*Pharmacology Biochemistry & Behavior*, Vol. 18, pp. 605–609, 1983. 

# Psychoneuroendocrine Effects of Neurotoxic Lesions in the Septum and Striatum of Rats[1]

DWIGHT M. NANCE

*Department of Anatomy, Faculty of Medicine*
*Dalhousie University, Halifax, Nova Scotia, Canada, B3H 4H7*

Received 9 August 1982

NANCE, D. M. *Psychoneuroendocrine effects of neurotoxic lesions in the septum and striatum of rats.* PHARMACOL BIOCHEM BEHAV 18(4) 605–609, 1983.—The psychoneuroendocrine effects of electrolytic septal lesions were compared with neurotoxic lesions in the lateral septum or striatum of rats induced by 6-hydroxydopamine (6-OHDA) or kainic acid (KA). Lesion effects were examined in terms of changes in body weight (BWt) regulation, ovarian compensatory hypertrophy (OCH) and female sexual behavior. Septal injections of 6-OHDA selectively reduced septal levels of dopamine (DA) by 60% whereas striatal injections reduced striatal levels of DA by 77% and septal levels by 30%. Significant effects of these various lesions were relative to controls (1) KA lesions in the septum increased and 6-OHDA lesions in the striatum decreased BWt; (2) 6-OHDA lesions in the striatum reduced ovarian weight and KA lesions in the septum increased OCH; (3) electrolytic septal lesions increased and KA septal lesions decreased female sexual behavior; (4) the effects of estrogen on food intake and BWt were attenuated in KA septal lesioned rats. Since this experiment failed to show an inhibitory role for DA on lordotic behavior, in a second experiment brain levels of DA were depleted by 6-OHDA injections in the ventral tegmental area or substantia nigra. Levels of female sexual behavior for these animals were comparable to controls. Thus, decreases in brain levels of DA previously shown to associated with electrolytic septal lesions may not be causally related to the observed increase in lordotic behavior. Lateral septal damage induced by KA appears to modify a variety of estrogen-sensitive systems.

Septum Striatum Kainic acid 6-Hydroxydopamine Lordosis behavior Body weight Ovarian compensatory hypertrophy

WITH respect to the hormone-dependent display of female sexual behavior in the rat, electrolytic lesions in the lateral septum increase behavioral sensitivity to sex steroids [15–17]. This facilitation in lordosis behavior following septal damage is specifically correlated with brain levels of dopamine (DA) in the striatum and GABA levels in the substantia nigra (SN) and ventral tegmental area (VTA) as indexed by the rate-limiting enzyme glutamic acid decarboxylase [4,5]. In contrast, brain levels of norepinephrine and serotonin are not altered by septal lesions.

Consistent with the neurochemical correlates of septal lesions, systemic injections of DA agonist such as amphetamine or apomorphine ([17], and unpublished data) "normalized" the lordotic behavior of septal lesioned rats. In further support of a critical role for DA in mediating the effects of septal damage on lordotic behavior, direct application of GABA receptor blockers to the SN reduced the high levels of lordotic behavior observed in septal lesioned rats [13]. The lateral septum receives a major DA input from the VTA [8, 10, 11] and a glutamine input from the hippocampus [12]. Thus, damage to these neurochemical systems in the lateral septum may reproduce the effects of septal lesions on lordosis behavior. Likewise, direct alterations in DA or GABA activity in the striatum may also modify reproductive function in female rats.

In the first study, the psychoneuroendocrine effects of neurotoxic lesions in the lateral septum or striatum, induced by 6-hydroxydopamine (6-OHDA) or kainic acid (KA) were assessed in terms of alterations in body weight (BWt) regulation, ovarian compensatory hypertrophy (OCH) and lordotic behavior. In a second study the effects of depleting DA levels by 6-OHDA injections into the VTA or SN on lordosis behavior were determined.

