Table 1. Enzymatic formation of catecholamines from monophenolic amines. Dialyzed microsomes and soluble supernatant fraction obtained from 30 mg of rabbit liver were incubated in air at 37°C with 100 μl of 0.5*M* phosphate buffer at *p*H 7.4, 25 μl of 0.5*M* $MgCl_2$, 0.5 μmole of NADP, 1.0 μmole of glucose-6-phosphate, and 0.5 μmole of substrate in a final volume of 250 μl. After 1 hour of incubation, the reaction mixture was assayed fluorometrically for catecholamines. These results are typical of five similar experiments.

System condition	Substrate	Catecholamine formed per gram of liver (mμmole)
Complete	*p*-Sympathol	158
NADP omitted	*p*-Sympathol	46
Microsomes + NADP	*p*-Sympathol	90
Microsomes + $NADPH_2$	*p*-Sympathol	230
Complete	*m*-Sympathol	730
Complete	*p*-Tyramine	500
Complete	*m*-Tyramine	200
Complete	*p*-Octopamine	37
Complete	*m*-Octopamine	30

tion with tyramine, the mixture was extracted with *n*-butanol and assayed for dopamine (*8*). Both tyramines formed a compound that had the same activation and fluorescence spectra as authentic dopamine after oxidation. The tyramines were incubated with the microsomes, soluble fraction, and *S*-adenosylmethionine-$C^{14}H_3$; the apparent C^{14}-methoxytyramine formed was isolated in the same manner as metanephrine had been isolated. Considerable quantities of radioactive methoxytyramine were formed from *p*- and *m*-tyramine which had the same R_F values as synthetic methoxytyramine when chromatographed as described above.

When *p*-octopamine was incubated with the catechol-forming enzyme, a small quantity of material resembling noradrenaline was formed (Table 1). When *p*-octopamine was incubated with the microsomal enzyme system, soluble supernatant fraction, and radioactive *S*-adenosylmethionine, a relatively large amount of a C^{14}-methoxy derivative was formed. The latter compound, however, did not have the same R_F values as expected for synthetic normetanephrine in the two solvent systems. In all probability *p*-octopamine or a transformation product formed a catechol; otherwise, a radioactive *O*-methylated derivative would not have been formed. The unknown *O*-methylated product had the solubility characteristics of a phenolic amine.

When *m*-octopamine was incubated with the microsomal enzyme, a small amount of noradrenaline was formed (Table 1). Incubation with catechol-*O*-methyl transferase and *S*-adenosylmethionine-$C^{14}H_3$ resulted in the generation of a radioactive compound having the same R_F values as synthetic normetanephrine.

The enzymes involved in the biosynthesis of catecholamines are relatively nonspecific. Dopa decarboxylase can decarboxylate tyramine as well as other amino acids (*9*); dopamine-β-oxidase not only oxidizes dopamine to noradrenaline but can form octopamine from tyramine and adrenaline from epinine (*10*); phenylethanolamine-*N*-methyl transferase *N*-methylates octopamine, noradrenaline, and a wide variety of phenylethanolamine derivatives (*11*); a nonspecific *N*-methyl transferase can *N*-methylate dopamine to epinine (*12*) and the enzyme system described here can transform a number of monophenolic amines to catecholamines. Hence the alternate pathways shown in Fig. 1 are suggested for the formation of catecholamines.

The ability of an enzyme in the rabbit liver microsomes to hydroxylate other phenolic compounds was examined by incubating the phenol with microsomes (Table 1). The catechol formed was trapped as a radioactive *O*-methylated derivative by incubating the microsomal preparation, *S*-adenosylmethionine-$C^{14}H_3$, and the soluble supernatant fraction of rabbit liver which contained catechol-*O*-methyl transferase. The radioactive metabolites were extracted and measured as described above. The following phenolic compounds formed catechols as trapped *O*-methylated derivatives: *p*-hydroxyephedrine, *N*-acetyl-*p*-aminophenol, estradiol, stilbestrol, and *N*-acetylserotonin. The relative nonspecificity of this reaction suggests that more than a single enzyme is involved. The enzymatic formation of a dihydroxytryptamine is of particular interest since it has been suggested that such compounds regulate the heart beat of crustaceans (*13*).

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Menstrual Cycle Influences Grooming Behavior and Sexual Activity in the Rhesus Monkey

Abstract. *The time spent by the female rhesus monkey in grooming the male fluctuates rhythmically and reaches a minimum at mid-cycle. At this time the male's grooming activity reaches a maximum. The rhythmic changes in male mounting behavior, together with the males' and females' grooming cycles, are abolished by ovariectomy and have a hormonal basis.*

Although it can be argued that any behavioral interchange between oppositely sexed members of the same species may possess a sexual component, nevertheless, that part of the behavioral interaction not directly concerned with copulation can also be regarded as part of the general social behavior of the species. Heterosexual grooming (picking through a partner's fur) in many monkeys, including the rhesus (*Macaca mulatta*), is without doubt an integral part of the total pattern of sexual behavior, but this same grooming activity in a different behavioral setting also serves to define an individual's position within the highly organized primate society (*1*). Thus, grooming behavior occupies a position intermediate between a specifically sexual and a more generally social type of activity. In lower mammals, the female's sexual behavior depends upon the secretory activity of the ovaries, but this dependence is less clear-cut in female primates, some of which accept males throughout their cycle (*2*). The role of ovarian hormones as a determining factor in nonsexual forms of behavioral interaction in primates has received little attention (*3, 4*).

