REM sleep, does seem to increase subsequent dream intensity, that is, the selective deprivation of ascending EEG stage 1 has immediate experiential, as well as the heretofore observed sleep-cycle, effects.

These results are also consonant with the Freudian conception of dreaming as a safety valve, which played a large role in earlier interpretations of the effects of dream deprivation. The dream content of sensitizers, whose safety valve is somehow always partially capped, and that of repressers under the capping effects of experimental deprivation, both exhibit intensification. In general, our results seem to indicate that the less a person dreams, the more intense are his dreams (*17*).

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References and Notes

1. E. Aserinsky and N. Kleitman, *J. Appl. Physiol.* **8**, 1 (1955); W. Dement and N. Kleitman, *J. Exp. Psychol.* **53**, 339 (1957).
2. W. Dement and N. Kleitman, *Electroencephalog. Clin. Neurophysiol.* **9**, 673 (1957).
3. W. Dement, *Science* **131**, 1705 (1960).
4. F. Snyder, *Archiv. Gen. Psychiat.* **8**, 381 (1963).
5. A. Kales, F. Hoedemaker, A. Jacobson, E. Lichtenstein, *Nature* **204**, 1331 (1964).
6. M. Jouvet, in *Aspects Anatomo-Fonctionnels de la Physiologie du Sommeil* (Centre National de la Recherche Scientifique, Paris, 1965), pp. 397–449.
7. W. Dement, in *ibid.*, pp. 571–611.
8. D. Byrne, *Psychol. Rep.* **13**, 323 (1963).
9. R. J. Berger, *Science* **134**, 840 (1961).
10. D. Foulkes, *The Psychology of Sleep* (Scribner, New York, 1966), pp. 92–95.
11. ———, *ibid.*, pp. 189–190.
12. All probability values reported in this paper are one-tail, since the alternative to the null hypothesis is, in every case, specific as to direction. Tests of sleep-cycle effects of deprivation and of represser-sensitizer differences in both sleep cycle and dream content are attempted replications of earlier published findings. In addition, results in the same direction as our finding of increased dream intensity following "dream deprivation" were obtained in an unpublished study by Rechtschaffen and Foulkes, but their results, obtained under somewhat different conditions than ours, did not attain statistical significance. Student's *t*-test was used to evaluate sleep-cycle and eye-movement effects, and the Wilcoxen matched-pairs signed-ranks test for the dream content effects of the deprivation variable. The Wilcoxen rank-sum test was employed in evaluating represser-sensitizer differences in dream context.
13. R. Berger and I. Oswald, *Science* **137**, 601 (1962).
14. D. Foulkes and A. Rechtschaffen, *Percept. Motor Skills* **19**, 983 (1964).
15. L. J. Monroe, unpublished thesis, University of Chicago, (1965).
16. C. Fisher, *J. Amer. Psychoanal. Assoc.* **13**, 271 (1965).
17. Supported by grant GS-860 from NSF to D.F. Based on a thesis submitted by T.P. to the department of psychology, University of Wyoming, in partial fulfillment of the requirements for the degree of Master of Arts. We thank Ethel Meginness and John Ahrens for rating dream reports, and the latter for performing the eye-movement counts.

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"Copulation-Reward Site" in the Posterior Hypothalamus

Abstract. *Posterior hypothalamic self-stimulation of male rats, in which monopolar, platinum electrodes had been bilaterally implanted, increased after systemic injection of testosterone. Constant stimulation to the same site elicited immediate copulation with estrous female rats. During constant stimulation, males would press a bar to open a door for access to females. Even after ejaculation, males continued to open the door and to display sexual activity until stimulation terminated. Posterior hypothalamic stimulation is like normal sexual stimulation; it is rewarding, the reward varies with the amount of the sex hormone, and it elicits motivated copulation.*

The reward of self-stimulation of the brain has been linked to normal appetitive behavior, particularly feeding. Self-stimulation of the lateral hypothalamus increases during food deprivation (*1*) and decreases after food intake (*2*). Stimulation of the same site elicits voracious feeding (*1, 2*). Even if a learned response is required to obtain food, the rat responds as soon as stimulation begins (*3*). Thus lateral hypothalamic stimulation not only elicits rewards that vary with food intake but it also motivates feeding.

