nine rays); however, the unisexual form has a very strong mode of eight rays.

We conclude that the unisexual *Menidia* is a separate, self-perpetuating species that reproduces without the genetic segregation and recombination expected of sexual populations (*18*). The abundance and consistent occurrence of the unisexual species at two locations over a geographic range of 390 km show that it is a persistent part of the fauna on the Gulf Coast of Texas.

Except for the fixed presence of unique alleles at PGM-B and IDH-A, the genetic structure of the all-female species of *Menidia* is readily explained as a product of past hybridization between *M. beryllina* and *M. peninsulae* (*15*). In another all-female fish, *Poecilia formosa*, Turner *et al.* (*7*) offered several alternative explanations for two "orphan alleles" that were absent in samples of both proposed parental species. Similar arguments apply to the unisexual *Menidia*. Orphan alleles aside, the unisexual *Menidia* species apparently arose by hybridization between two forms similar to *M. beryllina* and *M. peninsulae* (*15*).

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10. Nine Mile Point Pond is on Live Oak Point, near Fulton, San Patricio County, Texas; the pool on Galveston Island is at the north tip of the island, just outside Galveston's northern city limit, Galveston County, Texas.
11. In samples representative of relative abundance of the three forms of *Menidia*, the unisexual form represented 10 percent of 86 specimens in the one such sample from Galveston Island and 9 to 31 percent (mean, 19.4 percent) of 67 to 125 specimens in five such samples from Nine Mile Point Pond. In the past 3 years, the unisexual and both bisexual species were taken in all samples from Galveston Island (four samples) and Nine Mile Point Pond (eight samples).
12. No samples show statistically significant deviation from the expected 1:1 sex ratio (chi-square, $P > .05$).
13. These hybrids were heterozygous for typical *M. beryllina* and *M. peninsulae* alleles at three diagnostically different loci (*15*).
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19. We thank C. Hubbs, A. F. Echelle, C. Crozier, E. Marsh, D. A. Rutherford, E. Milstead, R. J. Edwards, G. Garrett, and M. Dean for helpful discussions or help in gathering data; B. Chernoff and C. Hubbs for providing access to their unpublished manuscripts. Supported by a grant from the Baylor University Research Committee and by NSF grant DEB-7912227 (to A.A.E. and A. F. Echelle).

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Memory Performance of Chemical Workers Exposed to Polybrominated Biphenyls

Abstract. *Twenty-five chemical workers who manufactured polybrominated biphenyls (PBB's) were given objective tests of learning and memory. Although this group had high concentrations of PBB's in adipose tissue, mean scores on all memory tests were normal. The PBB concentration was not correlated with memory performance; the most contaminated workers showed no evidence of memory dysfunction.*

Polybrominated biphenyls (PBB's) were inadvertently mixed into an animal feed supplement and sent to some Michigan farms in 1973 (*1*). The PBB's entered the food chain and were widely dispersed throughout the state's lower peninsula, contaminating urban as well as farm residents (*2*).

After exposure to PBB's, some Michigan residents complained of memory loss (*3*). In one study, 30 of 46 Michigan residents from both quarantined and unquarantined farms complained of memory problems (*4*). We have reported on the memory functioning of 21 Michigan farm residents who had persistent medical complaints after contact with PBB (*5*). The farm group had more difficulty than an urban group on tests of memory for prose and short-term retention of words. Poor memory on both verbal memory tasks was correlated with measures of anxiety and depression on the Minnesota Multiphasic Personality Inventory (MMPI) but was not correlated with the PBB concentration in adipose tissue. These findings suggest that memory dysfunction in some Michigan residents exposed to PBB's was related to psychological dysfunction and not PBB body burden.

Three aspects of our earlier study (*5*) limited the degree to which we would generalize its findings to other Michigan residents who had contact with PBB's. (i) The sample size was small. (ii) Most people studied had relatively low PBB contamination. (iii) There was a clear self-selection bias in our sample; most of the farm residents were studied because they had persistent medical complaints that had resisted diagnosis. Because depression and anxiety are often associated with multiple somatic complaints that are difficult to explain by a diagnosis of physical disease, this admission criterion may have selected for farm residents with psychological disorders (*6*).