## METHOD

In the first study, Simonsen Sprague-Dawley female rats (Gilroy, CA) weighing 200–250 g were housed six to eight per cage, given ad lib access to Purina rat chow and tap water and maintained in a reversed light room (lights on from 11:30 p.m. to 11:30 a.m.). Brain surgery was performed under nembutal (50 mgKg) anesthesia and for gonadectomies, ether was used as anesthesia. The 6-OHDA (8 $\mu$g/$\mu$l+2 $\mu$g ascorbic acid), or KA (0.5 $\mu$g/$\mu$l) was bilaterally infused via a

[1]These results presented in part at the Annual Meeting, Society for Neuroscience, Minneapolis, MN, 1982. Research supported by grants from the Canadian Medical Research Council No. MA6807 and MA6956.

TABLE 1

MEAN (±SE) WEEKLY GAIN IN BWt (g) FOR FOUR WEEKS POST-SURGERY

| Groups | N | Wk 1 | Wk 2 | Wk 3 | Wk 4 |
|---|---|---|---|---|---|
| Sham | 8 | 4.6 ± 2.6 | 16.6 ± 2.4 | 25.4 ± 2.6 | 29.7 ± 3.3 |
| KA Septum | 10 | 6.3 ± 5.0 | 31.6 ± 3.6* | 43.7 ± 3.8* | 52.4 ± 4.8* |
| DC Septum | 8 | −2.5 ± 4.6 | 7.3 ± 4.6 | 22.4 ± 3.3 | 25.9 ± 4.4 |
| 6-OHDA Septum | 7 | 7.3 ± 2.7 | 14.2 ± 2.2 | 26.1 ± 2.7 | 27.4 ± 2.7 |
| 6-OHDA Striatum | 6 | −14.3 ± 5.5* | 1.8 ± 7.3* | 16.2 ± 4.7 | 16.0 ± 5.0 |

*Significantly different from shams; $p<0.05$.

microsyringe (0.5 μl/min) into the lateral septum or striatum. The DeGroot [2] stereotaxic coordinate were 1.5 mm anterior to bregma, lateral 0.65 mm and 4.5 mm below the dura for the septal injections and 1.5 mm anterior to bregma, 3.0 mm lateral and 5.0 mm below the dura for the striatal infusions. Based upon the work of others [1,6] total volume of 1.0 μl was bilaterally infused into the septum whereas 2.0 μl was bilaterally infused into the striatum and the needle was left in place 10–15 min post-infusion. Also included were animals with electrolytic lateral septal lesions produced by passing anodal current (2 mA/20 sec) through a stainless steel insect pin, insulated except for 0.5 mm at the tip. Sham operated rats consisted of animals in which the electrode was lowered into the septum and no current passed or else saline-ascorbic acid infused into the septum or striatum. Weekly BWt was measured post-surgery. Three weeks post-surgery all animals were hemiovariectomized on the left side (weight recorded) and daily vaginal smears were collected for eight days prior to hemigonadectomy. The remaining ovary was removed one week later and weighed and the percent OCH calculated. Tests for female sexual behavior were initiated 2–3 weeks later and consisted of placing the test animal in a Plexiglas arena with 2–3 sexually active Long-Evans hooded male rats until 10–15 vigorous mounts had occurred. A lordosis quotient was computed for each animal by dividing the number of positive lordotic responses by the number of mounts and multiplying by 100. Lordosis behavior was tested under three hormone priming regimens. First, the animals were injected with 2 μg of estradiol benzoate (EB) per day for three days and tested on the fourth day (EB only). Immediately following the first test, animals were injected with 0.5 mg progesterone (P) and tested again 4–6 hr later (EB+P). Two weeks later, animals were tested a final time following a single injection of 2 μg EB and 0.5 mg P 24 hr later (tested 4–6 hr after the P injection) (EB+P−24). Due to an apparent effect of KA injections in the septum on BWt, the KA-septal rats, electrolytic septal lesioned rats (DC) and sham operated rats were placed in individual cages with ad lib powdered Purina rat chow and water and the effects of a 6 μg injection of EB on BWt and food intake (FI) determined.

