Ramakrishna & Prasad 1967).

The relative per rcent testis weights

species	percentage
Loris	0.96%
Hanuman langur	0.07%
Presbytis obscura	0.07%
rhesus monkey	0.74%
orangutan	0.05%
gibbon	0.08%
chimpanzee	0.27%
gorilla	0.01%
human	0.08%

The Steroid Hormones — Testosterone and Oestrogen

The steroid hormones play a great role in the reproductive biology of the Primates. I shall restrict myself to the two of the hormones viz., testosterone and oestrogen.

The Biological Clock: It is well known that the reproductive activity of the Primates shows a biological rhythm. Just as steroidogenic activity is linked with reproduction in the female (which made the Pittsburgh School say that the ovary is the centre of biorhythm), the cyclical reproductive activity in the male is linked with the secretion of testosterone (T) and 5-α dihydrotestosterone (DHT). If one studies man, there is a daily (circadian), an annual (circannual) and also a pulsatile (circhoral) rhythms (Ewing, Davis & Zirkin 1980). Descriptions of circadian and circannual biorhythms are available for a number of monkeys.

Remarkably the peak or surge secretion of testosterone in man and monkey shows a significant difference; in man, the peak or surge is reached in the early morning, whereas in the monkey it is reached in the evening. It has been experimentally proved that this rise in (T) levels is not due to poor metabolism or clearance rate or excretion. This difference in timing of the peak secretion of the androgen needs to be examined. It is remarkable that in free-ranging colonies of rhesus monkeys (as e.g. Cayo Santiago, Peurto Rico) where environment plays an important role and in the laboratory, where the environmental influences are completely eliminated and where the temperature and duration of light (LD 12 : 12) are controlled, the reproductive rhythm is the same (Michael & Kaverne 1971). These authors feel that the circadian rhythms of (T) concentration are due to physiological actions of the testis.

In this connection, the paradoxical behaviour of the owl monkey (*Aotus*) (Dixson

et al. 1980) is worth noting. In this Primate, the testes normally show a regressed condition even in males that are breeding successfully under laboratory conditions. Vandenberg (1973) was of the opinion that mating etc., are due to sequential environmental factors.

Wickings and Nieschlag (1980) and Anand Kumar et al. (1980) have studied circannual variations of male rhesus monkeys maintained under laboratory conditions thereby excluding all environmental influences and housed away from females. The diurnal variations in (T) levels can be abolished by administering HCG (Nieschlag et al. 1971).

While a large number of workers has shown the occurrence of a diurnal rhythm in blood (T) (Dray et al. 1965, Anand Kumar et al. 1980) others have denied such a rhythm (Alford et al. 1973).

Diurnal variations of (T) occur in the bonnet monkey (Mukku et al. 1976, Moudgal 1981) bled by venipuncture at intervals of 6hr from males housed separately from females in individual cages in rooms which were not air-conditioned, 12 : 12 L-D. A nycthermeral variation in serum(T) secretion in the bonnets is very much like in the rhesus monkey. There is a 6–12 fold increase of (T) variation during the night. If the monkeys are exposed to continuous illuminations as opposed to 12L: 12D regimen for four weeks, the variation is lost and it could be restored if the regimen is shifted back to the rhythm showing higher surge secretion in the night.

Nycthemeral variations in serum (T) in male M. radiata (*Moudgal 1981*)

Time of day	(T) equivalent ng/ml serum (n=7)
0200	26.0±3.90
0800	3.96±0.69
1400	2.29±0.26
2000	25.6±3.72

The adrenal secretion does not seem to have been examined in the bonnets after castration or dexamethasone injection.

Munshi (1980) also reported that in the bonnet, (T) concentration throughout the year did not show a circannual pattern. In the bonnet there does not appear to be a seasonal variation in serum concentration of (T) throughout the year and therefore, it is a better model than the rhesus monkey for contraceptive drug study (Murthy et al. 1980, Moudgal 1981).

