ment were administered to each infant at 12 months of age by a psychometrician who knew nothing about the early observations of the infants. In the group 1 infants, neither the amount of active or quiet sleep nor the total REM at any age was related to the Bayley scores. However, there was a significant negative correlation between REM storms at 6 months and Bayley scores at 1 year ($r = -.65$, $P < .01$). The REM storm rate was relatively low at this age, and in fact ten of the subjects had scores of zero. Therefore, the REM storm data were also analyzed with a biserial r test, yielding a value of $-.59$ ($P < .05$).

For group 2 infants the correlation between REM storms at 6 months and Bayley scores at 1 year was $-.88$ ($P < .01$). This finding replicated that obtained for group 1 and was the only significant finding consistent across the two groups. Of the 14 subjects in group 2, five had scores of zero for REM storms at 6 months. Therefore, the relation was further examined by dividing the ranked scores for the 14 subjects into three groups based on the rate of REM storms at 6 months: no REM storms ($N = 5$), moderate rates ($N = 5$), and high rates ($N = 4$). The mean Bayley scores for these groups were 112.6, 104.8, and 88, respectively. An analysis of variance revealed a significant linear trend across means [$F(1, 11) = 5.2$, $P < .05$]. Figure 1 presents the rate of REM storms over the 12 months for the two groups combined.

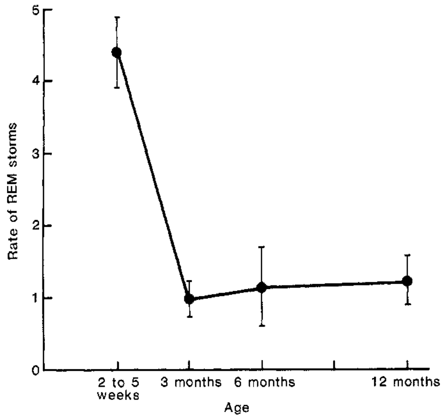

Fig. 1. Rate of REM storms during active sleep in the two groups of subjects.

Several sources of potential bias in the findings were explored. Although sex differences have been found in some sleep measures (*5*), no such differences were found for either the 6-month REM storm rates or the Bayley scores in either group of infants. There were no differences in group 2 between the first- and second-born infants in either REM storm rates at 6 months or Bayley scores. Six of the infants in group 2 had siblings in group 1 and one had a sibling in group 2; there were no significant correlations in REM or Bayley scores between these first- and second-born sibling pairs. Thus, there is no evidence that our results were influenced by either of these factors. The findings, from two independent samples, demonstrate that the rate of REM storms at 6 months is predictive of mental development at 1 year (*6*).

We could find no other report describing a study in which the amplitude of REM in infants or children was assessed. In fact, REM intensity is generally defined strictly on the basis of frequency (*7*); accordingly, previous studies have investigated both the overall frequency and the distribution or clustering of REM during periods of active sleep. These temporal characteristics have been found to discriminate between normal and abnormal children (*8*), but they have not been reported to discriminate differences among normal individuals. Similarly, in the present study temporal characteristics alone (REM frequency) did not have predictive validity. Only the REM storm measure, which takes into account both frequency and amplitude, predicted developmental scores. This finding indicates that REM amplitude, as well as clustering and overall frequency, is an important expression of the phasic CNS activity that occurs during the sleep of infants.

As a sleep phenomenon in infancy, REM storms may be viewed as resulting from immature inhibitory feedback controls in the CNS pathways responsible for sleep organization and sleep-related eye movements. Eye movements are triggered in the pontine vestibular nuclei, and specific neural networks responsible for burst patterns (as opposed to single eye movements) have been described (*9*). Bursting is facilitated by input from the occipital cortex and is inhibited by input from the frontal cortex—influences that are further mediated in the midbrain (*10*). Thus, control over burst patterning should become more refined as encephalization progresses, leading to the observed decrease in the incidence of REM storms with age. Failure of these control systems to develop may reflect a more general disturbance of CNS organization. The findings of this study suggest that the persistence of REM storms at 6 months of age is an expression of inadequacy in the developing CNS.