In a second experiment, the effects of depleting brain DA levels on lordosis behavior was further examined. Briefly, Sprague Dawley CBFL female rats were bilaterally ovariectomized 6–8 weeks prior to brain surgery and weighed 222–297 g at the time of the 6-OHDA injections. The injection procedure and dose of 6-OHDA was identical to the first study. Using DeGroot coordinates [2] animals were bilaterally injected in the SN (3.5 mm posterior to bregma, lateral 2.0 mm and 7.5 mm below the dura) with 1.5 μl of 6-OHDA (8 μg/μl) or else given a single injection of 1.5 μl of 6-OHDA in the VTA (3.5 mm posterior bregma), lateral 0.0 and 7.0 mm below the dura). Sham animals were given saline-ascorbic acid vehicle injections. Beginning 2–3 weeks post-surgery, animals were tested for lordotic behavior under the same three hormone conditions and sequence utilized in the first experiment (EB alone, EB+P and EB+P−24).

Subsequently the DC septal lesioned and KA lesioned rats were perfused with 10% Formalin and the brains removed for histology. However, brain levels of DA in the striatum, septum and nucleus accumbens (including olfactory tubercle) were determined for 6-OHDA injected and sham operated animals from both experiments. Briefly, the animals were decapitated and the brains quickly removed and placed on ice. Tissue samples (20–100 mg) were then dissected out, weighed and then placed in ice cold 0.1 N perchloric acid and 0.1 M EDTA (10 μl/mg tissue). Tissue samples were rapidly sonicated and then centrifuged in a cold room for approximately 5 min at 1100 g. A 100 μl aliquot was then frozen for subsequent assay or else immediately run on a BAS catecholamine analyzer equipped with an electrochemical detector. The HPLC column was a RP8 having a 20 μl injection loop and a flow rate of 2.0 ml/min. Levels of DA were derived by comparison with known standards and subsequently expressed as ng/mg tissue. Data was statistically analyzed by $t$-test, paired $t$-test and, where appropriate, analysis of variance. Probabilities less than 0.05 were regarded as statistically significant.

## RESULTS

All animals survived the brain surgery well except for the group injected with KA in the striatum. With the exception of a single rat, animals injected with KA in the striatum died within 2 days post-surgery. In general, KA injections exerted a rapid activational effect on the animals shortly following injection and consistently produced urination, defecation, hyperventilation and motor activation. The animals also exhibited "piano playing" and other motor abnormalities lasting up to several hours following brain surgery.

Histology indicated that the electrolytic septal lesions bilaterally destroyed the lateral, and occasionally medial septum and were in general comparable to lesions previously reported following similar parameters (see [15]). However, the septal region of the rats injected with KA in the septum were unremarkable at the light microscopic level (50 μm frozen sections). The overall size of the septal region, especially dorsolateral portion, was reduced in size, but all major septal

TABLE 2

MEAN (±SE) PERCENT DAYS OF VAGINAL ESTRUS (E), OVARIAN WEIGHT (mg) AND PERCENT OVARIAN COMPENSATORY

| Groups | N | % Days E | Left ovary (1st) | Right ovary (2nd) | % OCH |
|---|---|---|---|---|---|
| Sham | 8 | 37.5 ± 6.1 | 37.5 ± 1.6 | 44.9 ± 2.1 | 20.5 ± 5.8 |
| KA Septum | 10 | 38.8 ± 3.9 | 35.4 ± 1.2 | 55.6 ± 3.7* | 58.4 ± 10.5* |
| DC Septum | 8 | 18.8 ± 5.8* | 31.1 ± 2.6 | 41.6 ± 3.5 | 36.3 ± 12.4 |
| 6-OHDA Septum | 7 | 48.2 ± 10.4 | 37.4 ± 2.1 | 47.5 ± 2.8 | 36.3 ± 13.3 |
| 6-OHDA Striatum | 6 | 20.8 ± 5.3* | 29.2 ± 2.2* | 43.3 ± 1.8 | 52.5 ± 13.5 |

*Significantly different from shams; $p<0.05$.