A study of (T) excretion in the Hanuman langur showed diurnal and nocturnal variation as shown below (Lohiya et al. 1982b):

Day: 6.484 (nmol/L); Night :10.496 (nmol/L)

A diurnal and circannual study of (T) was made in the male bonnet monkey (Kamboj et al. 1984) and it showed diurnal variations (expressed in nmol/L: see below) :

Diurnal study: 1 pm		7.18±2.20	1 am	46.61±18.28
	5	20.23±8.12	5	15.86±2.83
(peak)	9	74.83±2.63	9	10.26±2.84

Circannual study of (T) in male bonnet (expressed in nmol/L) (Moudgal 1981)

April–June (Summer)	:	5.69±1.60
July, August (rains)	:	9.80=2.80
Sept.–Oct. (breeding season)	:	11.90±2.72

Hansen et al. (1980) have conducted a parallel behavioural experiment using the West African talapoin monkey (*Cercopithecus talapoin*) concentrating on the most dominant (D) and the most subordinate (SO) of animals in the group. In both groups of males, if they are isolated from females, the LH and T levels are very much the same (however, prolactin was higher in the (SO) group). When the (D) and (SO) males were housed with sexually attractive females, the (T) and LH levels *increased* in (D) group only. If the (D) males were removed the (SO) males show a rise in LH and (T) levels. Therefore in studying (T) and LH levels in

at least the above monkey species, their behavioural situation must also be taken into account.

It is not merely the adult testis that goes on secreting (T) in a rhythmic manner in the monkey species enumerated above; fetal testis can also actively synthesize (T) (Resko 1970, Resko et al. 1973). In rhesus monkey fetuses of 36 and 60 days of fetal life, the testis can convert ^{14}C-pregnenolone into (T) and androstenedione *in vitro*. In fetuses of 100, 125, or 150 days of fetal life, the male umbilical artery showed more of (T) than in the female fetus. While fetal testis synthesizes and releases (T) into fetal circulation, the fetal ovary is relatively quiet. Castration of male fetus on day 100 of gestation abolishes the (T) secretion found on 150–156 days of gestation (Resko et al. 1973). This is sufficient indication to show that the fetal testis develop in a different hormonal milieu than the female fetuses.

At least six important functions are attributed to the steroid hormone testosterone:

(1) transduces chemical signals into the germ cells through the Sertoli cells,
(2) differentiation of the reproductive organs,
(3) neonatal organization of the hypothalamus,
(4) sexual behaviour co-ordination,
(5) maturation of sperm in the epididymis, and
(6) spermatogenesis in the adult.

Oestrogen Profiles

In the excretion of oestrogen in the human, macaque and other species of monkeys, there exists great differences. Short and Eckstein (1961) studied the oestrogens in pregnant rhesus monkey and concluded that great differences appear to exist between pregnant humans and pregnant monkeys in the production of oestrogens. In the rhesus monkey, the major oestrogen was oestriol alongwith two unidentified substances; Laumas (1965), Liskowski and Wolf (1972) stated that in rhesus urine, unknown substances exhibiting properties of oestrogens occur. On the other hand, human pregnancy urine contained very different oestrone, oestriol and oestradiol (quantitatively and qualitatively) than those of rhesus monkey (Hopper & Tullner 1967). Humans excrete primarily oestriol during pregnancy which may be low or even absent in Old World monkeys Lasley et al. (1981) (see table below):

Pregnant primates: percentages of immunoreactive oestrone (oe_1), oestradiol (oe_2) and oestriol (oe_3) and one unidentified oestrogen peak

Species	Oestrone	Oestradiol	Oestriol	Unidentified oestrogen peak
Lion-tailed monkey	73	1	25	16
Douc langur (*Pygathrix nemeus*)	58	2	40	59
Human	3	1	95	14
Capuchin (*Cebus albifrons*)	69	13	17	170

Hodges et al. (1981) studying the South American monkeys described that in the tamarin (*Sanguinus fuscicollis*), squirrel monkey (*Saimiri sciureus*) and the spider monkey (*Ateles fusciceps robustus*) the largest immunoreactive oestrogen corresponded with oestrone. In capuchin urine there was a large immunoreactive substance adjacent to oestriol peak (see table below):

Oestrogen peaks in new world monkeys

Species	oestrone	oestradiol 17β	oestriol
Capuchin	0.210	0.019	0.065
Tamarin	3.240	0.095	0.030
Squirrel	0.392	0.024	0.008
Spider	0.408	0.113	0.079

The finding that oestriol is the major urinary oestrogen in the Hanuman langur according to Shandilya et al. (1976) requires to be re-examined. They estimated the oestrogens during menstrual cycle and pregnancy. In both these phases of langur's reproductive life oestrone, oestradiol 17β and oestriol were found. During the luteal phase, oestradiol 17β and oestriol could not be detected. During pregnancy all the three oestrogens increased and oestriol was the major pregnancy oestrogen. Chromatographically, the samples exhibited four spots, the fourth being an immunoreactive unidentified one.