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4. A 10-second epoch in which eye movements with moderate excursions occurred sporadically or continuously for less than 5 seconds would be judged as light REM. An epoch in which moderate eye excursions occurred for about 5 to 8 seconds, or one in which wide excursions occurred but for less than 5 seconds, would be judged as moderate REM. An epoch in which moderate eye movements occurred continuously throughout the epoch, or one in which there was intensive eye movement, would be judged as an REM storm. Interobserver reliability on observation of REM storms, based on correlations over 32 observations, was .98.
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6. Although the subjects in this study were all normal full-term infants, one infant subsequently experienced serious developmental difficulties. The data for this infant highlight the potential significance of REM storms. There were no apparent problems until the infant was about 6 months of age, at which time an assessment indicated some delay in his mental development. Shortly thereafter he was diagnosed as suffering from infantile seizures with electroencephalographic hypsarrhythmia. The sleep observation at 6 months showed that the distribution of sleep states and total REM levels were within the normal range. However, the rate of REM storms was 3 standard deviations above the mean for the group. At 12 months the infant's developmental quotient was 50, and he has continued to show severe developmental delay. The group correlation remains significant when this subject is excluded from the analysis.
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Foot-Length Asymmetry, Sex, and Handedness

Levy and Levy (*1*) found that right-handed males had longer right feet and right-handed females had longer left feet, while the reverse relationship occurred in non–right-handed individuals. We have analyzed data obtained and classified primarily for other purposes to see if the data support Levy and Levy's conclusion.

Our sample consisted of 146 undergraduates, 56 percent of whom were male. Handedness was categorized into two classes, right and left, on the basis of writing hand. The classification of handedness is controversial, but McManus (*2*) has shown that a person's handedness is best assessed by means of the hand used for writing, provided that no forced change of writing hand had occurred. We therefore excluded five persons who experienced such a history from the analysis. The distribution of handedness by sex did not differ between our study and that of Levy and Levy.

Foot length was measured by standard anthropometric technique (*3*). All measurements were taken by one of us (A.M.M.) without prior knowledge of the subjects' handedness.

For the total sample, length of the left foot (L) exceeded that of the right foot (R) measured by both absolute length [L = 257.76 mm ± 1.48, R = 256.99 mm ± 1.42; paired t (280) = 2.62, $P <$ .01] and standardized length of 100(L − R)/(L + R) (*4*) (mean, 0.140 ± 0.057; t = 2.46, $P <$ .02). This finding that L > R is in agreement with previously published results of either paired comparisons of foot length of adults and fetuses (*5–8*) or measures of osteological asymmetrics (*9–11*), but is in the opposite direction to Levy and Levy's findings for males (*12*).

Analysis of variance of 100(L − R)/(L + R) by handedness and sex showed no evidence of a main effect due to handedness [F(1, 137) = 0.112, P = .738]. In agreement with the work of Garn *et al.* (*13*), there was no sex-handedness interaction [F(1, 137) = 1.174, P = .280]. The main effect of sex was significant [F(1, 137) = 3.934, P = .049]; previous studies have found a similar trend (*6, 7*).

The mean foot-length differences for each study by sex and handedness are shown in Table 1. Because of measurement differences between studies, it is difficult to compare our results with Levy and Levy's directly. However, sign differences indicate that our results are in the opposite direction.

Our failure to replicate Levy and Levy's findings of a sex-handedness interaction could be due to many factors, but at least sample sizes and distributions of right- and non–right-handers were similar in the two studies. The major difference was one of methodology. Our results were obtained from a recognized anthropometric and quantitative approach, whereas Levy and Levy used a rating method and a less quantitative analysis.

Table 1. Mean foot-length asymmetry (L − R) by sex and handedness. The number of subjects in each cell is shown in parentheses.

