in the EP response to the flicker. This EP asymmetry is measured as an alternating large and small area under the EP curve. It is greater for the faster than for the slower flicker frequencies and may thereby enhance visual detection of high-frequency flicker. This apparent enhancement mechanism is sensitive to as little as 30-μsec change in the flicker asynchrony.

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References and Notes

1. D. M. Regan, *Evoked Potentials in Psychology, Sensory Physiology and Clinical Medicine* (Chapman and Hall, London, 1972), pp. 75–77.
2. A. L. Diamond, *Electroencephalogr. Clin. Neurophysiol.* **42**, 125 (1977).
3. D. A. Jeffreys, *Nature (London)* **229**, 502 (1971).
4. Similar results in the human electroretinogram are summarized by J. C. Armington [*The Electroretinograph* (Academic Press, New York, 1974), pp. 320–329].
5. For subject A.D., an increased interval was introduced every 2, 4, 8, 16, 32, 128, or 256 flashes, with the alternation consistently associated with the asynchrony regardless of the number of flashes in the flicker train.
6. H. Spekreijse, *Analysis of EEG Responses in Man* (Junk, The Hague, 1966), pp. 49–50; S. M. Peacock, Jr., *Electroencephalogr. Clin. Neurophysiol.* **34**, 71 (1973).
7. As measured in two subjects, A.D. and C.W., this microsecond sensitivity holds for a twofold change in the light-adapting luminance, as well as for a change in visual fixation to the center of the test field. Fixation near the lower border significantly reduces both this sensitivity and EP amplitude. An alternation in luminance between successive flashes has less than one-tenth the effect on the EP as the alternation in duration of the IFI does.
8. M. R. Harter and C. T. White, *Science* **156**, 406 (1967).
9. Supported in part by NRC grant A9940. I thank R. Koopman, C. Davis, and R. Blackman for critical suggestions and H. Gabert and W. Tressel for invaluable technical assistance.

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Phase Advance of the Circadian Sleep-Wake Cycle as an Antidepressant

Abstract. *Sleep in depressed patients resembles sleep in normal subjects whose circadian rhythms of temperature and rapid-eye-movement sleep are phase-advanced (shifted earlier) relative to their sleep schedules. If this analogy is relevant to the pathophysiology of depressive illness, advancing the time of sleep and awakening should temporarily compensate for the abnormal timing of depressed patients' circadian rhythms. Four of seven manic-depressive patients studied longitudinally spontaneously advanced their times of awakening (activity onset) as they emerged from the depressive phase of their illness. In a phase-shift experiment, a depressed manic-depressive woman was twice brought out of depression for 2 weeks by advancing her sleep period so that she went to sleep and arose 6 hours earlier than usual. The antidepressant effect of the procedure was temporary and similar in duration to circadian desynchronization induced by jet lag in healthy subjects. This result supports the hypothesis that abnormalities of sleep patterns in some types of depression are due to abnormal internal phase relationships of circadian rhythms.*

The human circadian system has been described (*1–3*) as consisting of multiple, self-sustained oscillators that are mutually coupled and that can be entrained by the zeitgebers in the environment to ensure temporal order within the organism. Aschoff has recently concluded (*3*): "It is still unknown whether there are illnesses specific to changes in circadian organization, and whether these disturbances can be sufficiently characterized to enable their use as diagnostic criteria. Although the hypothesis of desynchronized circadian rhythms in affective illness [*4, 5*] underlies much psychiatric theorizing, there is not yet a sound experimental base to these theories" (*3*, p. 1855). We describe a clinical study that directly tests this hypothesis.