During the cycle of the Hanuman langur, more oestrone was excreted; maximum amount of oestrogen was excreted on day 9 of the cycle and this was presumably the day of ovulation.

Czekala et al. (1981) reported that oestriol was the major urinary metabolite in the human and is also the quantitatively most important oestrogen during pregnancy in orangutan, pigmy chimpanzee, chimpanzee and gorilla.

Chowdhury and Chandra (1984) reported that as menstrual cycles were irregular in the Hanuman langurs, exogenous administration of 2 mg of oestradiol and 20 mg of progesterone brought the cycle into order. The cycle was noticed between day 22–24 of the month. With regard to the male, spermatogenesis was noticed throughout the year in the Hanuman langur (Lohiya & Sharma 1982).

Reproduction in the Marmosets (*Callithrix jacchus*: *Callitrichidae*)

The marmosets show a number of peculiarities in their reproduction. Hearn (in Press) has studied this aspect extensively in this south American anthropoid:

(1) These monkeys do not menstruate but all the same they show an ovarian cycle of 16.4$\pm$1.7 days. In captivity they mate frequently. It has been found that the vaginal cytology is no index of ovulation. Hysterectomy during the luteal phase of the ovarian cycle does not prolong the life of the corpus luteum; the latter is under luteotropic control as in woman and rhesus monkeys and not luteolytic control as in the guinea pig, etc.

(2) Gestation period in the marmoset is 148$\pm$4.7 days. Lutectomy does not appear to cause abortion even when performed as early as sixth week of pregnancy. They do show a postpartum estrus.

(3) Early stages of pregnancy can be terminated in female marmosets with active or passive immunization using β-subunits of HCG. Subsequent pregnancies are also suppressed by active immunization. A year after primary immunization, titres of circulating antibodies fall, abortions occur. These results according to Hearn suggest that antibodies act not only to block luteotropic support of corpus luteum and to affect the developing fetus or the placenta.

(4) Adult males show very high levels of (T) concentration released in a pulsatile manner. The testes size or plasma (T) did not show any seasonal variation.

(5) They bring forth commonly twins (80%), triplets (15%) and singletons (5%).

(6) It has been found that early stages of embryonic development occur more slowly in marmosets than in monkeys and humans.

(7) They start mating 3–10 days after parturition. Lactation does not seem to prevent ovulation.

(8) In pregnancies carrying twins producing chimeric young on account of placental anastomoses, the babies are immunologically tolerant to each other and are helpful in fetal studies.

Some available parameters of reproduction of non-human primates

	Common name	Age of matur. (yrs)	Menst. (estrual) cycle (days)	Menses (estrus) length (days)	Gesta. length (days)	Season of birth
I PROSIMIANS						
(A) Tupaiidae						
Tupaia	Tree shrews	0.5	9–12	continuous	41–56	all year
(B) Lemuridae						
Lemur	Lemurs	1.5	39.3	4.7	120–135 or 120–150	Mar-June Sep-Nov Dec-Jan
(C) Indriidae						
Indri	Indrises	—	—	—	60	
(D) Lorisidae						
Loris	Slender loris	—	—	—	160–174	Apr-May Nov-Dec
Nycticebus	Slow lorises	—	42.3	—	193	all year
Galago	Lesser Galago	—	30–37	4–6	121–124	Aug-Sept Apr-May
(E) Tarsiidae						
Tarsius	Tarsiers		24	1	180	all year
II ANTHROPOIDEA						
(A) Callithricidae						
Callithrix	Marmosets	1.2	—	—	130–140	—
(B) Cebidae						
Cebus	Capunchins	3–4	18	—	180	all year
Saimiri	Squirrel monkey	3	8–12	—	163	Jul-Aug
(C) Cercopithecidae						
Cercopithecus (*C. aethiops*)	Vervet, Green	—	30.9–33.0	3.7	163	