Sex	Right-handed		Non–right-handed	
	Cambridge	Levy and Levy	Cambridge	Levy and Levy
Male	+0.26 (62)	−1.2 (40)	+0.20 (17)	+1.1 (12)
Female	−0.02 (56)	+0.9 (87)	+0.29 (6)	−1.4 (11)

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Levy and Levy (*1*) reported foot-length asymmetries that related significantly to sex and handedness. We have collected contradictory data.

We measured the lengths of the right and left feet of 365 undergraduate university students; all were volunteers. Handedness was assessed by recording which hand was preferred for writing, throwing, hammering a nail, drawing, and brushing the teeth. [These are items categorized by Bryden (*2*) under factor 1, common activities.] Subjects who performed all these activities with the right hand were classified as right-handers, while subjects who did not were classified as non-right-handers. Foot preferences were assessed by recording which foot was preferred for kicking a ball.

Levy and Levy used foot sizes to measure foot length; we recorded the exact length. For measurement, each subject was required to sit and plant each foot firmly on a sheet of paper. A mark was made where a vertical stop, against which the heel rested slightly, touched the paper. Another mark was made where a vertical stop, against which the most protruding part of the anterior end of the foot rested, touched the paper. Lines were drawn through these marks at right angles to the length of the foot, and the distance between these lines was measured to the nearest millimeter (Table 1). The differences between the feet were often close to or within the error of measurement (± 1.5 mm). There were no significant differences between the left and the right foot for any sex or handedness group.

There remains the possibility that the measure used in this study was inadequate. However, anthroprometric data support our results (compare values with those in Table 1). A study of right-foot length of 565 adult Canadian males (*3*) gives an average length of 26.46 cm. Another study of the left-foot length of 2000 English adult males (*4*) gives an average of 26.49 cm. Finally, a study of right-foot length in 137 adult Canadian females (*5*) gives an average of 23.77 cm.

Unfortunately, none of these studies provide values for both the right and left

Table 1. Average length of left (L) and right (R) feet and direction of asymmetry.

Handedness	N	Foot length (cm)		Direction of asymmetry		
		L	R	L > R	L = R	R > L
		Females				
Right-handed	208	24.08	24.06	96	18	94
Non-right-handed	27	23.82	23.89	11	3	13
		Males				
Right-handed	114	26.47	26.51	44	15	55
Non-right-handed	16	26.39	26.36	9	1	6

feet. Nevertheless, it is clear that the values reported in these anthroprometric studies correspond closely to our values. This leads us to question a systematic relation between left- and right-foot differences, sex, and handedness.

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Levy and Levy (*1*) reported that sex and handedness are related to pedal asymmetry, "right-handed males having larger right feet and right-handed females having larger left feet. . . ." The reverse was seen in those who were not right-handed. This finding, if true, would confound traditional neurological tests of trophic limb changes, especially in the contralateral lower extremities, which are known to be altered after infantile brain insult (*2*).

There are, however, some methodological concerns regarding the rating scale, selection of statistical tests, sample composition, and measurement procedures (*3*) which cause us to question the validity of their findings. A replication study was performed to correct for these errors.

A sample of 105 individuals, 58 males (24 right-handed and 34 left-handed) and 47 females (25 right-handed and 22 left-handed) were selected. The age range was 17 to 47 (mean age, 19.56 years). A second sample of 20 subjects (9 male, 11 female) were selected to assess day-to-day variability of the measures. The measuremnts of the subjects' feet were obtained by tracing the outline of each foot onto a large data-coding sheet. Information regarding age, sex, hand preference, and family history of sinistrality was collected. The raw data were analyzed with the chi-square statistic. The data were then transformed to replicate the Levy and Levy seven-point scale and were analyzed with the Kruskal-Wallis statistic. No differences were found in the direction of foot-size differences (asymmetry) of either males or females, dextrals or sinistrals, with or without a family history of sinistrality, for either foot length or width. In fact, the directional frequency of pedal asymmetry across subjects was notably absent (that is, no laterality effect). Contrary to the Levy and Levy findings, when a pedal asymmetry did occur, the number of individuals with longer left feet was virtually equivalent to the number with longer right feet, regardless of sex or hand preference. Moreover, the measurement of foot width revealed an equal distribution of pedal asymmetries (*4*).