TABLE 3

MEAN (±SE) LORDOSIS QUOTIENTS (L.Q.) FOR THREE TESTS AND MEAN (±SE) DOPAMINE (DA) LEVELS (ng/mg) IN THE SEPTUM, ACCUMBENS (Acc.) AND STRIATUM (Str.)

| | | Mean L.Q. | | | Mean DA Levels | | |
|---|---|---|---|---|---|---|---|
| Group | N | EB alone | EB + P | EB + P-24 | Septum | Acc. | Str. |
| Sham | 8 | 22.5 ± 11.8 | 95.5 ± 1.6 | 32.5 ± 11.5 | 0.92 ± 0.10 | 2.74 ± 0.46 | 8.84 ± 0.72 |
| KA Septum | 10 | 9.0 ± 4.6 | 83.0 ± 4.7 | 5.0 ± 3.1* | — | — | — |
| DC Septum | 8 | 60.0 ± 9.4* | 95.0 ± 2.7 | 87.5 ± 4.5* | — | — | — |
| 6-OHDA Septum | 7 | 2.9 ± 1.8 | 95.7 ± 4.3 | 17.1 ± 9.2 | 0.38 ± 0.08* | 3.10 ± 0.37 | 9.61 ± 1.01 |
| 6-OHDA Striatum | 6 | 6.7 ± 2.1 | 90.0 ± 6.8 | 18.3 ± 13.2 | 0.65 ± 0.11 | 2.95 ± 0.43 | 2.05 ± 0.45* |

*Significantly different from shams; $p<0.05$.

nuclei were present and in general not readily distinguishable from normal brains. There was also an absence of gliosis, due perhaps to the long survival time between lesion and sacrifice. There was, however, consistent and selective cell loss in the hippocampus primarily in areas CA3 and occasionally CA4. Despite this inability to demonstrate a definite "lesion" in the animals injected in the septum with KA, the behavioral and endocrine data support the idea that the particular dose of KA utilized in the present study modified septal function. The neurochemical data associated with the 6-OHDA injections (see below) verified the effectiveness of this drug on brain DA levels.

Shown in Table 1 are the average weekly BWt gains for the various groups in the first experiment for four weeks post-surgery. Relative to the sham animals, the KA-septal group showed an increase in weight gain that was statistically significant by the second week post-surgery. The only other effect on BWt was a reduction in BWt for the animals injected with 6-OHDA in the striatum and relative to controls, was statistically significant for the first two weeks post-surgery.

Table 2 summarizes the effects of the various lesions on ovarian function. Considering first the percentage of days of vaginal estrus prior to hemigonadectomy, the groups with DC septal lesions and 6-OHDA lesions in the striatum showed significantly fewer days of vaginal cornification than the sham group. Likewise, these same two groups had smaller ovaries than sham rats at the time of the first hemiovariectomy, but this difference was statistically significant only for the 6-OHDA striatal group. One week following the first hemiovariectomy, the remaining ovary of the KA septal rats was significantly heavier than the ovary of the sham rats and this resulted in significantly greater OCH in the KA septal rats as compared to the controls.

Table 3 summarizes both the female sex behavior tests and neurochemical effects of the 6-OHDA lesions. Considering first the neurochemical results, 6-OHDA injections in the septum selectively reduced septal DA levels by 60%. Striatal injections of 6-OHDA reduced striatal levels of DA by 77%, septal levels by 30% and had no effect on DA levels in the accumbens. For the EB only test the DC septal lesion rats showed a significantly higher L.Q. than all the other groups. For the EB+P test, there was a tendency for the KA septal group to show less female sexual behavior than the sham rats. The final test (EB+P-24) produced the clearest separation of the experimental groups in that the DC septal rats showed significantly higher and the KA septal rats showed significantly lower levels of lordotic behavior relative to sham animals.

At the time the DC septal, KA septal and sham rats were placed in individual cages with powdered rat chow, their average BWts were 312.3±8.0, 335.1±7.3 and 334.6±8.5, respectively. Thus, post-ovariectomy the earlier weight differences between the KA septal and sham rats (Table 1) was reduced and the DC septal rats tended to have lower BWts than the sham rats. There were group differences in the anorexia and BWt suppressing effects of a single 6 $\mu$g injection of EB. Sham rats showed a maximal relative decrease in FI on the 3rd post-injection day and was significantly reduced 10.1±4.1% below baseline FI (computed as

