Figure 1 compares the Verbal IQ distributions for the preoperative sample tested on the WISC and an enlarged postoperative sample of 93 boys and 78 girls. This postoperative sample includes the initial group of 60 boys and 58 girls and an added group of 33 males and 20 females tested more recently. The boys' Verbal IQ's closely approximate the normal curve. This is especially true for the large group of boys tested postoperatively. In marked contrast, the Verbal IQ distributions of the girls are clearly below normal for both the preoperative and postoperative samples. These comparisons strongly suggest that the Verbal deficit in the girls did not result from the operative procedures but is in some way associated with the heart defects.

The results are clear but they are not easily explained. A differential mortality rate has been suggested as a causal factor but it is difficult to see why the surviving girls should perform so much better on Performance than on Verbal tests. Recent studies have increased our knowledge of the far-reaching effects of early experience on the developing brain. We know that the maturation of the central nervous system proceeds more rapidly in girls than in boys, so that periods of maximum susceptibility to experience might differ for boys and girls (*4*). We are becoming increasingly aware of the effects of specific environments in infancy and early childhood on later abilities (*8*). We know, for example, that severe paranatal anoxia or Western encephalitis occurring in early infancy may seriously affect mental growth (*9*). And we know that there are sex differences in the relevant family interactions as they relate to specific mental abilities (*8*, *10*). The basis for the deficiency in verbal storage in girls with congenital heart difficulties possibly lies in one or a combination of the above factors. The question is which if any of these experiential factors is relevant, or is the deficiency due to a sex-associated genetic factor? These hypotheses should be tested and considered by other investigators, many of whom neglect to report results for boys and girls separately (*11*).

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12 February 1969

Encephalic Cycles during Sleep and Wakefulness in Humans: A 24-Hour Pattern

Abstract. *Twenty-four-hour polygraphic tracings from normal humans indicate that a pattern of alternating periods of the presence and absence of rapid eye movement, shown to exist for normal sleep, exist over all 24 hours of the daily period. This finding suggests that the so-called sleep-dream cycle of human sleep is not specific to sleep, but is a general activity pattern of the brain.*

Rapid eye movement (REM), a phenomenon which has been linked to dream activity (*1*), occurs with rhythmic periodicity of about every 90 minutes during human sleep. Thus, certain researchers have concluded that human sleep consists of alternating periods of sleep, during which REM