In patients with major depressive illness, disturbed sleep is a primary symptom. The architecture of sleep and the duration of sleep are regulated by processes that undergo circadian fluctuations. When sleep is sampled during short naps around the clock in normal subjects, rapid-eye-movement (REM) sleep exhibits a circadian rhythm, with a maximum in midmorning and a minimum in the late afternoon (*6*). Thus, REM sleep normally predominates in the latter half of the sleep period. Extensive electroencephalographic studies of the sleep-wake cycle in depression indicate that in depressed patients REM sleep occurs earlier in the sleep period than it does in controls (*7*). The sleep disturbance of depression can be mimicked in some respects—short REM latency (elapsed time from sleep onset to REM sleep onset), short total sleep time, and increased awakening at the end of the sleep period—by shifting the onset of normals' sleep period from 10 p.m. to 10 a.m. (*8*). Furthermore, experimental manipulations of the circadian sleep-wake cycle in healthy subjects have shown that it is possible to change internal phase relationships between different circadian rhythms (*1, 2, 9*) and that these changes may be associated with psychopathological symptoms ranging from emotional and psychosomatic disturbances (*1, 10*) to depressive reactions, hostility, and even suicide (*11*).

Thus, it has been inferred that, in depression, the circadian rhythm of REM sleep may occur abnormally early, that is, phase-advanced relative to the sleep period (*8, 12*). Additional evidence from biochemical and physiological measurements supports the hypothesis that certain circadian rhythms of depressive patients are phase-advanced (*13, 14*).

If this inference is relevant to the etiology of affective illness, advancing a depressive patient's sleep period by several hours should alter the internal phase relationship between the circadian sleep-wake cycle and other circadian rhythms (such as temperature or the probability of REM sleep) so as to normalize both sleep architecture and mood.

We now report some clinical observations and an experiment based on this model. In seven manic-depressive patients (*15*) we continuously monitored the 24-hour rest-activity cycle with a computer-based nontelemetered ambulatory monitor worn on the nondominant wrist (*16, 17*). Plots of motor activity data (Fig. 1) revealed that four patients rapidly advanced their time of awakening as they emerged from the depressive phase of their illness (usually patients switched from depression into mania or hypomania). Although each patient's total sleep time was also markedly reduced, the shortening of the sleep period was almost entirely due to the earlier onset of awakening. In some cases patients reported that they were drowsy early in the evening, but did not go to bed until later because of hospital routine. If this earlier awakening represents a sudden spontaneous phase advance of the sleep-wake cycle relative to other rhythms, it suggests that such a procedure could be associated with improvement in depression.

These observations encouraged us to test the circadian rhythm phase-advance hypothesis directly by advancing the sleep period of one of the patients by several hours during a depressive episode. The patient, a 57-year-old woman, had a history of responses to tricyclic antidepressants, monoamine oxidase inhibitors, electroconvulsive treatment, and sleep deprivation therapy. We found that a 6-hour phase advance of her sleep-wake cycle was sufficient to normalize sleep architecture and cause a rapid remission of symptoms (characteristic of a

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response to sleep deprivation but not to tricyclic drugs) that was relatively long-lasting (characteristic of a response to tricyclic drugs but not to sleep deprivation).

The patient's clinical state was evaluated daily by nurses' ratings and monitoring of continuous motor activity. During part of the study, her sleep was recorded electroencephalographically, and sleep stages were scored conventionally (*18*); while awake, oral temperature was measured with an ovulation thermometer every 2 hours. Starting during a depressive episode, the patient's sleep-wake schedule was advanced 6 hours on four different occasions approximately 2 weeks apart (Fig. 2). Two days after the first 6-hour shift (when the sleep time was advanced from the conventional 11 p.m. to 7 a.m. period to a new 5 p.m. to 1 a.m. period), her depression remitted completely and was succeeded by a normal or slightly hypomanic state; 2 weeks later she relapsed into depression. A second 6-hour phase advance (sleep time from 11 a.m. to 7 p.m.) produced a similar remission (*19*).

