Nocturnal changes in serum melatonin during female puberty in rhesus monkeys: a longitudinal study

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ABSTRACT

Diurnal concentrations of serum melatonin were determined longitudinally in female rhesus monkeys throughout sexual maturation to ascertain how levels varied with advancing age and reproductive onset. Females were housed either in outdoor enclosures \( n = 8 \) exposed to ambient environmental conditions, or indoors \( n = 4 \) under a photoperiod of 12 h light:12 h darkness and fixed temperature of 20–23 °C. Animals were studied from immaturity (15 months) through first ovulation and were additionally compared with fully adult female rhesus monkeys \( n = 5 \) studied during the annual breeding season. The diurnal melatonin pattern was described for the developing females in the summer, autumn and winter in 3 successive years from samples collected at 10.00, 18.00, 22.00, 02.00, 06.00 and 10.00 h.

Nocturnal levels of melatonin declined significantly during development in both indoor- and outdoor-housed females with a progressive decrease up to 33 months of age. Daytime values were consistently low but exhibited a slight decline also with age. Nocturnal values in all months sampled fell significantly with greater decreases occurring at the earliest ages. Furthermore, superimposed upon this developmental change, animals housed outdoors responded to seasonal changes in photoperiod with diurnal increases in melatonin occurring after sunset. The females in the present study exhibited first ovulation at two distinct ages: 32–37 months ('early', \( n = 6 \)) and 41–45 months ('later', \( n = 5 \)). One female did not ovulate within the study period. Although nocturnal levels of serum melatonin were similar between the two groups up to 29 months of age, a post-hoc analysis revealed that concentrations were significantly lower by 34 months of age for the early group, a time coincident with first ovulation. Nocturnal levels of melatonin remained high, relative to the early group, in the later ovulating females until 43 months of age, coincident with first ovulation for these animals. The diurnal pattern of serum melatonin at first ovulation, regardless of chronological age, was similar to that observed during the ovulatory season for adult female rhesus monkeys.

These data suggest that nocturnal melatonin concentrations decline with advancing chronological age in prepubertal female rhesus monkeys. Furthermore, the timing of sexual maturation was inversely related to nocturnal melatonin. Whether this change in melatonin is causally related to reproductive onset or, rather, is a consequence of other factors regulating the occurrence of first ovulation remains to be determined. Furthermore, the observation that the melatonin rhythm in outdoor-housed females follows the prevailing photoperiod permits the hypothesis that this rhythm may mediate any photoperiodic effect on the seasonal occurrence of first ovulation characteristic of rhesus monkeys housed outdoors. Journal of Endocrinology (1989) 121, 553–562

INTRODUCTION

The signal which initiates the transition from juvenile to pubertal status is not known. Although changes in the diurnal secretion of melatonin have been proposed as such a signal (Wurtman & Waldauser, 1986), different studies have produced widely varied data both for the specific role of melatonin in the initiation of puberty and for the pattern of developmental changes. Examination of overnight excretion (Penny, 1982) or daytime serum samples (Penny, 1985) revealed a significant rise in melatonin or its metabolite with advancing chronological age in children. In contrast, other studies with children report no change in either daily rhythms of plasma melatonin (Ehrenkranz, Tamarkin, Comite et al. 1982; Sizonenko, Lang & Aubert, 1982) or total 24-h excretion (Tetuso, Poth & Markay, 1982). Boys with
delayed puberty have higher nocturnal melatonin levels than age-matched normal children, although these individuals subsequently show the initial signs of puberty without an appreciable change in melatonin (Cohen, Hay, Annesley et al. 1982). Nevertheless, melatonin levels at night are reduced at later stages of puberty (Cohen et al. 1982). However, daytime melatonin values are significantly higher at Tanner stage 1 in boys but not girls (Silman, Leone, Hooper & Preece, 1979). Furthermore, infants have significantly higher levels of nocturnal melatonin which progressively fall from Tanner stage 1 to 5 in both boys and girls (Attanasio, Borrelli & Gupta, 1985); however, other analyses suggest that the decrease is related to advancing age and not necessarily to reproductive development (Waldhauser, Weizsenbacher, Tatzer et al. 1988). It is obvious that no consistent pattern of changes in melatonin secretion has emerged from these cross-sectional studies of children.