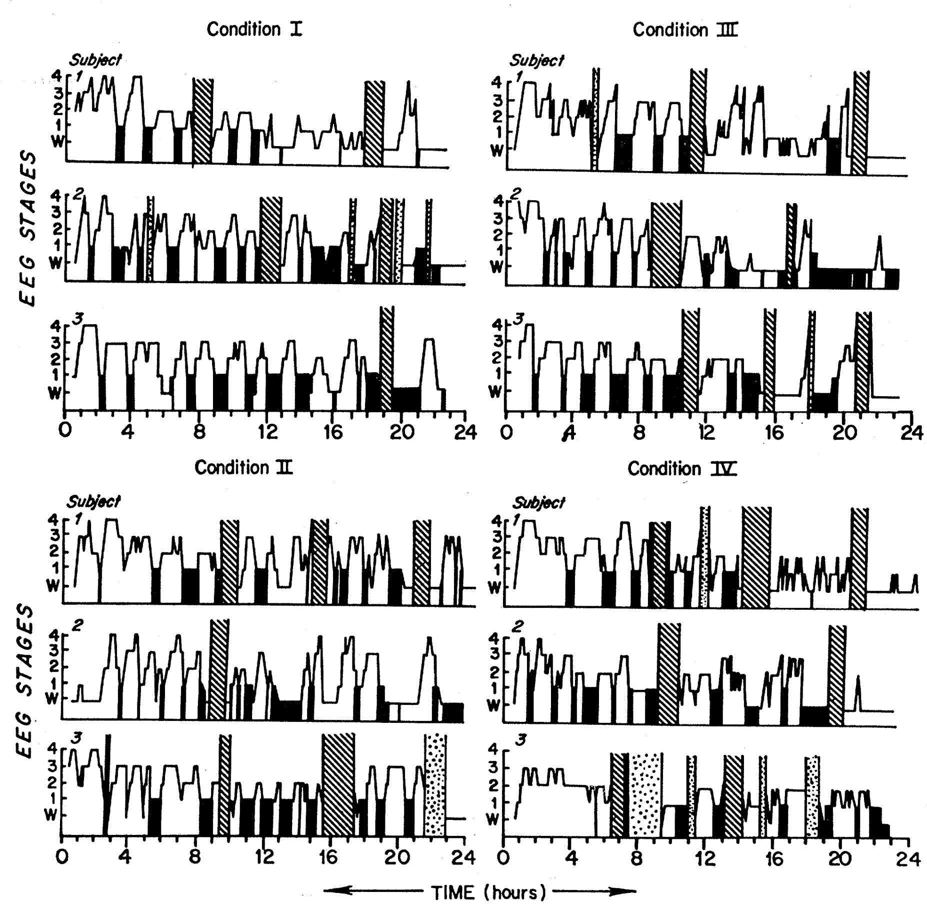

Fig. 1. Changes in EEG activity under varying conditions, recorded over 24 hours, showing alternating presence (solid areas under curve) and absence of REM. Striped areas, meal breaks; dotted areas, interruptions due to technical problems; and 0 time, equivalent of approximately 10 p.m.

does not occur, and dream activity, during which REM, a blocking out of muscle tonus, and changes in some other physiological variables appear (*2*, p. 24). The phrase "sleep-dream cycle" was coined to describe the patterned nature of sleep (*2*, p. 74).

Our studies, which have centered around the hypothesis that the rhythm between REM and non-REM is not specific to sleep, have indicated that the cyclic REM pattern continues round the clock, during both sleep and wakefulness, and, therefore, ought not to be considered as sleep-dream cycles, but rather as general encephalic cycles, the meaning of which, in terms of brain function, remains to be explored.

Three female students, selected at random from the female student population available, slept without any medication on four separate occasions in the customary horizontal sleep position, with light out, from 10 p.m. until they expressed a desire for a meal the next morning. After the meal, the experiment was resumed, under one of the following four conditions (these varied randomly from experiment to experiment): (i) Subject continued to lie in bed, undisturbed, with room remaining darkened. (ii) Subject continued to lie in bed, undisturbed, with light on. (iii) Subject was placed in a sitting position in an electroencephalograph chair, with light on, undisturbed. (iv) Subject continued to lie in bed, with light on, but was interrupted and interviewed whenever "sleep spindles" occurred in the EEG tracing for 3 minutes. Periods of REM were not disturbed. The subject's eyes remained closed under all of these conditions. Brain potential (electroencephalogram, EEG), eye movement (electrooculogram, EOG), and muscle tonus (electromyogram, EMG) were recorded on four channels of a Grass model-7 polygraph, by standard techniques. The EEG shown in each 20-second polygraphic sample was classified as stage W, 1, 2, 3, or 4, where stage W represents wakefulness and the stages 1 to 4 represent drowsiness to deep sleep (*3*). Each sample was also classified as a REM or non-REM sample according to the appearance or absence of rapid eye movement. The muscle tonus channel provided further information about the presence of a REM period, a sudden disappearance of muscle tonus usually being associated with a REM period. The data for each trial were reduced to codable form and analyzed by an IBM-7072 computer (*4*). The changes in electrical brain potential and REM over the 24-hour periods were plotted against the time (Fig. 1) (*5*). Rapid eye movement occurred periodically throughout the 24-hour experiment, in nearly all trials. The 5- or 6-hour delay of REM occurrence evident under condition (iii), subject 1, and conditions (ii) and (iv), subject 3, may be accounted for by the fatigue the subjects said they experienced as a result of a lack of sleep during the preceding night. The only trials which failed to demonstrate a periodicity of 24-hour REM activity were under conditions (iii) and (iv) for subject 1. Although the periodicity is fairly apparent, there seems to be no strict pattern of chronological regularity in the occurrence of REM activity as found before (*6*).