On the basis of the discovery of a "feeding-reward site," we decided to look for a "copulation-reward site." Olds (*4*) found that in some areas of the brain self-stimulation decreased after castration and increased after testosterone replacement. Herberg (*5*) confirmed this for a specific site in the posterior hypothalamus where self-stimulation elicited ejaculation. If somewhere in this posterior region self-stimulation is related to mating, in the same way that lateral hypothalamic self-stimulation is related to feeding, stimulation should motivate an animal to copulate. We have explored this possibility and now report the results.

The subjects were ten sexually experienced male Sherman rats with monopolar, platinum electrodes (0.023 cm outside diameter) bilaterally implanted in the posterior hypothalamus (*6*). The implants were made perpendicular to the skull, 4.5 mm anterior to the intra-aural line, 1.2 to 1.5 mm lateral to the midline, and 8.5 mm below the surface of the cortex.

Females for mating tests were brought into constant behavioral estrus by subcutaneous placement of two 26-gauge stainless steel tubes coated at the tips with estradiol (*7*).

The electrical stimulus was a train of 100 cy/sec, monophasic, negative, 0.1-millisecond square pulses passed through an isolation transformer to exclude direct current and produce a biphasic wave form. The intensities used were between 0.1 and 0.2 ma. All tests were conducted in a 46-cm, circular, opaque, chamber with a glass floor and an underview mirror. For self-stimulation, a lever was mounted on the chamber wall. Each time this lever was pressed it triggered a 0.5-second train of stimulation.

Because rats are most likely to be sexually active at night, dim red illumination was used for observation of behavior during the dark period of a reverse day-night cycle. Brain stimulation tests began a week after the implantation of electrodes. The male rat to be tested was allowed 30 minutes to become acclimated to the observation cage before a female rat was placed in the cage. The male then received continuous brain stimulation in 3-minute periods alternated with 3-minute periods when there was no stimulation. Mounts, intromissions, and ejaculations were recorded on an event recorder.

In these tests copulation became stimulus-bound, that is, the males copulated repeatedly when stimulation was on but seldom when it was off. At the end of one test session the male was resting far from the female while the stimulus was left off for 12 minutes; when the stimulus was again turned on, the male began copulating within 10 seconds (Fig. 1). Even after ejaculating, the male remained sexually excited, often sniffing, nudging, and, in several instances, mounting the female until stimulation terminated (Fig. 1). The other rats behaved similarly (see Fig. 2).

Unlike copulation elicited from the anterior hypothalamus (*8*), the overall frequency of copulation during stimulation was not unusually high. The striking fact is the extent to which stimulation controls copulatory behavior (Figs. 1 and 2). At the beginning of a test session the animals sometimes copulated whether stimulated or not, but after one or two stimulation periods they rarely copulated unless stimulated.

Stimulus-bound copulation was a per-

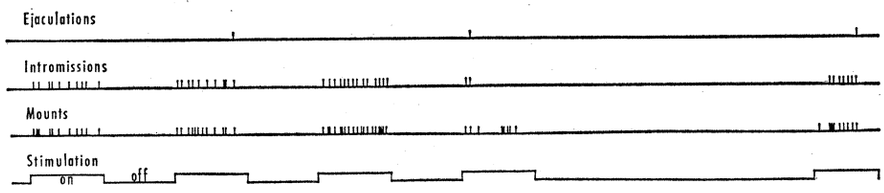

Fig. 1. Copulation during brain stimulation. Electrical stimulation in a posterior hypothalamic self-stimulation site elicits immediate sexual behavior which persists even after ejaculation. Each "on" period lasts 3 minutes.

sistent phenomenon. In one test session lasting 66 minutes (eleven 3-minute periods of stimulation), 115 mounts, 82 intromissions, and 6 ejaculations were recorded. During the eleven 3-minute periods, without stimulation there were only 5 mounts, 5 intromissions, and no ejaculations. Week after week the effect was reproducible in all ten animals. In one animal, stimulus-bound copulation occurred on each of 7 test days over a 4-month period.

Stimulation of the posterior hypothalamus induced copulation, not feeding. Four rats were tested with food, and then with both food and a female rat. Stimulation never elicited eating. If a male in the process of eating was stimulated, he stopped eating and mounted the female.