TABLE 4

MEAN (±SE) LORDOSIS QUOTIENTS (L.Q.) FOR THREE TESTS AND MEAN DOPAMINE (DA) LEVELS (ng/mg) IN THE SEPTUM, ACCUMBENS (Acc.) AND STRIATUM (Str.)

| | | Mean L.Q. | | | Mean DA Levels | | |
|---|---|---|---|---|---|---|---|
| Groups | N | EB alone | EB + P | EB + P-24 | Septum | Acc. | Str. |
| Shams | 5 | 5.0 ± 2.6 | 92.0 ± 3.7 | 30.0 ± 13.0 | 1.08 ± 0.12 | 2.91 ± 0.71 | 9.52 ± 1.03 |
| VTA | 5 | 0.0 ± 0.0 | 88.0 ± 7.4 | 6.0 ± 4.0 | 0.13 ± 0.04* | 0.56 ± 0.14* | 2.31 ± 0.64* |
| SN | 4 | 12.5 ± 4.8 | 80.0 ± 13.5 | 0.0 ± 0.0 | 0.81 ± 0.15 | 2.13 ± 0.27 | 2.79 ± 0.47* |

*Significantly different from shams; $p<0.05$.

the mean of the three days prior to EB). FI for the DC septal rats on the same day was significantly reduced by 12.4±4.8%; in contrast, the FI of the KA septal rats was 6.2±9.4% above baseline and not significantly different from pre-injection FI. Similarly, the relative reduction in BWt was less in the KA septal rats than in the other two groups. On day 5 post-injection the BWt of the shams, DC septal and KA septal rats was reduced 3.6±0.2, 5.0±1.4, and 0.7±1.2% below pre-injection BWt's, respectively. Overall, these results suggest that the anorexic effects of EB are reduced in animals with KA septal lesions whereas the DC septal lesioned rats are comparable to sham operated rats.

Summarized in Table 4 are the behavioral and neurochemical data for the SN, VTA and sham operated rats from the second experiment. The 6-OHDA injections in the SN produced a selective decrease in striatal DA of 71%. In contrast, the VTA injection of 6-OHDA reduced septal, accumbens and striatal levels of DA by 88, 71 and 76%, respectively. Despite the major depletion of brain levels of DA, the female sex behavior of the VTA and SN lesioned rats was comparable to the sham animals.

## DISCUSSION

Behavioral and endocrine effects of the various lesions indicated that, relative to controls: (1) KA in the lateral septum increased and 6-OHDA in the striatum decreased BWt; (2) 6-OHDA in the striatum reduced ovarian weight and KA in the septum increased OCH; and (3) DC septal lesions increased whereas KA septal lesions decreased female sexual behavior. The increased weight gain of the KA septal lesioned rats may be due to a lesion induced decrease in responsiveness to the anorexic effects of estrogen on FI and BWt. In support of this, the weight differences between KA septal and sham rats was reduced post-ovariectomy and the KA septal rats were significantly less responsive than the sham rats to exogeneous estrogen in terms of changes in FI and BWt. In fact, the reduced lordosis behavior, reduced effects of EB on FI and BWt and increased OCH shown by the KA septal lesion rats are all suggestive of a generalized alteration in estrogen sensitivity.

The opposite effects of KA and DC septal lesions on lordotic behavior were unexpected, especially in view of the recent demonstration that KA septal lesions were as effective as electrolytic lesions in terms of female sexual behavior [6]. One major difference between this last experiment and the present study is that the KA septal lesions of Gorzalka and Gray [6] were focused in the medial septum whereas in the present study KA was infused into the lateral septum. Other potentially important differences in the two studies are that Gorzalka and Gray [6] noted complete cell loss in the medial septum and major cell loss in the lateral region whereas the septal "damage" observed in the present study was not as easily identified. Relevant to this point is the fact that they used twice the concentration of KA and an extremely slow rate of infusion, both of which would potentiate the toxicity of KA injections. However, the location and extent of hippocampal damage appeared to be identical between the two experiments.