According to our hypothesis, clinical remission resulted from the sudden change in internal phase relationships between the sleep-wake cycle and other circadian rhythms—a situation analogous to the jet lag that accompanies eastward travel. As a corollary, clinical relapse into depression resulted from the reestablishment of pathological internal phase relationships when all circadian rhythms eventually became entrained to the new schedule. On the basis of this reasoning we thought that a second relapse could be prevented by a third 6-hour phase advance scheduled a few days before the relapse was expected to occur. Our attempt at prophylaxis, however, was unsuccessful. Furthermore, a fourth 6-hour phase advance of the sleep-wake schedule failed to terminate the ensuing depression. Temperature data suggest an explanation for these experimental results (Fig. 2). The patient's circadian temperature rhythm was successfully advanced by the first and second 6-hour schedule shifts, with concomitant improvement in depressive symptoms. The temperature rhythm failed to advance and instead delayed after the third and fourth shifts, and no improvement of mood was seen. Simultaneous advance of one rhythm (sleep-wake) and delay of another (temperature) in response to a schedule shift, an example of reentrainment by partition (*20*), presumably reestablished the phase relationship between temperature and sleep that existed prior to the experiment, when the patient was depressed.

Sleep recordings revealed that (i) sleep architecture during depression was typical of endogenous depression with short REM sleep latency and increased early morning awakening, a high percentage of early REM sleep (first REM sleep period as a percentage of total sleep), and high REM density (mean number of eye movements per minute based on a scale of zero to eight per minute of REM sleep); (ii) after 6-hour phase advance of the sleep-wake cycle but before remission, several indices approached normal values; and (iii) after remission, further normalization of sleep architecture oc-