Males were highly motivated to mate during stimulation. This was demonstrated in two animals. A plexiglass partition with a closed door, separated the male and the female. The door opened when the male pressed a small bar protruding from the partition. If the male did not seek the female and did not copulate within 10 seconds, he was again confined to his side of the chamber. If he did enter the female's compartment and did copulate, he was allowed one intromission before he was returned to his side of the chamber. One rat had prior training in opening the door; the other was trained during stimulation. In both cases, the animals pressed the bar significantly more often when the stimulus was on than when it was off. The animal without prior training pressed the bar to open the door 29 times during nine stimulation periods, and only one time during alternate nonstimulation periods. He copulated within 10 seconds after 14 of the 29 bar presses. The fact that stimulation motivated animals to emit a learned response arbitrarily required by the experimenter shows that stimulus-bound copulation was neither mere indiscriminate activation nor rigid reflex. Stimulation elicited copulation with motivation characteristic of normal sexual behavior.

The same stimulation intensities which elicited copulation were also suitable for self-stimulation. Response rates in daily 10-minute sessions were 50 to 75 presses per minute.

Self-stimulation was sometimes accompanied by a penile discharge containing motile sperm. Five of the ten rats ejected seminal plugs. This usually occurred several seconds after deactivation of the self-stimulation lever. One of the rats exhibited ejaculation on ten different occasions. Penile erection was usually absent during self-stimulation, and neither pelvic thrusts nor the customary post-ejaculatory posture ever occurred in the absence of a female.

Self-stimulation varied positively with the androgen level. To date, two of the rats have been given daily injections of 50 μg of testosterone propionate in oil for 7 days. The self-stimulation rate during the 7 days of injection was compared with the 7-day base line immediately preceding the injections. Such comparison showed that self-stimulation increased 17 percent for one rat and 37 percent for the other rat. After 1 month of self-stimulation tests with no androgen injections (to reestablish the baseline rate) the test was repeated on the first animal. Self-stimulation again increased significantly—this time 23 percent. All increases were statistically significant ($P < .01$). This is similar to Herberg's result (*5*).

	MOUNTS	INTROMISSIONS	EJACULATIONS
STIM. ON	30 (13-61)	18 (7-44)	2 (1-4)
STIM. OFF	1 (0-5)	1 (0-3)	0 (0)

Fig. 2. Control of copulatory behavior by electrical stimulation of the posterior hypothalamus of male rats. Mean values are based on the last 30 minutes of one test session for each of ten rats. Sessions lasted 30 to 75 minutes. Range of individual scores are in parentheses.

Histological examination of the brains revealed that the electrode tips had been in the medial forebrain bundle, just lateral to the fornix at the level of the premammillary nuclei in the posterior hypothalamus.

Thus, self-stimulation in the posterior hypothalamus is related to motivated sexual behavior. Electrical stimulation, like sexual stimulation, heightens sexual excitability to the point of copulation and orgasm and reinforces behavior leading to the stimulus. Therefore neural activity in the posterior hypothalamus may be normally involved in generating the excitement and reward of copulation.

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References and Notes

1. D. L. Margules and J. Olds, *Science* **135**, 374 (1962).
2. B. G. Hoebel and P. Teitelbaum, *ibid.*, p. 375.
3. E. E. Coons, M. Levak, N. E. Miller, *ibid.* **150**, 1320 (1965).
4. J. Olds, *J. Comp. Physiol. Psychol.* **51**, 320 (1958).
5. L. J. Herberg, *ibid.* **56**, 679 (1963).
6. B. G. Hoebel, *Electroencephalogr. Clin. Neurophysiol.* **16**, 399 (1964).
7. R. D. Lisk, private communication.
8. E. Vaughan and A. E. Fisher, *Science* **137**, 758 (1962).
9. Supported by NIH grant MH-08493.
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High-Pressure Reactions and Shear Strength of Serpentinized Dunite

Abstract. *The recently reported pronounced decrease in shear strength of serpentine-bearing rocks at 30 to 40 kilobars in the temperature range 300° to 520°C may be attributed to the transformation of serpentine to a pressure-dependent, 10-angstrom, 2:1 layer silicate plus brucite and periclase. This reaction increases density by about 8.5 percent.*

Riecker and Rooney's (*1*) experimental data show that the shear strength of serpentinite, and of dunite containing about 5 percent serpentine, decreases markedly as the temperature rises from 300° to 520°C under pressures of 30 kb or greater. They concluded that weakening is caused by dehydration of the serpentine. Our recent experimental work (*2*) on the stability of serpentine at high pressure