To determine whether high PBB body burden would correlate with memory deficits, we studied a group of chemical workers with high PBB contamination who were selected in a way to avoid the selection bias of the sample of farm residents. These chemical workers demonstrated normal memory functioning, and their scores on memory tests were unrelated to the concentration of PBB in adipose tissue.

The Michigan Department of Public Health identified 25 PBB chemical workers on the basis of their proximity to PBB contact. Fifteen of the chemical workers directly handled PBB's or performed maintenance work in the area where PBB's were manufactured. The rest worked in a different department at the same plant. The chemical workers did not differ significantly in age, education, IQ, or predicted IQ from the farm residents whom we studied previously. The predicted IQ is an estimate based on a subject's educational, occupational, and cultural background (*7*). There were no significant differences between the chemical workers' observed full scale IQ and the predicted IQ; this suggests that as a group their intellectual functioning was typical of people of their educational, occupational, and cultural backgrounds (see Table 1).

The mean ($\bar{X}$) PBB concentration in fat for the chemical workers was 9.33 parts per million (ppm) with a standard deviation (S.D.) of 15.26 ppm. In the farm residents studied earlier, $\bar{X}$ was 3.94 ppm (S.D. = 9.96 ppm). Because distributions of PBB values have a strong posi-

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Table 1. The IQ's, education, age, and scores on six tests of memory (means ± 1 standard deviation) of chemical workers and farm residents.

Statistic	Chemical workers	Farm residents
Number of subjects	25	21
Predicted IQ	100.0 ± 4.05	101.2 ± 6.14
Full scale IQ	106.2 ± 9.03	104.7 ± 9.37
Verbal IQ	102.6 ± 10.33	103.8 ± 9.81
Performance IQ	110.4 ± 10.3	105.0 ± 9.62
Education (years)	11.4 ± 1.44	11.8 ± 1.98
Age (years)	38.3 ± 10.03	41.4 ± 14.93
Wechsler memory quotient	112.04 ± 14.13	105.2 ± 20.65
Prose (number of ideas)	10.6 ± 2.87	9.0 ± 2.62
Geometric designs	11.6 ± 2.64	9.3 ± 3.41
Word pairs (weighted total)	15.2 ± 2.83	14.9 ± 4.58
Short-term memory with 10-second distraction (percent)	86.6 ± 13.17	79.3 ± 17.60
Short-term memory with 20-second distraction (percent)	85.6 ± 16.05	79.7 ± 13.06

tive skew (Fig. 1), we normalized the raw scores by a common logarithmic transformation: for chemical workers X was 0.60 ppm (S.D. = 0.591 ppm) and for farm residents $\bar{X}$ was 0.037 ppm (S.D. = 0.639 ppm). The two groups had significantly different normalized mean PBB concentrations [$t(44) = 3.08$, $P < .01$, one-tailed test].

A short-term memory (STM) distractor test and the Wechsler Memory Scale were used to evaluate memory functioning. The STM test required subjects to remember one word during intervals (0, 10, and 20 seconds) in which they subtracted by three's, beginning with a three-digit number. Patients with classical amnesias, for example, alcoholic Korsakoff patients, or individuals with bilateral hippocampectomy perform poorly on this test (*8*). The Wechsler Memory Scale required subjects to immediately recall digits, prose, geometric designs, and word pairs; it also tests general orientation.

The mean scores of the chemical workers on six memory tests—the Wechsler memory quotient, prose recall, memory for geometric designs, paired associate learning, STM after 10 seconds of distraction, and STM after 20 seconds of distraction—were all in the normal range (Table 1).

Because group statistics may obscure poor performance by a few subjects, we examined scores in the lowest 15th percentile on the Wechsler Memory Scale and selected subtests (*9, 10*). No chemical workers scored in the lowest 15th percentile on the Wechsler memory quotient. On selected subtests, the number scoring below the 15th percentile were two (8 percent) on prose recall, one (4 percent) on visual reproduction, and three (12 percent) on word pairs.