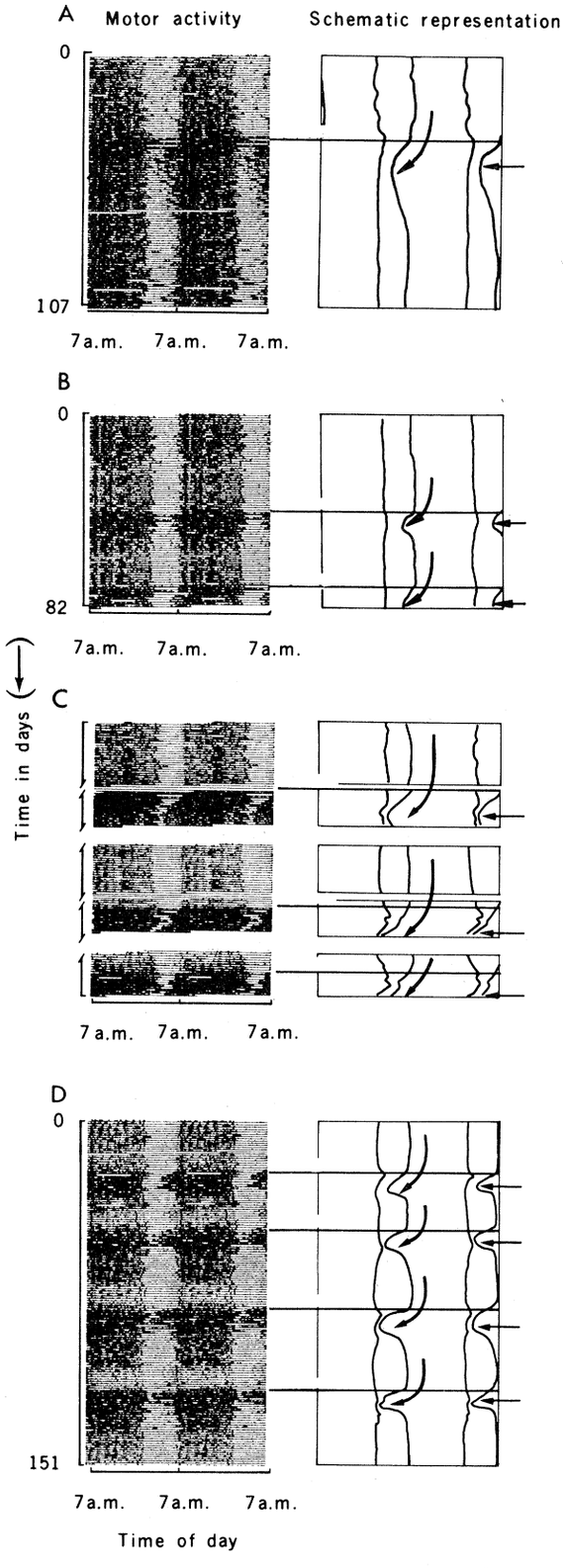

Fig. 1. Longitudinal records of motor activity in four manic-depressive (bipolar-BP) patients during one or more switches (horizontal lines) out of depression (into hypomania or mania). In two of the patients (A and C) the prior history, current course, or both included full clinical mania (BP I); in the other two (B and D) only hypomania had been evidenced (BP II). Motor activity was recorded with a small electronic accelerometer worn on the wrist. Movement counts per 15-minute sampling interval were recorded in solid-state memory and later retrieved and analyzed by computer. Activity data are displayed here as actograms similar to those used in animal circadian rhythm studies. Each day's data are plotted as a histogram along a horizontal line beginning at 7 a.m.; consecutive days' data are plotted in sequence beneath each other; the entire display is double-plotted to facilitate visual inspection of changes in the rest-activity cycle. Activity is higher (darker) in hypomania or mania and lower (lighter) in depression. These four patients (of seven studied) slept less because of an advance in the time of awakening as they switched out of the depressed phase of their illness. The progressively earlier onset of activity may represent a phase advance (arrows) of the rest-activity cycle (schematic representation). Patient D was the subject of the phase-shift experiment (Fig. 2). Patient descriptions: (A) male, 46 years old; (B) female, 49 years old; (C) female, 49 years old; and (D) female, 57 years old.

curred. Sleep characteristics in depression before the phase advance, depression after the phase advance, and remission, respectively, were (i) early morning awakening: 55 ± 24, 16 ± 7.9, 6 ± 1 minutes; (ii) REM sleep latency: 15.3 ± 12, 20.5 ± 10.3, 49.8 ± 5.6 minutes; (iii) percentage of early REM sleep: 13.5 ± 7, 8.8 ± 3.9, 10.3 ± 2.5; and (iv) REM density: 2.8 ± 0.2, 2.2 ± 0.2, 1.3 ± 0.2. The therapeutic effect of the 6-hour schedule advance could not be attributed to acute sleep deprivation (total sleep time was 335.5 ± 1.7, 330 ± 16, and 359 ± 11 minutes, respectively), nor to chronic REM sleep deprivation (REM sleep time was 105 ± 10, 102.9 ± 7.5, and 110 ± 6.5 minutes, respectively), procedures known to act against depression (*5*, *21*).

The patient's motor activity, monitored almost continuously for $1^1/_2$ years, provided an objective measure of clinical state changes as well as a long-term context in which to view the phase-shift experiment. The actogram (Fig. 2) shows that while taking a placebo the patient was depressed for more than 70 days. A tricyclic antidepressant (desmethylimipramine, 75 to 150 mg) precipitated rapid cycles between hypomania and depression (*17*), and tricyclic-induced switches out of depression were associated with a temporary advance in the time of morning awakening. The phase-shift experiment mimicked these two effects of the tricyclic antidepressant. Lithium carbonate had no beneficial effect. Amelioration of depression associated with sleep deprivation for a night lasted only 1 day each time (*22*).

In our patient, the analogy between the effects of tricyclic antidepressants and schedule shifts suggests that agents or events that alter clinical state in affective illness may act through their ability to alter the timing of circadian rhythms relative to the sleep-wake cycle. In this context, the lithium ion, tricyclic antidepressants, and estrogen, all of which have profound effects on depressive illness, also alter the basic timekeeping function of the circadian clock (*23*). Furthermore, the seasonal incidence of mania and depression (*24*) may also be related to circadian phase-shifts induced by changes in the daily photoperiod.

Three other depressed patients, all unresponsive to tricyclic antidepressant therapy, have subsequently been phase-advanced. A 65-year-old man (unipolar) partially improved after both sleep deprivation and phase advance. The symptoms of a 28-year-old woman with a prior history of mania (bipolar I) completely remitted after sleep deprivation and partially improved after phase advance. A 49-year-old woman with a prior history of hypomania (bipolar II) switched into hypomania after sleep deprivation and also after breaking off the phase-advance