Studies of other animals have also provided equivocal data. Nocturnal melatonin levels are significantly reduced in older compared with younger, sexually mature Syrian hamsters (Reiter, Richardson, Johnson et al. 1980), suggesting that the changes may be related to ageing itself rather than reproductive development. Although diurnal melatonin rhythms are critical for the onset of ovulatory cycles in lambs (Yellon & Foster, 1986), the effect is likely to be due to the photoperiodic regulation of puberty in this seasonal breeder rather than to a maturational event independent of photoperiod. Although nocturnal infusions of melatonin into pinealectomized lambs produced levels which exceeded endogenous levels in age-matched controls housed under identical conditions, ages at first ovulation were indistinguishable between groups (Yellon & Foster, 1986). This observation suggests that the absolute magnitude of nocturnal melatonin may be unrelated to the regulation of puberty.

The present study examined longitudinal changes in diurnal patterns of circulating melatonin in female rhesus monkeys to determine how levels were related to age and maturational events of menarche and first ovulation. Furthermore, since first ovulation in rhesus monkeys housed in an outdoor environment is restricted to the autumn and winter months (Wilson, Gordon & Collins, 1986), animals housed outdoors exposed to natural conditions were compared with females housed indoors under fixed environmental conditions.

MATERIALS AND METHODS

Subjects studied longitudinally were 12 female rhesus monkeys (Macaca mulatta) subdivided into outdoor- and indoor-housed groups as shown in Table 1. The outdoor-housed animals were obtained from the outdoor breeding colony at the Yerkes Center (monkey nos: Vc, Ed, Wd, Re) in which the middle of the birth season occurs in early May (Walker, Gordon & Wilson, 1982), an indoor timed-breeding programme at the California Primate Center (Tf, Uf), and from the outdoor breeding colony at the Caribbean Primate Center (Ag, Cg) in which the middle of the birth season typically occurs in February (Rawlins & Kessler, 1985). All indoor-housed animals were obtained from the outdoor breeding colony at Yerkes. Table 1 also lists the timing of menarche and first ovulation for these animals which have been described previously in detail (Wilson, Gordon, Rudman & Tanner, 1988; Wilson & Gordon, 1989). As can be seen, the birth dates for the outdoor-housed group ranged from autumn to spring, a span of 5-9 months, whereas the indoor-housed females were born exclusively in the spring. The outdoor-housed females were members of social groups containing multiple adult males, females and juveniles. These animals were maintained in outdoor enclosures (30 × 30 m) with attached indoor quarters from birth or 6 months of age (Tf and Uf only) as described previously (Walker et al. 1982). The indoor quarters were illuminated with artificial light only during the daytime so the animals in this group were exposed to the ambient photoperiod throughout the study. The indoor quarters provided for the inclement winter months. The indoor-housed females were transferred from the outdoor facility at 12 months of age and were maintained in a light-sealed building having a fixed photoperiod of 12 h light and 12 h darkness (12L:12D) and constant temperature range of 20–23 °C. The room was illuminated by cool, white fluorescent light providing 560 lux at the level of the cage. The indoor-housed females were housed together in cages (2 × 2 × 1.5 m) with three animals per cage. The room in which these females were housed contained other sexually mature and immature rhesus monkeys of both sexes. In addition to these immature females, data from sexually mature, adult female rhesus monkeys (n = 5; > 10 years old) housed under conditions identical to the outdoor-housed group were also obtained. All animals had continuous access to water and monkey chow, with fresh fruit provided once daily.

Subjects were studied from July 1985 to October 1987, encompassing the age range of 15–48 months for individual animals and the occurrence of menarche and first ovulation. Blood samples were collected once weekly until 24 months of age and twice weekly thereafter. These samples were collected 4–5 h after sunrise or 'lights on'. Diurnal patterns of melatonin were described from blood samples collected at 4- to 5-month intervals throughout matura-
TABLE 1. Birthdates and age at menarche and first ovulation of female rhesus monkeys