To study this problem, mature, intact male and female rhesus monkeys (7 to 14 kg) were studied in glass-

fronted observation cages 42 by 36 by 33 inches deep for 60-minute periods at regular 3- and 4-day intervals by two observers. Tests were conducted in an isolated, quiet room behind a one-way vision screen under carefully standardized conditions. Females were housed singly, trained to enter a transfer box, and were introduced into the male's cage at the beginning and removed at the conclusion of each test period. Observations were made upon four females each tested with two males for a total of 12 menstrual cycles involving 130 hours of observation. Menstruation was recorded and vaginal smears were collected by aspiration after each test and stained by a modified Papanicolaou method. Despite a basic similarity, the patterns of behavior seen during tests were highly individual and quite characteristic for pairs. Periods of grooming by one animal of the other were interspersed with attempts by the male to mount the female, some of these being accepted by the female and resulting in intromission; a variable number of mounts and thrusts preceded ejaculation. The initiation of the behavioral sequence after a grooming period appeared to rest with the animal that was actively grooming, and this initiative passed, therefore, from one animal to the other as the grooming activity changed over between them. A system was devised for scoring individual components of male and female behavior at 30-second intervals giving their temporal sequence. These items included many details concerning copulatory and grooming behavior (for example, the initiation and occurrence of mounts, acceptances and refusals, thrusts and ejaculations, and sites and durations of grooming, as well as masturbatory and aggressive behavior). The present report is confined to the way in which the menstrual cycle influences grooming and mounting activity.

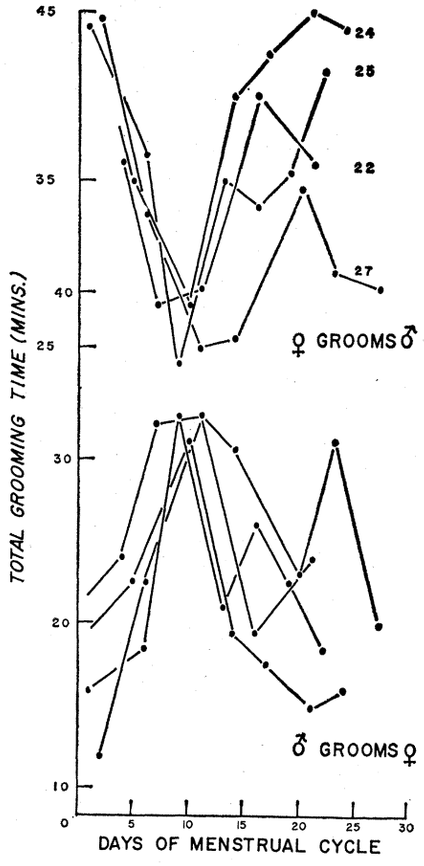

Fig. 1. Variation in grooming behavior with the menstrual cycle in three female monkeys. Illustrated are four representative cycles of the twelve showing this effect. Insert numbers indicate cycle lengths.

Figure 1 (top) shows that the times spent by the females in grooming a male in a series of 60-minute tests vary with the menstrual cycle such that the female's grooming time reaches its minimum at about mid-cycle. Figure 1 (bottom) shows that the time spent by the male in grooming the females varies reciprocally and reaches a maximum in the middle part of the female's cycle. Values for the grooming times (male and female) at mid-cycle vary by as much as 50 to 100 percent compared with those near menstruation. Figure 2 shows the mounting activity of the same male toward the same females during the same tests. The number of successful mounts reaches a maximum near mid-cycle and this maximum occurs slightly later in the cycle than the greatest changes in grooming activity. The impression obtained from correlating the behavioral data with that derived from the timing of menstruation (and also the appearance of vaginal smears) is that the peak in mounting activity occurs near the expected time of ovulation while the grooming changes precede this.

The crucial importance of studying individual pairs of animals was clearly revealed when the same females were tested on the same days of their cycles, under identical conditions, but with a second male, differing from the first in being very nervous and excitable. No rhythmic changes either in grooming or mounting were displayed with this male. All mounting and grooming cycles were totally abolished by bilateral ovariectomy.

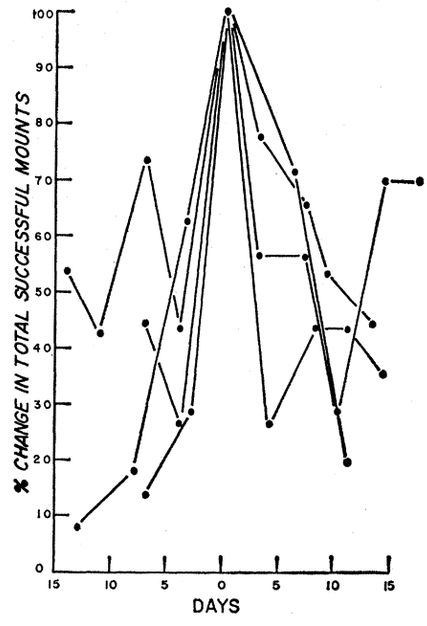

Fig. 2. Distribution of mounting activity during four cycles, calculated as a percentage of the maximum value recorded in each. The zero in the abscissa indicates the day in the cycle when maximum mounts occurred, cycles of different lengths being arranged about this day.

The evidence presented suggests that the amount of social interaction expressed in a primate by heterosexual grooming activity may depend upon the endocrine status of the female. It is perhaps remarkable that grooming behavior, which is of considerable general importance in the organization of the primate society, should appear to be influenced by endocrine mechanisms. In the human, behavior analogous to grooming is represented by a great range of socio-sexual interactions and the possible role of the gonadal hormones in determining these actions needs further investigation (*5*).

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