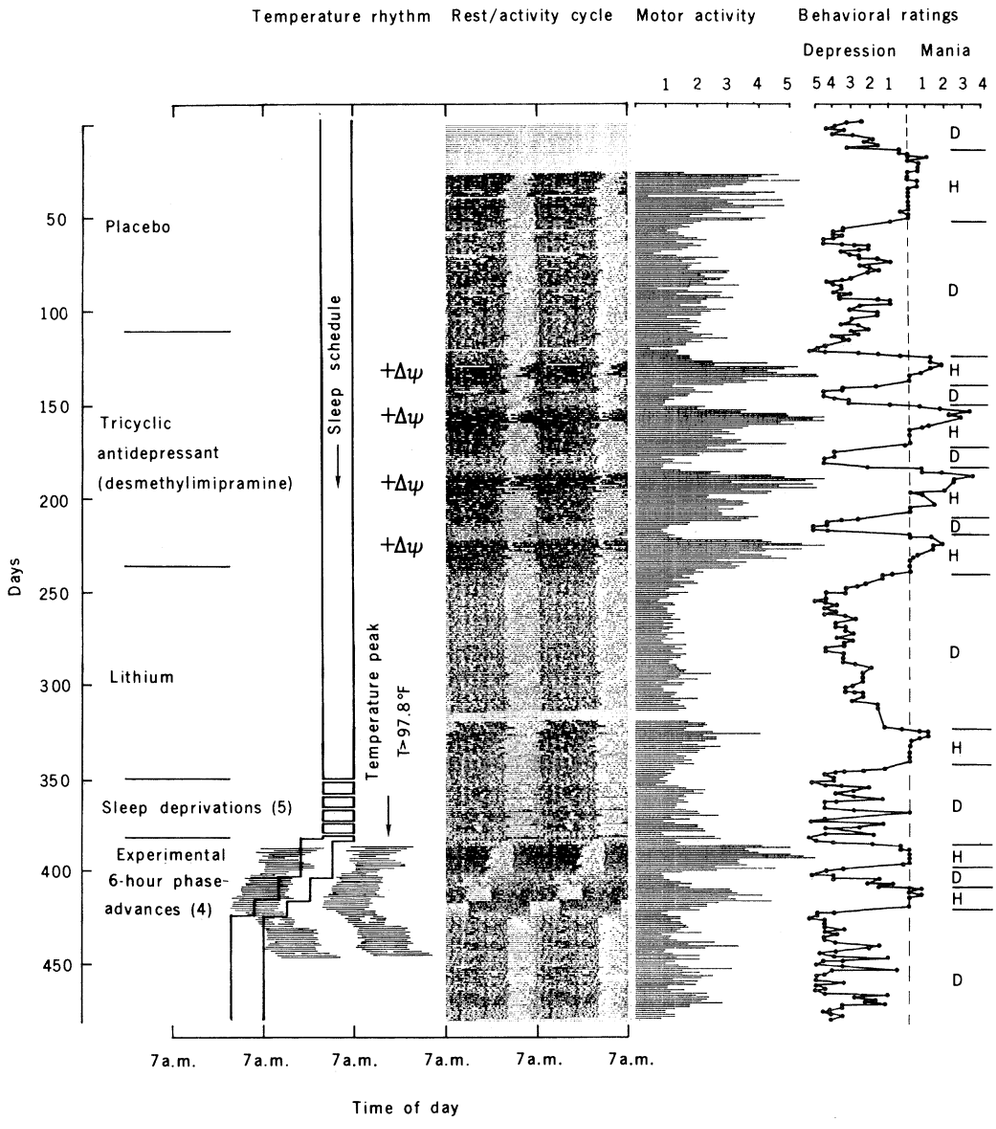

Fig. 2. Longitudinal record of drug and sleep schedule, motor activity, and nurses' behavioral ratings during the phase-shift experiment and the year preceding it. The double-plotted rest-activity actogram includes Fig. 1D. Total motor activity (counts per 24 hours divided by 1000) paralleled the clinical state [periods of depression (*D*) are characterized by low activity]. Desmethylimipramine induced rapid cycling between depression and hypomania (*H*). Drug-induced switches into hypomania are associated with increased motor activity as well as advances of its daily onset time (+ $\Delta\psi$). Clinical remission induced by 6-hour phase advances, reflected in increased activity, mimics the drug effect. The sleep schedule which was normal ward routine (11 p.m. to 7 a.m.) for the first year, was interrupted by five weekly deprivations of a single night's sleep (each inducing a day's transient remission), and then followed by the experimental 6-hour phase advances of the sleep schedule. At this time, temperature measurements were taken every 2 hours during waking. The times of day when the longitudinally smoothed temperature curve exceeded 97.8°F are indicated by horizontal lines. The temperature maximum advanced with the first two sleep schedule advances (associated with remission) but broke away after the third phase advance and slowed (associated with unremitting depression).

experiment. Her response was equivocal because the experiment was interrupted and also because she had a history of rapid cycles.

Conclusions drawn from responses of a small number of patients to a phase-shift experiment cannot be generalized. Nevertheless, our results support the hypothesis that disturbances in a central circadian pacemaker are involved in the pathophysiology of some types of depression and raise the possibility of new nonpharmacological treatment of the illness.