<table>
<thead>
<tr>
<th>Group</th>
<th>Subject</th>
<th>Birthdate</th>
<th>Menarche</th>
<th>First ovulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outdoor-housed</td>
<td>Vc</td>
<td>19 February</td>
<td>11 Nov</td>
<td>25 October</td>
</tr>
<tr>
<td></td>
<td>Fd</td>
<td>20 March</td>
<td>7 Nov</td>
<td>13 November</td>
</tr>
<tr>
<td></td>
<td>Ud</td>
<td>5 April</td>
<td>6 Dec</td>
<td>6 November</td>
</tr>
<tr>
<td></td>
<td>Re</td>
<td>19 April</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tf</td>
<td>24 October</td>
<td>13 Jun</td>
<td>21 November</td>
</tr>
<tr>
<td></td>
<td>Ud</td>
<td>26 October</td>
<td>1 July</td>
<td>19 November</td>
</tr>
<tr>
<td></td>
<td>Ag</td>
<td>23 January</td>
<td>2 Sept</td>
<td>6 December</td>
</tr>
<tr>
<td></td>
<td>Cg</td>
<td>5 February</td>
<td>21 Oct</td>
<td>2 November</td>
</tr>
<tr>
<td>Indoor-housed</td>
<td>Gd</td>
<td>20 March</td>
<td>18 Sept</td>
<td>8 September</td>
</tr>
<tr>
<td></td>
<td>n860</td>
<td>21 March</td>
<td>12 Jun</td>
<td>3 December</td>
</tr>
<tr>
<td></td>
<td>n862</td>
<td>22 March</td>
<td>28 April</td>
<td>24 November</td>
</tr>
<tr>
<td></td>
<td>n891</td>
<td>27 April</td>
<td>16 June</td>
<td>1 January</td>
</tr>
</tbody>
</table>

TABLE 2. Diurnal sampling periods and corresponding mean (± S.E.M.) ages for both indoor- and outdoor-housed female rhesus monkeys. L:D refers to the hours of light and darkness respectively at each sampling point and 'sunset' is expressed in clock time

<table>
<thead>
<tr>
<th>Date</th>
<th>L:D</th>
<th>Sunset (h)</th>
<th>Outdoor</th>
<th>Indoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 1985</td>
<td>13:6:10:4</td>
<td>19.51</td>
<td>17.8 (±0.8)</td>
<td>15.8 (±0.3)</td>
</tr>
<tr>
<td>October 1985</td>
<td>10:6:13:4</td>
<td>17.26</td>
<td>20.8 (±0.8)</td>
<td>18.8 (±0.3)</td>
</tr>
<tr>
<td>February 1986</td>
<td>11:4:12:6</td>
<td>17.56</td>
<td>24.9 (±0.8)</td>
<td>22.9 (±0.3)</td>
</tr>
<tr>
<td>July 1986</td>
<td>13:6:10:4</td>
<td>19.51</td>
<td>30.0 (±0.8)</td>
<td>28.0 (±0.3)</td>
</tr>
<tr>
<td>December 1986</td>
<td>10:0:14:0</td>
<td>17.51</td>
<td>34.2 (±0.8)</td>
<td>32.2 (±0.3)</td>
</tr>
<tr>
<td>February 1987</td>
<td>11:4:12:6</td>
<td>17.56</td>
<td>36.9 (±0.8)</td>
<td>34.9 (±0.3)</td>
</tr>
<tr>
<td>July 1987</td>
<td>13:6:10:4</td>
<td>19.51</td>
<td>41.5 (±0.8)</td>
<td>39.5 (±0.8)</td>
</tr>
<tr>
<td>October 1987</td>
<td>10:6:13:4</td>
<td>17.26</td>
<td>44.8 (±0.8)</td>
<td>42.8 (±0.3)</td>
</tr>
</tbody>
</table>

Serum progesterone concentrations were determined by radioimmunoassay (RIA) with commercially prepared reagents (Diagnostic Products Corporation; Los Angeles, CA, U.S.A.). The assay had a sensitivity (80% B/B₀) of 0.954 nmol/l. Inter- and intra-assay coefficients of variation averaged 5.4 and 2.6% respectively. Serum melatonin levels were determined by the double-antibody RIA initially described by Rollag & Niswender (1976) and modified for analysis of melatonin in rhesus serum by Reppert, Perlow, Tamarkin & Klein (1979). Samples (200 µl) were assayed in duplicate following extraction with 2 ml chloroform. The extract was washed with NaOH (0.1 mol/l) and deionized water. One ml of the chloroform extract was then dried under N₂ and resuspended in 0.5 ml of the assay buffer (0.01 mol phosphate-buffered saline/1 with 0.1% (w/v) gel, pH 7.0), placed in an ice bath, and extracted with 3 ml petroleum ether. Following aspiration of the ether layer, the extracted buffer solution was assayed. The
extraction efficiency was 76.5 ± 3.0% \((n = 6\) assays). A final antibody dilution of 1:256,000 was used. The sensitivity of the assay \((80\% \text{ B/B}_0\) was 8.61 fmol/tube. Intra- and interassay coefficients of variation averaged 6.5 and 18.9% at 50% \(\text{B}/\text{B}_0\) respectively. Analyses of melatonin added \((0-0.21\) pmol/tube) to pooled rhesus monkey serum yielded a correlation \((\text{added in comparison with observed})\) of 0.97, a slope of 0.80, and a Y-intercept, reflecting a concentration of melatonin in the serum pool, of 0.09 pmol/l. Serial dilutions \((50-200\) µl) of pooled rhesus serum yielded an inhibition curve with a slope, based on log-log analyses of -0.97, similar to the slope of -1.01 obtained for the inhibition curve using purified melatonin.