The STM test has not been standardized on a large sample of normal subjects. Therefore, judgments about normality on this test must be based partly on clinical experience. Two chemical workers were judged to be clinically impaired after a 10-second delay and three after 20 seconds. No chemical worker was impaired on three or more of the six memory tests. We did not find an unexpected number of poor memory scores.

The average scores for three chemical workers with PBB concentrations in adipose tissue more than 1 standard deviation above the mean were in the normal ranges on the Wechsler memory quotient (112.3), prose recall (13.0), geometric designs (10.67), word pairs (14.83), STM after 10-second distraction (91.63 percent), and STM after 20-second distraction (80.53 percent).

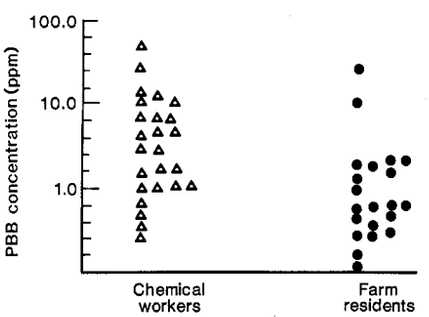

Fig. 1. Concentrations in parts per million (ppm) of PBB's in adipose tissue of chemical workers and farm residents as measured by the Division of Environmental Epidemiology at the Michigan Department of Public Health. Surgical incision or needle aspiration was used to remove fat tissue from the abdominal wall. A small amount of tissue (0.5 to 1.0 g) was ground with sand and sodium sulfate to a powder that was extracted with warm hexane (*13*). One portion was evaporated to dryness in a tared aluminum dish for determination of lipid content, and another was evaporated to a small volume and eluted with hexane through a miniature Florisil column. The eluate was concentrated to 2.0 ml and analyzed by electron capture gas chromatography (*13, 14*). The PBB concentrations in the extractable fat were quantitated on the basis of the major hexabromobiphenyl peak. All subjects had detectable concentrations. None reported any significant recent weight change.

We also examined the relation between performance on the MMPI and memory test scores among the chemical workers by performing a canonical correlation analysis between the 13 standard MMPI scales and the Wechsler memory quotient, memory for prose, geometric designs, word pairs, STM after a 10-second distraction, and after a 20-second distraction. The canonical correlation analysis, a multivariate statistical technique, tests for significant linear correlation between two sets of variables (*11*). We used a subprogram of the Statistical Package for the Social Sciences (CANCORR) to perform this analysis (*12*). There was no significant relation between the MMPI scales and the memory tests. Neither depression nor psychasthenia correlated with prose recall or short-term retention after 20 seconds of distraction.

Since the chemical workers were more contaminated with PBB's than were the farm residents, they should have performed worse than the farm residents on memory tasks if greater PBB contamination causes poor memory performance. We used multivariate analysis of variance to compare the chemical workers with the farm residents on our six memory variables. The multivariate statistic was not significant [$F(6, 39) = 2.22$, $P = .061$], indicating that the chemical workers did not score worse than the farm residents on the memory measures taken as a whole. Although the lack of overall group difference makes it likely that any difference on univariate tests is due to chance, we inspected the group means for each memory measure in order to detect possible trends. Chemical workers were more accurate than farm residents on tests of prose memory [$F(1, 44) = 4.18$, $P < .05$] and memory for visually presented geometric designs [$F(1, 44) = 6.96$, $P < .05$]. No other comparisons differed significantly. These univariate tests suggest that the chemical workers, with the higher PBB body burden, performed better on some memory tests than the less contaminated farm residents.

Inasmuch as the chemical workers and farm residents did not differ greatly from each other on the memory measures taken as a whole, we examined the combined sample of 46 Michigan residents.

There was no significant negative correlation between normalized PBB concentrations in adipose tissue and any of the six memory tests. The statistical test for such correlations detected linear associations between PBB concentrations and memory performance where the PBB concentration in adipose might account for as little as 9 percent of the variability in memory performance.