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References and Notes

1. J. Aschoff, *Science* **148**, 1427 (1965).
2. R. Wever, in *Rhythmus-Probleme in der Psychiatrie*, H. Heimann and B. Pflug, Eds. (Fischer, Stuttgart, 1978).
3. J. Aschoff, *Arzneim. Forsch.* **28**, 1850 (1978).
4. F. Halberg, *Symposium Bel-Air III* (Masson, Geneva, 1968), p. 73; G. C. Curtis, *Psychosom. Med.* **34**, 235 (1972); F. A. Jenner, *Chronobiologia* **1**, 151 (1974); M. Papousek, *Fortschr. Neurol. Psychiatr. Ihrer Grenzgeb.* **43**, 381 (1975); U. Supprian, *ibid.*, p. 358; R. Wever, *Arzneim. Forsch.* **26**, 1050 (1976); D. F. Kripke, D. J. Mullaney, M. Atkinson, S. Wolf, *Biol. Psychiatry* **13**, 335 (1978).
5. B. Pflug and R. Tölle, *Nervenarzt* **42**, 117 (1971).
6. H. W. Agnew and W. B. Webb, *Psychophysiology* **5**, 142 (1968); E. D. Weitzman, C. Nogeire, M. Perlow, D. Fukushima, J. Sassin, P. McGregor, T. F. Gallagher, L. Hellman, *J. Clin. Endocrinol. Metab.* **38**, 1018 (1974); J. N. Mills, D. S. Minors, J. M. Waterhouse, *J. Physiol. (London)* **268**, 803 (1977); K. I. Hume and J. N. Mills, *ibid.* **270**, 32P (1977).
7. D. J. Kupfer, *Biol. Psychiatry* **11**, 159 (1976); G. W. Vogel, F. Vogel, R. S. McAbee, A. J. Thurmond, *Arch. Gen. Psychiatry*, in press.
8. E. D. Weitzman, D. F. Kripke, D. Goldmacher, P. McGregor, C. Nogeire, *Arch. Neurol. (Chicago)* **22**, 483 (1970).
9. E. D. Weitzman, C. A. Czeisler, M. Moore-Ede, *Naito International Symposium on Biorhythm and Its Central Mechanism* (Elsevier/North-Holland, New York, in press).
10. J. M. Taub and R. J. Berger, *Psychosom. Med.* **36**, 164 (1974); R. Lund, *ibid.*, p. 224.
11. D. A. Rockwell, M. Hodgson, J. Beljan, C. M. Winget, *Aviat. Space Environ. Med.* **47**, 1087 (1976); D. A. Rockwell, C. M. Winget, L. S. Rosenblatt, E. A. Higgins, N. W. Hetherington, *J. Nerv. Ment. Dis.* **166**, 851 (1978); N. R. Cutler and H. B. Cohen, *Compr. Psychiatry* **20**, 61 (1979); C. M. Winget, paper presented at the Conference on Circadian Dysrhythmias, Moffet Field, California, 3 to 4 March 1975.
12. M. Papousek, *Fortschr. Neurol. Psychiatr. Ihrer Grenzgeb.* **43**, 381 (1975); T. A. Wehr, *Ann. Intern. Med.* **87**, 321 (1977).
13. The circadian rhythm of urinary 3-methoxy-4-hydroxyphenylglycol, a possible marker of central noradrenergic activity, has been found to be 3 hours phase-advanced in manic-depressive patients when compared with controls (*14*). This biochemical finding may be relevant to the hypothesis that the circadian rhythm of REM sleep is phase-advanced in depression because central noradrenergic activity is thought to inhibit REM sleep in humans [I. Oswald, V. R. Thacore, K. Adam, V. Brezinova, R. Burack, *Br. J. Clin. Pharmacol.* **2**, 107 (1975); A. Autret, M. Minz, T. Beillevaire, H. P. Cathala, P. Castaign, *C. R. Acad. Sci. Ser. D* **283**, 955 (1976); J. A. Hobson, R. W. McCarley, T. M. McKenna, *Prog. Neurobiol.* **6**, 280 (1976)]. It is on the monoamine-containing cells of the locus coerulus and the raphé, which turn off during REM sleep, that tricyclic antidepressants may act [T. H. Svensson and T. Usdin, *Science* **202**, 1089 (19 → C. de Montigny and G. K. Aghajanian, *ibid.*, p. 1303]. The physiological measures of oral temperature rhythm and motor activity are also phase-advanced in both depression and mania (*14*). Longitudinal studies of circadian temperature rhythms in rapidly cycling manic-depressive patients showed that their circadian clocks run faster than normal [D. F. Kripke, D. J. Mullaney, M. Atkinson, S. Wolf, *Biol. Psychiatry* **13**, 335 (1978)]. Since a fast circadian pacemaker, when entrained to a 24-hour day, adopts an earlier phase relative to the entrainment schedule, these data indirectly support the phase-advance hypothesis.
14. T. A. Wehr, G. Muscettola, F. K. Goodwin, *Arch. Gen. Psychiatry*, in press.
15. The patients met Research Diagnostic Criteria [R. L. Spitzer, J. Endicott, E. Robins, *ibid.* **35**, 773 (1978)] for major depressive illness and bipolar (manic-depressive) type; they were studied on a psychiatric research ward, where their clinical states were assessed with nurses' global ratings of mania and depression [W. E. Bunney, Jr., and D. A. Hamburg, *ibid.* **9**, 280 (1963)].