Before discounting the Levy and Levy findings, the issue of measurement error was addressed. To explore between-subject variability, the observed means and standard deviations of foot length and width were compared with, and found to closely parallel, those previously reported when the Brannock Foot Measuring Device was used (*5*). Thus, there was little reason to suspect that tracing was any less accurate a method of assessing foot size. Statistical checks were made for within-subject variability of the measures, through the use of a pooled variance of repeated measures; day-to-day variability was also assessed with a repeated-measures analysis of variance design. No differences were observed with respect to foot length. A slight day-to-day variability was noted in the repeated-measures analysis of right-foot width (*6*). Widths increased over days. This result may merely reflect a statistical artifact or may suggest that foot width is more susceptible to environmental factors (temperature, type of shoe worn, and so forth). The average difference in foot length (*7*) closely paralleled that found in the Levy and Levy study (*8*). These findings reduce the likelihood that the lack of significant findings was a result of measurement error. Tracing thus seems to be a reliable and valid method of assessing foot size. Using it, we were unable to replicate any of the Levy and Levy results regarding the direction of pedal asymmetries within an adult sample.

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3. Levy and Levy devised a rating scale based largely on subjective measurements. They then used a t-test to analyze half their data, selecting this test over chi-square because of an insufficient number of non-right-handed subjects. Herein they violated two major statistical assumptions. Parametric tests require adequate sample size and interval data, both of which were absent in their data for sinistrals. Their sample was composed of both children and adults, without separate tests for age by sex effects. This procedure left ambiguous whether the sex differences in pedal asymmetries were an artifact of age, especially in view of their incidental report of larger asymmetries in children.
4. For males, 28 had wider left feet, 23 had wider right feet, and 12 showed no difference. For females, 19 had wider right feet, 18 had wider left feet, and 10 showed no difference.
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6. $F(3) = 3.16, P < .05$.
7. The average difference was 3.5 mm ± 0.35 for males and ± 0.24 for females.
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In contrast to our findings (*1*) that right-handed females had larger left feet and right-handed males, larger right feet, with the reverse obtaining for non–right-handed individuals, Mascie-Taylor *et al.*, using standard anthropometric techniques, found that all groups except right-handed females had larger left feet. As they note, their data went in the opposite direction from ours and conform with a number of reports that the left foot is larger than the right. Peters *et al.*, measuring foot length from heel to the end of the longest toe with subjects seated and the foot placed flat, found no asymmetries of foot length for any group, disconfirming our observations as well as those of Mascie-Taylor *et al.* Although the distributions were nonsignificant, they found a preponderance of right-handed males with larger right feet and more non–right-handed males with larger left feet, the data for right-handers tending in the same direction as ours and in the opposite direction from that of Mascie-Taylor *et al.* Finally, Yanowitz *et al.* assessed foot size by tracing around the foot and compared asymmetries between groups for both length and width. No asymmetries appeared for any group, confirming Peters *et al.*

The different measurement techniques may have yielded assessments of different aspects of foot size. We measured the distance from the heel to the end of the big toe, rather than to the end of the longest toe. Of possibly more significance, in the Mascie-Taylor *et al.* measurements, no pressure was put on the feet, and it can be assumed that static anatomic dimensions were being indexed. Peters *et al.* had subjects sitting, and a slight degree of pressure may have been placed on the feet. Yanowitz *et al.* do not specify whether subjects were lying down, sitting, or standing.

In our study, except for the few subjects with extreme asymmetries between feet, detected when they were seated, foot size was measured with subjects standing. With full body weight placed on the feet, there could be differential flattening and lengthening of the two feet, either due to varying flexibilities of the feet or to a biased posture that placed more weight on one foot than the other. Although we attempted to have subjects stand with equal weight on the two feet, this could only have been assured by direct measurement of muscle tension in the two legs. It is conceivable, in other words, that our measurements, and to some extent those of Peters *et al.*, were picking up dynamic aspects of foot flexibility, postural biases, or both. If so, our observations would imply that among right-handers, the left foot of women and the right foot of men flattens and lengthens more when supporting body weight, either because of biased posture or because of asymmetries of reaction to weight.