Grouped data were expressed as means ± S.E.M. Comparisons between groups throughout development were made with analysis of variance for repeated measures. Specific comparisons were made with the Scheffé post-hoc test. Linear relationships among variables were evaluated with Pearson product moment correlations. Comparisons between indoor- and outdoor-housed females addressed the effects of housing on developmental changes. Since the range in ages of females in the outdoor-housed group at each sampling point was 5-9 months, comparisons among outdoor-housed females at specific sampling periods were made to evaluate the effects of chronological age. Given the bimodal distribution of the age at first ovulation \((\text{Table 1); }\sim 34\) and \(\sim 43\) months), post-hoc comparisons were made between those early and late ovulating females. For analytical purposes, daytime values were considered as the mean of samples collected at 10.00 h and nocturnal values as the mean of samples collected at 22.00, 02.00 and 06.00 h. Values of \(P < 0.05\) were considered significant.

**RESULTS**

Nocturnal levels of serum melatonin fell significantly throughout puberty as a function of both advancing chronological age and degree of sexual maturation. Illustrated in Fig. 1 are diurnal patterns of serum melatonin for both indoor- and outdoor-housed groups at five ages. Analysis of melatonin concentrations for indoor-housed females, which were housed in a fixed photoperiod throughout, revealed that a significant nocturnal decline occurred with advancing age \((F(2,14) = 74.22; \ P < 0.05)\) in two stages from 23 to 28 months and 28 to 33 months. A slight but insignificant decline for daytime samples also occurred \((F(7,21) < 1; \ P > 0.05)\). A similar pattern was observed for outdoor-housed females \((\text{Figs 1b and 2b). A comparison of July data at three successive ages revealed a significant decline in nocturnal levels \((F(2,14) = 126.10; \ P < 0.05)\) and a slight decline in daytime values \((F(2,14) = 4.17; \ P < 0.05)\). Further analyses revealed significant declines in nocturnal but not daytime samples for autumn \((\text{nocturnal } F(2,14) = 66.23; \ P < 0.05; \text{daytime } F(2,13) < 1; \ P > 0.05)\) and February samples \((\text{nocturnal } F(1,7) = 78.78; \ P < 0.05; \text{daytime } F(1,7) < 1; \ P > 0.05)\). When the absolute magnitude of nocturnal melatonin was related to age during each sampling period for outdoor-housed females, significant negative correlations were found at the three youngest ages and again at a later age \((\text{Fig 2b). In addition to chronological age, the degree of sexual maturation was also related to nocturnal melatonin levels. As indicated in Table 1, six of the 12 females exhibited first ovulation between 32 and 36 months of age whereas five of the remaining six had first ovulation between 42 and 45 months. One female did not ovulate during the study. Figure 3 illustrates the profile of serum progesterone concentrations for these two groups of females at first ovulation. A post-hoc analysis of nocturnal melatonin levels comparing the females which ovulated at an earlier age \((\text{‘early’}; \ 32-37\) months) to those that ovulated at the later age \((\text{‘later’}; \ 41-45\) months) \((\text{Fig. 4), revealed that although no differences were detected at 29-3 months of age, concentrations were significantly lower for the ‘early’ group by 33-7 months or the age at first ovulation for this group \((F(4,40) = 4.80; \ P < 0.05)\). Nocturnal melatonin levels were significantly higher in the later ovulating group from 33-7 to 40-8 months of age \((F(1,10) = 5.72; \ P < 0.05)\) but at 44-1 months, the time of first ovulation for this ‘late’ group, serum concentrations had declined and were again indistinguishable from the early group. The outdoor-housed female which did not exhibit menarche or first ovulation during the study had consistently higher mean levels of nocturnal melatonin concentrations \((770 ± 43\ pmol/l)\) than the other outdoor-housed females \((456 ± 34\ pmol/l, \ n = 7; \text{eight sampling periods). A comparison of the diurnal melatonin pattern between the developing females and fully adult females revealed that nocturnal concentrations at first ovulation were similar to those observed for the adult females during the ovolatory season \((\text{Fig. 5; } t(14) = 1.09; \ P > 0.05)\). In contrast, concentrations of serum melatonin were higher at 24 months of age in the developing females compared with the adult females \((t(14) = 6.81; \ P < 0.05)\). In order to assess whether the outdoor-housed females were responding to the prevailing photoperiod, the values observed at 18.00 h were calculated as a percentage of the values obtained at 10.00 h for July and February. The value at 18.00 h was used as it occurred before sunset in July and after sunset in February \((\text{Table 2). The values were normalized in}}