Cyclic changes in EEG stages, usually interpreted as indicative of changes

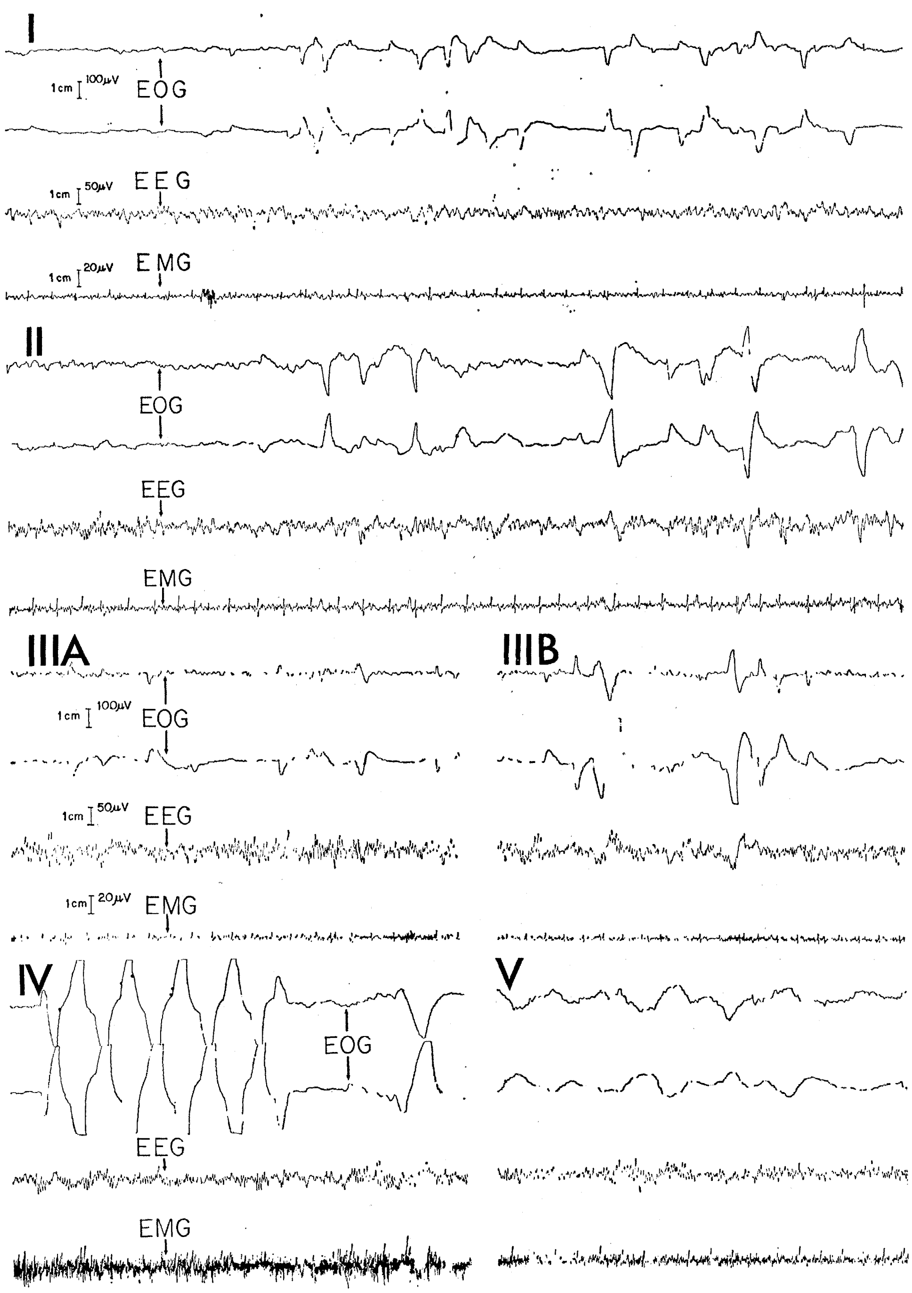

Fig. 2. Comparison of various types of EOG phenomena for the same subject occurring during EEG stages W and 1. (I) Stage-1 REM occurring during nighttime; (II) stage-1 REM, daytime; (III) stage-W REM, single (A) and REM-burst (B) 50 seconds later; (IV) voluntary eye movement for calibration purposes; and (V) slow eye movement. Calibrations are the same for all tracings.

Table 1. Similarities and differences among epochs scored as REM (night and day), W-REM, and W according to EOG and EMG tracings. The plus signs show the presence of the indicated phenomenon in the scored epoch. For abbreviations, see text.

Presence of	Epoch score			
	REM night (10 p.m.–7 a.m.)	REM day (7 a.m.–10 p.m.)	REM W-	W
Rapid eye movements*	+	+	+	–
REM (single and bursts) in groups	+	+	+	–
Periodicity of REM groups	+	+	+	–
Muscle tonus block out or marked decrease	+	+	(+)	–
Slow eye movements	–	–	–	+
Eye blinks	–	–	–	+

* Aserinsky criteria (*1*).

Table 2. REM-stages W and 1 and their preceeding EEG stages during first and second 12 hours of recording time.