Only 16 of our 150 subjects were assessed in the seated position, and 12 of these were right-handed females, of whom 11 had larger left feet. This subgroup of 12, however, had asymmetries of a half shoe size or more and, thus, are not representative of the population.

Clearly, more research will be needed to resolve the discrepancies among studies and to gain an understanding of the relationships between static anatomical dimensions and dynamic dimensions of foot asymmetry reflecting either different reactions of the two feet to weight or postural biases in subjects. Experienced shoe salesmen generally test fit of shoes with customers standing, and it would be of interest to determine whether standard anthropometric measurements of the feet conform or not to the subjective impressions of shoe salesmen and their customers of relative tightness of shoes on the left and right feet. Peters *et al.* report that differences in foot length for individual subjects were often close to or less than 1.5 mm, a difference so small that it seems a priori unlikely that a person would notice any difference in tightness of fit of shoes, yet in the experience of J.M.L., a substantial number of customers spontaneously report that although a shoe is comfortable on one foot, it is too tight on the other. Perhaps the standing and walking feet are different organs, having different asymmetries, from the static lumps of tissue attached to the ends of the legs.

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27 April 1981

Identification of Living and Fossil Bivalve Larvae

In an earlier report (*1*), we documented the existence of exceptionally well-preserved larval bivalve shells in Late Cretaceous (Maestrichtian) sediments. Using criteria established by various workers (*2*, *3*) for the larvae of Recent bivalve species, we identified specimens to the familial level on the basis of gross shell morphology and hinge structures. Having conducted extensive studies on living bivalve larvae over the past 3 years, we would like to comment here on some of the identification criteria of earlier workers and qualify a few of the statements made in (*1*).

In his classic monograph, Rees (*2*) discussed the usefulness of larval hinge structures in identification studies for superfamilial separation. He recognized five major categories of larval hinges and found the hinge of every larva investigated to agree with one of 18 basic types. We used Rees' criteria to assign the Cretaceous specimen depicted in figure 1D of (*1*) to the family Mytilidae. According to Rees (*2*, p. 83), the lateral thickening of the mytilacean provinculum is "quite unlike anything to be found in the usual lateral hinge system." The micro- and ultrastructural details of the mytilid hinge have been described by several workers (*4*). Figure 1 depicts the hinge region of a larvae of *Arca noae*, the type species of the genus (family Arcidae), which has been cultured under laboratory conditions from positively identified adult organisms. The provinculum of this specimen is clearly different from the arcacean (*Glycymeris*) hinge depicted by Rees (*2*). Careful comparison of the specimen shown in Fig. 1 with that shown in figure 1D of (*1*) reveals a striking similarity. Detailed examination of gross shell morphology, hinge structures, and orientation of the ligament pit strongly suggests that the Cretaceous specimen we "unambiguously identified" (*1*, p. 439) as a mytilid belongs in the family Arcidae. This and other discrepant conclusions arising from observations we have made over the past few years on the larvae of numerous Recent bivalves largely reflect the lack of adequate data accumulated by workers in the field. Until larval hinge structures have been documented for a considerably larger number of species, considerable caution should be exercised in utilizing such structures for the identification of larval specimens from past and present marine environments.

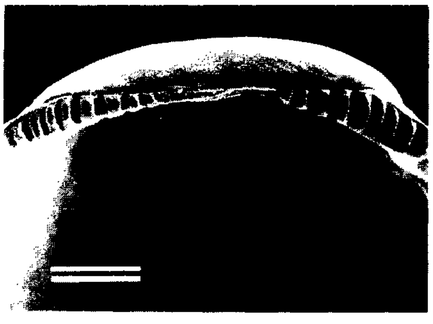

Fig. 1. Scanning electron micrograph of the hinge apparatus (provinculum) of a disarticulated shell valve of a larval *Arca noae* (family Arcidae). Compare with figure 1D of (*1*). Scale bar, 25 μm.

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