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FIGURE 1. Mean ± S.E.M. concentrations of serum melatonin at five successive ages for (a) indoor-housed \((n = 4)\) and (b) outdoor-housed \((n = 8)\) female rhesus monkeys. Diurnal melatonin patterns for the outdoor-housed females are illustrated for February \((11\text{.}4\text{L}:12\text{.}6\text{D})\) and July \((13\text{.}6\text{L}:10\text{.}4\text{D})\). The solid bar below each graph indicates period of darkness.
this fashion since the absolute level of melatonin was decreasing with age. Furthermore, the comparisons were carried out for these months as the females had been exposed to long days for 4 months in July and short days for 5 months in February. Nocturnal melatonin levels at 18.00 h were, on average, 17.2±8.7% higher than values obtained at 10.00 h in July, but were 76.8±17.3% higher than those at 10.00 h during the short days of February. This increase in the 18.00 h levels during February was significantly greater than that observed in July (t(7)=2.75; P<0.05), suggesting that melatonin secretion was timed to the prevailing photoperiod.

DISCUSSION

The present study, a longitudinal assessment of female rhesus monkeys from immaturity through first ovulation, demonstrated that there was a significant decline in nocturnal melatonin levels in serum in association with this development sequence. Furthermore, this pattern was observed regardless of whether females were housed in a controlled photoperiod or outdoors exposed to normal seasonal light fluctuations. These data are consistent with some cross-sectional studies in children (Attanasio et al. 1985; Waldhauser et al. 1988) but are in contrast to the results of other studies.
which found either increases (Penny, 1982) or no change (Ehrenkranz et al. 1982; Sizonenko et al. 1982) in melatonin with advancing age.

Although a decline in nocturnal melatonin secretion occurred with advancing age in all subjects, the rate of the decrease was also related to the timing of sexual maturation. A subset of females which, on the average, had first ovulation some 10 months earlier than similarly aged animals, also had significantly lower serum levels of nocturnal melatonin at approximately 34 months of age, the time of their first ovulation, compared with the later ovulating females. These group differences were no longer present when the remaining females had first ovulation 10 months later.

Cross-sectional studies of children have provided disparate data regarding the amplitude of nocturnal melatonin levels and the timing of puberty (Cohen et al. 1982; Ehrenkranz et al. 1982; Attanasio et al. 1985). The monkeys in the present study should not be considered as having either precocious or delayed puberty in the same sense as children. The age range and bimodal distribution of first ovulation for these monkeys is normal for the colony under study (Wilson, Gordon, Blank & Collins, 1984; Wilson et al. 1986). As in normal children, some female monkeys simply mature reproductively earlier than others. In this regard, it is interesting to note that previous assessments of melatonin rhythms both in adult female monkeys (Brainard, Asch & Reiter, 1981) and women (Berga, Mortola & Yen, 1988) report higher nocturnal levels for anovulatory females compared with females exhibiting normal ovulatory cycles. Furthermore, supporting previous data on rhesus monkeys (Jenkin, Mitchell, Hopkins et al. 1980) the diurnal pattern of melatonin exhibited by females at the time of first ovulation, whether housed indoors under 12L:12D or outdoors in a 11L:13D photoperiod, was similar to that observed for adult females during the autumn ovulatory season.