Our findings indicate that among people exposed to PBB's, factors affecting psychological functioning may be more important causes of memory complaints and low scores on objective tests of memory than the level of PBB contamination.

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Rapid Eye Movement Storms in Infants: Rate of Occurrence at 6 Months Predicts Mental Development at 1 Year

Abstract. *Intense rapid eye movements (REM) during sleep were investigated as a possible indication of delay in the neurodevelopment of infants. The rate of occurrence of REM storms was determined by monitoring the sleep of 15 normal, first-born infants during weeks 2 through 5 and at 3, 6, and 12 months. The amount of REM within each 10-second interval of active sleep was rated on a four-point scale based on frequency and intensity of eye movements. When the babies were 12 months old, the Bayley Scales of Mental Development were administered. A significant negative correlation was found between the frequency of REM storms at 6 months and Bayley scores at 1 year. To verify this, an independent sample of 14 subjects was also studied. The negative correlation was confirmed. The findings support the suggestion that by 6 months of age REM storms express dysfunction or delay in the development of central inhibitory feedback controls for sleep organization and phasic sleep-related activities.*

During a longitudinal study (*1*) that included observations of the sleep of normal infants, a form of dramatic, intense rapid eye movement (REM) was observed. These REM bursts occur in active sleep and involve eye movement of very great amplitude, often accompanied by other facial movements such as brow raising and eye opening. In some instances the episodes have an almost seizure-like appearance, giving the clinical impression of instability in the controls of the central nervous system (CNS). We have adopted the term REM storm to describe this phenomenon, a designation that has been used to refer to REM bursts in some adults with severe sleep disturbance (*2*).

Our observations indicate that, in normal infants, the frequency of REM storms is relatively high during the neonatal period, then drops sharply after about 5 weeks of age, suggesting a developmental course for this form of phasic activity during active sleep. If the REM storms result from phasic fluctuation in inhibitory control, their diminution with age would reflect increasing stability of feedback mechanisms as the CNS matures. These considerations led us to investigate the relation between REM storms and CNS integrity as measured in terms of cognitive development. The frequency of REM storms in active sleep was studied through the first year of life and compared with developmental quotients obtained from the Bayley Scales of Mental Development administered at 1 year.

Two successive groups of infants were studied. Group 1 babies were the first 15 subjects enrolled in the larger project to undergo a 1-year developmental assessment, and consisted of eight males and seven females, all first-born infants. Group 2 babies were the next 14 subjects to be enrolled, and consisted of six males and eight females, seven of whom were first-born and seven second-born. All of the infants were full-term and normal at birth, as indicated by 5-minute Apgar scores of 9 or 10 (an infant in group 1 was delivered by cesarean section and had a 5-minute Apgar score of 7).

On weeks 2, 3, 4, and 5 the infants' sleep was monitored during continuous 7-hour observations of the infant and mother which were designed to record the normal flow of a day's activity in the home. When the infant was put into the crib for a nap, sleep states were observed and a simultaneous recording of respiration was obtained from a pressure transducer under the infant's crib pad. The amount of time the babies slept during each observation period was 3.6 ± 0.76 hours (mean ± standard deviation).

Observations of sleep at 3, 6, and 12 months were also made, starting when the infant was put to bed in the evening and lasting for approximately 2 hours (2.0 ± 0.20 hours). Because of illness or other unavoidable reasons, no data were obtained for three infants at 3 months in group 1 and three infants at 12 months in group 2.

Throughout each observation, behavioral states and state-related behaviors were recorded at 10-second intervals (*3*). The sleep states included active sleep, quiet sleep, and sleep-wake transition. During each epoch of active sleep the level of REM activity was rated on a four-point scale based on both the frequency and intensity of eye movement. Ratings ranged from the absence of any REM activity to the occurrence of an REM storm (*4*). Each level of REM was measured as a percentage of the time spent in active sleep, and all sleep measures were averaged over weeks 2 through 5.

The Bayley Scales of Mental Develop-

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