16. The device is completely self-contained and records in solid-state memory the percentage of time during 15-minute sampling intervals during which patients' movement exceed a threshold. Periodically, a computer was used to retrieve, compile, analyze, and plot the data [T. R. Colburn, B. M. Smith, J. J. Guarini, N. N. Simmons, *International ISA Biomedical Sciences Instrumentation Symposium Publ. BM 76322* (1976), p. 117; *14, 17*].
17. T. A. Wehr and F. K. Goodwin, *Arch. Gen. Psychiatry* **36**, 555 (1979).
18. A. Rechtschaffen and A. Kales, Eds., *A Manual of Standardized Terminology, Techniques and Scoring System for Sleep Stages of Human Subjects* (NIH Publ. No. 204, Bethesda, Md., 1968).
19. Psychiatrists have long considered diurnal mood changes to be typical of endogenous depression. However, patients (as well as normal subjects) differ among themselves, and over time, as to whether their mood is better in the morning or evening or does not vary at all [P. Hall, F. G. Spear, D. Stirland, *Psychiatr. Q.* **38**, 529 (1964); H. Hampp, *Arch. Psychiatr. Nervenkr.* **201**, 335 (1961); H. D. Middlehoff, *ibid.* **209**, 329 (1967); H. Waldmann, *ibid.* **213**, 177 (1970); U. Supprian, *ibid.* **220**, 9 (1975); L. von Knorring, C. Perris, E. Strandman, *ibid.* **224**, 295 (1977); F. Stallone, G. J. Huba, W. G. Lawlor, R. R. Fieve, *Br. J. Psychiatry* **123**, 311 (1973)]. Longitudinal data [H. Waldmann, *Fortschr. Neurol. Psychiatr. Ihrer Grenzgeb.* **40**, 83 (1972)] suggest that the presence or absence of diurnal variation may depend on the phase of the depression: a lack of diurnal fluctuation of mood at the depth of depression and diurnal variation at the beginning and end of a depressive episode. Our patient's self-ratings during the phase-advance experiment support Waldmann's description of longitudinal changes throughout the phase of illness. Before the phase shift, the patient showed no mood swings in her depression. The first effect of the phase shift was improvement of mood in the evening. Then the patient became euthymic without any fluctuations of mood. The first sign of relapse was a worsening of mood in the evening, and again, when the patient became depressed, no diurnal rhythm was seen. After the phase shift, diurnal improvement in mood occurred progressively earlier each day (approximately 2 hours per day initially), and appeared to parallel the rate of shift of the daily rise in temperature that also advanced to synchronize with the new schedule.
20. J. Aschoff, in *Environmental Endocrinology*, I. Assenmacher and D. S. Farner, Eds. (Springer-Verlag, Berlin, 1978), pp. 172-181.
21. G. A. E. Rudolf, B. Schilgen, R. Tölle, *Nervenarzt* **48**, 1 (1977); G. W. Vogel, R. McAbee, K. Barker, A. Thurmond, *Arch. Gen. Psychiatry* **34**, 96 (1977).
22. Since patients sometimes spontaneously switch out of the depressive phase of their illness, it is possible that the depressive remissions that occurred after experimental phase shifts were coincidental. Detailed clinical records demonstrated that the patient tended to remain indefinitely depressed when not treated with medications. Four previous untreated depressive episodes all exceeded 70 days and ended only when antidepressant medications were prescribed.
23. W. Engelmann, *Z. Naturforsch.* **28**, 733 (1973); K. Hofman *et al.*, *ibid.* **33**, 231 (1978); T. A. Wehr, A. Wirz-Justice, F. K. Goodwin, *Chronobiologia* **6**, 169 (1979); L. P. Morin, K. M. Fitzgerald, I. Zucker, *Science* **196**, 305 (1977).
24. M. R. Eastwood and J. Peacocke, *Br. J. Psychiatry* **129**, 472 (1976); R. L. Symonds and P. Williams, *ibid*, p. 45; S. D. Walter, *ibid.* **131**, 345 (1977).
25. We thank T. Colburn and B. Smith for developing, producing, and maintaining the activity monitoring devices used in this study, and W. Vaughn for computer programs used to process and display the activity data. A.W.-J. is a visiting Fellow of the Swiss Foundation for Biomedical Research.