The correlation between chronological age, degree of sexual maturation and nocturnal melatonin secretion need not imply a role for melatonin in the initiation and maintenance of puberty. Pinealectomy of gonadectomized infants did not influence the
A decrease in gonadotrophin levels following neonatal hypersecretion, suggesting that the pineal was not involved in the initiation of non-gonadal restraint of gonadotrophin secretion during the juvenile phase of development (Plant & Zorub, 1986). This study, though, was not continued past 35 weeks so it is not known whether the loss of non-gonadal restraint, characteristic of the initial stages of puberty, was altered in these animals. Furthermore, administration of melatonin to pinealectomized lambs produced significantly higher levels than observed in control animals, but did not adversely affect the timing of first ovulation (Yellon & Foster, 1986). Although the pattern of melatonin may mediate the oestradiol negative feedback effects on gonadotrophin secretion in lambs (Yellon & Foster, 1986), this is likely to be related to the photoperiodic influences on puberty in lambs and not to effects independent of photoperiod. In contrast, administration of melatonin to prepubertal rats delays sexual maturation with decreases observed in peripheral concentrations of both luteinizing hormone (LH) and follicle-stimulating hormone and pituitary receptors for gonadotrophin-releasing hormone (GnRH; Lang, Aubert, Conne et al. 1983) as well as GnRH secretion itself (Rivest, Lang, Aubert & Sizoneko, 1985). These data suggest that melatonin may have a direct central effect on the regulation of GnRH secretion. In addition, other reports in rats (Martin, McKeel & Sattler, 1982) and dogs (Yamashita, Mieno, Shimizu & Yamashito, 1978) indicate that melatonin inhibits the response of the pituitary to stimulation from LH-releasing hormone. Melatonin also has been isolated in human follicular fluid, indicating a possible direct role on ovarian steroidogenesis (Brzezinski, Seibel, Lynch et al. 1987). Analyses of ovulatory activity in women living under extreme fluctuations in photoperiod (Finland), indicate that nocturnal melatonin levels are increased and follicular phase oestradiol levels decreased during the winter season (4L:20D; Kauppila, Kivelä, Pakarinen & Vakkuri, 1987). Also, acute treatment with oestradiol to women can lower daytime melatonin levels (Penny & Goebelsmann, 1984) whereas plasma melatonin concentrations are increased following ovariectomy in sheep (Arendt, Laud, Symons & Pryde, 1983). In contrast, progestins given to women increased serum concentrations of melatonin (Webley & Leidenberger, 1986). Although these data suggest that ovarian steroids may modulate melatonin secretion rather than melatonin secretion affecting the reproductive axis, it is difficult to hypothesize how decreases in nocturnal melatonin which occur before menarche and any appreciable change in serum oestradiol concentrations could be due to an ovarian steroid influence. Assessment throughout development in agonal females would address the importance of a non-gonadal, central nervous system influence on melatonin secretion. Furthermore, studies are needed in primates to determine the effects of nocturnal melatonin levels on the initiation and

![Graph showing diurnal melatonin levels](image-url)
maintenance of gonadotrophin secretion and ovarian responsivity to gonadotrophins, in order to determine whether the observed decreases with age are a prerequisite to, consequence of, or unrelated to the timing of reproductive maturation.

In addition to these maturation changes in nocturnal melatonin secretion, animals did respond to the prevailing photoperiod as melatonin concentrations were higher in samples collected at 18.00 h relative to 10.00 h samples during short days compared to long days. Given the age-dependent fall in serum melatonin levels, it was not possible to assess seasonal changes in melatonin secretion during maturation. Since first ovulation for rhesus monkeys housed outdoors is restricted to the short, cooler days of autumn and winter (Wilson et al., 1984, 1986), regardless of season of birth (Wilson & Gordon, 1989), it seems obvious that some environmental cue is playing a critical role in regulating the timing of this event. If the seasonal restriction of first ovulation in rhesus monkeys is due to a photoperiodic influence, one must entertain the hypothesis that, as in the lamb (Yellon & Foster, 1986), photoperiodic-induced changes in the rhythm of melatonin secretion may be the cue which sets the timing for these events. This would suggest, then, that for the seasonal breeding rhesus monkey, the diurnal pattern of melatonin secretion may serve two functions. First, the decreasing amplitude of nocturnal melatonin secretion may provide a signal for the initiation of puberty independent of season and secondly, once maturation has been initiated, photoperiodically driven changes in the daily rhythm of melatonin secretion restricts the occurrence of first ovulation to the autumn months.

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