REM stage	EEG stages before onset of REM				
	W	1	2	3	4
	Hours 1 to 12				
W	0	0	0	0	0
1	2	4	27	27	6
	Hours 13 to 24				
W	15	3	2	1	0
1	4	3	17	16	0

in depth of sleep (*7*), occurred periodically over all 24 hours. Under condition (iv), in which we disturbed the subjects after 3 minutes of stage 2 sleep, only subject 2 showed very rapid changes of EEG pattern, going sometimes within 3 minutes from stage W to 3 and 4.

Events possessing the characteristics of REM occurred in the EOG during EEG stage 1 and sometimes, after 12 to 16 hours of recording, in stage W. We scored such events as REM phenomena, regardless of whether they occurred during EEG stage W or 1. The justification for this approach lies in the similarity of appearance between tracings of such events occurring under both W- and 1-EEG (Fig. 2) and the tendency for episodic and periodic occurrence of such events (Table 1) (*8*). Figure 2 further points out the distinctions between this REM phenomenon, slow eye movements, and voluntary eye movements (that is, eye movements performed by the subject at the command of the experimenter) (*9*). In interviews, we found that when W-REM was accompanied by a decrease in muscle tonus the subject reported a dramaturgic daydream and active subjective involvement. When W occurred without REM, the subject reported a more abstract, nondramaturgic thought content. It should further be noted here that none of our subjects were "eye-rollers."

During the first 12 hours of any trial, REM occurred only during stage 1; during the second 12-hour period of some trials, however, REM was found during stage W (*10*). Muscle tonus often decreased during stage W with REM but did not disappear completely as during stage 1 with REM. The EEG stage occurring over the 6-minute period immediately before the onset of a stage-1 REM period was usually stage 2 or 3; for W-REM, the immediately preceding EEG stage was generally stage W or 1. Table 2 shows the relative frequencies of occurrence of the various EEG stages immediately preceding REM periods.

The continuation of REM periods during daytime indicates that there is no saturation of REM, as seemed to be indicated by some findings in REM-deprivation experiments (*11*). Rather, there exists a continuing alternation of these two kinds of central brain activity, measurable by changes in peripheral physiological variables, such as EEG, EOG, and EMG (*12*). The lack of regularity in the occurrence of REM periods indicates that timing of cycles may be a function of such variables as subject-identity, environmental influences, and absolute time, all of which have observable influence in other cyclic biological phenomena.

Our results indicate that REM occurs at intervals throughout a 24-hour period and not solely during the usual periods of sleep and thus that the sleep-dream cycle is too limited a concept in that it constitutes only one manifestation of an overall cyclic activity, the significance of which has yet to be established.

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4. The Washington University Computing Facilities are supported through NSF grant G-22296.
5. Each set of 18 20-second samples were averaged to give a 6-minute aggregate index of EEG activity.
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8. REM has previously been observed during "wakefulness," but no mention was made about periodicity (*3*, p. 4).
9. In Fig. 2A the muscle-tone decrease during stage-W REM is nearly the same as during stage-1 REM. Our sample is particularly emphatic; in other cases the decrease is less impressive.
10. Where a delay occurred in the onset of REM [subject 1, condition (iii), and subject 3, conditions (ii) and (iv)], there was no stage W with REM observable.
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12. Muscular relaxation under sitting condition caused subject 1 to fall forward in the EEG chair, preventing the onset of the REM period. Under the awakening condition, subject 1 was erroneously disturbed by the operator before she finished 3 minutes of stage 2. She reported that she was interrupted several times during the onset of dreaming.
13. Supported by National Institute of Mental Health grants MH-07081 and MH-19247.

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Cochlear Distortion: Effect of Direct-Current Polarization

Abstract. *Intermodulation components (combination tones) appearing in microphonic potentials were measured from guinea pig cochleas with and without polarizing direct currents passing through the cochlear partition. At moderate intensities of stimulus the polarization had a qualitatively different effect on the distortion components than on their eliciting primaries or on pure tones simulating the distortion products. At high intensities, the primaries and the combination tones were similarly influenced by the polarizing current. It is concluded that cochlear distortion is a two-stage process, mechano-electrical at low levels and mechano-hydraulic at high levels.*

Some manifestations of distortion by the ear were noted as early as the beginning of the 18th century, but even today there is disagreement about the mechanism by which distortion is generated. Studies of distortion components in the cochlear microphonic potential proved that, at least up to ex-