Experimental variation in the extent of KA "lesions" in the septum is further demonstrated by the work of Clough and Rodriguez-Sierra [1]. They injected 2.5 μg of KA in a 2.0 μl volume into the medial septum. Despite dramatic changes in puberty and gonadotropin regulation, they did not report massive cell loss in the septum as observed by Gorzalka and Gray [6]. Only by using the electron microscope were Clough and Rodriguez-Sierra able to detect significant signs of neuronal damage and degeneration ([1], personal communication). Thus, results of the present experiment verify that KA injections in the septum can alter psychoneuroendocrine function in the absence of obvious or massive loss of neurons. Related to this, we have recently found that in terms of lordotic behavior, electrolytic lesions confined to the medial septum are as effective as lesions in the lateral septum (King and Nance, unpublished data). Since the medial septum is a major recipient of efferent output from the lateral septum [19], it is possible that the effects of lateral septal lesions on lordosis are mediated via the medial septum. Given that the moderate concentration of KA infused into the lateral septum in the present study produced very limited or selective neural damage to neurons or afferent systems in the lateral septum, one can speculate that the neural control exerted on the medial septum by the lateral inputs could be modified in these animals. Herein may lie the eventual explanation of the present observation of an actual *decrease* in lordotic behavior in animals infused with KA in the lateral septum.

Munoz and Grossman [14] have reported a transitory hyperphagia produced by very localized KA lesions in the medial septum (i.e., no concurrent hippocampal damage); however, the temporary increase in FI was not reflected in terms of increased BWt. The more persistent effect of KA injections in the lateral septum on BWt reported here may be related to the localization of estrogen concentrating neurons in the lateral septum [18], especially in view of the observation that this effect on BWt appears to depend upon the

presence of intact ovaries or exogenous estrogen treatment. Together, these results suggest that neurons in the septal region may participate in the neural control of energy balance.

The failure to see a potentiation in lordotic behavior in the animals with 6-OHDA lesions in the striatum and possibly septum was another unexpected observation in the present experiment. For example, we have reported previously that, in rats with electrolytic lesions in the lateral septum, striatal levels of DA showed a highly significant inverse correlation with lordotic behavior of estrogen primed rats; i.e., the higher an animal's L.Q. the lower was its brain levels of DA. This lack of effect on lordosis in animals with significant depletion of striatal DA is also contrary to the multitude of pharmacological studies (see [3,20]) demonstrating an inhibitory role for DA on the lordotic response. The results of the second experiment (Table 4) failed to demonstrate an inhibitory role for DA on lordosis behavior. Thus, the present results demonstrate that the proposed inhibitory role of DA on lordotic behavior may be less than direct and major depletion of brain levels of DA is not invariably associated with high levels of female sex behavior. The recent demonstration that 6-OHDA lesions in the ventral noradrenergic pathway produce a decrement in the display of female sexual behavior [7] is particularly relevant. Although norepinephrine levels were not determined in the present studies, it is quite likely that brain norepinephrine could be modified by the present 6-OHDA lesions. Thus, any loss in inhibitory control over lordotic behavior due to reduced DA function may have been counteracted by a concurrent loss of a norepinephrine-dependent facilitory system.

In conclusion, the present experiments indicate a primary involvement of the septal region in a variety of psychoneuroendocrine processes of female rats involving such diverse functions as BWt regulation, lordotic behavior and hypothalamo-pituitary-gonadal regulation. One common feature of all these systems is that they involve a hormone-brain interaction and one essential function of the septum in psychoneuroendocrine control may be the modulation of the actions of sex steroids on brain function. The richness and variety of neural transmitters identified in the septal region [9–12, 21] argue against a quick answer to the functional role of the septum and suggest a level of neural complexity yet to be fully appreciated or understood. However, the present results do indicate that the continued use of various neurotoxic agents may permit a neuropharmacological dissection of the diverse functions of the septal region as well as provide new insight into its organization.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the technical assistance of R. Sanderson, T. R. King and G. Myatt plus the generosity and help of Dr. Harold Robertson with the neurochemical assays.