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Functional Organization of Lateral Geniculate Cells Following Removal of Visual Cortex in the Newborn Kitten

Abstract. *When the visual cortex of a newborn kitten is removed, most neurons in the dorsal lateral geniculate nucleus degenerate, but a small population of large cells is spared. Electrophysiological recording revealed that detailed visual topography in the nucleus is abnormal and that single cells have unusually large receptive fields. These results suggest that optic axons deprived of their normal synaptic targets rearrange their connections to converge on local surviving neurons.*

The visual cortex of the cat receives a direct input from the dorsal lateral geniculate nucleus (LGN) of the thalamus. If areas 17, 18, and 19 of the visual cortex are removed in the adult cat, neurons in the LGN that relay information from the retina to the cortex undergo retrograde degeneration (*1*). By contrast, if a similar lesion is made in the newborn kitten, some of the neurons in the LGN survive the operation and do not degenerate (*2, 3*). Figure 1A shows a frontal section through the LGN of an adult cat in which most of areas 17, 18, and 19 of the visual cortex had been removed at birth. Although almost all of the cells in the nucleus have degenerated, large surviving neurons can be seen. These spared cells (Fig. 1B) are scattered throughout the LGN and are especially prominent ventrally in the vicinity of the C layers (*4*).

Since large surviving LGN neurons are rarely seen after damage to areas 17, 18, and 19 in the adult, we wondered if their presence in the cat operated on as an infant might represent an example of neuronal plasticity in which both structure and function are spared. We there-

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