	Common name	Age of matur. (yrs)	Menst. (estrual) cycle (days)	Menses (estrus) length (days)	Gesta. length (days)	Season of birth
(D) Macaca	Formosan macaque (*M. cyclopis*)	—	29.9	3.3	—	
	Japanese macaque (*M. fuscata*)	4	24.4	3.5	—	Mar-May
	Cynomolgus macaque (*M. fascicularis*)	3.3	30.8	2.8	164.4	Apr-July
	Rhesus macaque (*M. mulatta*)	3.5–4.5	28	4.6	168	
	Stump tail macaque (*M. arctoides*)		30.5		180	
	Pig-tailed macaque (*M. nemestrina*)		32.1			
	Bonnet macaque (*M. radiata*)		29.5		162	
	Lion-tailed macaque (*M. silenus*)		39.6	2.5		
	Toque monkey (*M. sinica*)		29	1–4		
	Barbary ape (*M. sylvana*)		27–33	3–4		May-Sept
	Celebes macaque (*M. maurus*)	4.5	30–3A		155–175	June
	Hanuman monkey (*Presbytis entellus*)		21–26	2–4		
	Purple-faced leaf monkey (*Presbytis senex*)	4			194–217	May-Aug
(E) Hylobatidae						
Hylobates	Gibbon	5–8	29–8	2–5	210	All year
Symphalangus	Siamang	—	—	—	230–235	—
(F) Pongidae						
Pongo	Orangutan	6–9	29–32	3–4	233	—
Pan	Chimpanzee	7–10	37	2–3	227–242	All year
Gorilla	Gorilla	6–7	31	8	265	All year

Sex cycle of some nonhuman primates

Species	Menstrual cycle length in days	Duration of menstruation in days	Vaginal cornification	Sex skin
	32.6	–	+	–
Vervet (*Cercopithecus aethiops*)	72.3±36.23[2]	3.6±0.49	–	–
Talapoin (*Miopithecus talapoin*)	33	2.6	+	+C
Formosan macaque (*Macaca cyclopis*)	29.9	3.34	?	+C
Japanese macaque (*Macaca fuscata*)	24.4	3.5	?	+
Crab-eating macaque (*Macaca fascicularis*)	30.8±4.6	2.8	+	+C
Rhesus macaque (*Macaca mulatta*)	27.36±0.17	4.6	+	+
Pig-tailed macaque (*Macaca nemestrina*)	32.08±0.8	–	?	+C
Bonnet macaque (*Macaca radiata*)	29.5	–	+	+
Lion-tailed macaque (*Macaca silenus*)	39.6	2.5	?	+C
Toque monkey (*Macaca sinica*)	29	1.4	?	+
Barbary ape (*Macaca sylvana*)	27–33	3.4	?	+C
Celebes macaque (*Macaca maurus*)	30–40	–	?	+C
Chacma baboon (*Papio ursinus*)	35.6±0.16	4.9	+	+C
Hanuman langur (*Presbytis entellus*)	21–26	2–4	+	–

+ = present – = absent ?= not known C= cyclic changes
[1]. Rowell (1970b) [2]. Butler (1966)

Gestation and Life-span

Napier and Napier (1967) argue that during the course of evolution, there is a tendency to prolong post-natal life. Referring to the prosimians where the life-span is 14 years, it is noticed that it is extended to 75 in man. While this is so, least change is noticed in the gestation periods of apes and man and it has remained the same while life-span has doubled as shown below:

	Gestation period	Life-span
Gibbon	210 days	30+ years
Orangutan	275	30+
Chimpanzee	225	40
Gorilla	265	35
Man	266	70–75

From accounts of the ecological studies made by devout field workers, the social patterns of life among the apes and man are described by Diamond (1985) and are as follows:

Adult gibbons (*Hylobates*) live in separate monogamous pairs,

Chimpanzee is promiscuous; a group of adult males and feamales live together,

Orangutan is solitary; when the female becomes receptive, there is usually a consort relationship,

Gorilla is polygamous and a male dominates a harem,

Men marry one or more women; they live in tribes.

Concluding Remarks

The primate studies have diverse branches. Works of authors in this field have been exhaustively collected and referred. The review article has tried to cover the different aspects of primate studies in depth.

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