## REFERENCES

1. Clough, R. W. and J. F. Rodriguez-Sierra. Intrinsic neurons of the septal area are involved in reproductive development of the female rat. *Neuroendocrinology* **33**: 363–371, 1981.
2. DeGroot, J. The rat forebrain in stereotaxic coordinates. *Verh K Ned Acad Wet* **52**: 1–40, 1959.
3. Everitt, B. J., K. Fuxe, T. Hökfelt and G. Jonsson. Role of monoamines in the control by hormones of sexual receptivity in the female rat. *J Comp Physiol Psychol* **80**: 556–572, 1975.
4. Gordon, J. H., D. M. Nance, C. J. Wallis and R. A. Gorski. Effects of estrogen on dopamine turnover, glutamic acid decarboxylase activity and lordosis behavior in septal lesioned female rats. *Brain Res Bull* **2**: 341–346, 1977.
5. Gordon, J. H., D. M. Nance, C. J. Wallis and R. A. Gorski. Effects of septal lesions and chronic estrogen treatment on dopamine, GABA and lordosis behavior in male rats. *Brain Res Bull* **4**: 85–89, 1979.
6. Gorzalka, B. B. and D. S. Gray. Receptivity, rejection and reactivity in female rats following kainic acid and electrolytic septal lesions. *Physiol Behav* **26**: 39–44, 1981.
7. Hansen, S., E. J. Stanfield and B. J. Everitt. The effects of lesions of lateral tegmental noradrenergic neurons on components of sexual behavior and pseudopregnancy in female rats. *Neuroscience* **6**: 1105–1117, 1981.
8. Hervé, S., M. LeMoal and A. Calas. Efferents and afferents of the ventral tegmental-A10 region studied after local injection of [$^3$H] leucine and horseradish peroxidase. *Brain Res* **178**: 17–40, 1979.
9. Jacobowitz, D. M. and M. Palkovits. Topographic atlas of catecholamine and acetylcholinesterase-containing neurons in the rat brain. *Comp Neurol* **157**: 13–28, 1974.
10. Lindvall, O. Mesencephalic dopaminergic afferents to the lateral septal nucleus of the rat. *Brain Res* **87**: 89–95, 1975.
11. Lindvall, O., A. Bjorklund and I. Divac. Organization of mesencephalic dopamine neurons projecting to neocortex and septum. *Advances in Biochemical Psychopharmacology, Vol. 16*, edited by E. Costa and G. L. Gessa. New York: Raven Press, 1977, pp. 39–46.
12. Malthe-Sørenssen, D., E. Adden and I. Walaas. Selective destruction by kainic acid of neurons innervated by putative glutanergic afferents in septum and nucleus of the diagonal band. *Brain Res* **182**: 461–465, 1980.
13. McGinnis, M. Y., J. H. Gordon and R. A. Gorski. Influence of αaminobutyric acid on lordosis behavior and dopamine activity in estrogen primed spayed female rats. *Brain Res* **184**: 179–181, 1980.
14. Munoz, C. and S. P. Grossman. Behavioral consequences of selective destruction of neuron perikarya in septal area of rats. *Physiol Behav* **24**: 779–788, 1980.
15. Nance, D. M., J. Shryne and R. A. Gorski. Septal lesions: Effects on lordosis behavior and pattern of gonadotropin release. *Horm Behav* **5**: 73–81, 1974.
16. Nance, D. M., J. Shryne and R. A. Gorski. Effects of septal lesions on behavioral sensitivity of female rats to gonadal hormones. *Horm Behav* **6**: 59–64, 1975.
17. Nance, D. M., J. E. Shryne, J. H. Gordon and R. A. Gorski. Examination of some factors that control the effects of septal lesions on lordosis behavior. *Pharmacol Biochem Behav* **6**: 227–234, 1977.
18. Pfaff, D. and M. Keiner. Atlas of estradiol-concentrating cells in the central nervous system of the female rat. *J Comp Neurol* **151**: 121–158, 1973.
19. Raisman, G. The connections of the septum. *Brain* **89**: 317–348, 1966.
20. Sandler, M. and G. L. Gessa. *Sexual Behavior: Pharmacology and Biochemistry*. New York: Raven Press, 1975.
21. Wamsley, J. K., S. Young, III and M. J. Kuhar. Immunohistochemical localization of enkephalin in rat forebrain. *Brain Res* **190**: 153–174, 1980.