The effects of dopamine but not apomorphine were attenuated by phenoxybenzamine (0.1 μmol) given previously into the hypothalamus. In contrast, the effects of apomorphine were attenuated by spiroperidol (0.0025 μmol/100 g i.v.). Phentolamine, even in doses as small as 0.005 μmol given centrally, elevated body temperature 1°C for 4–5 h, so precluding testing with an adequate dose-ratio against the agonists. Propranolol was ineffective against both substances. Whereas the effects of apomorphine resembled those of dexamphetamine, doses of methysergide (0.01 μmol/100 g i.v.) that prevented arousal with dexamphetamine did not affect response to apomorphine. The results are compatible with the existence of two types of central dopamine receptor in chickens.

B.A.K. is an MRC Student.

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Origin of dopaminergic afferents to the rat frontal cortex

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(Introduced by L.L. IVERSEN)

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Dopamine is present in two areas of the rat frontal cortex, the medial prefrontal and cingulate cortex, where it is believed to be contained in nerve fibres (Thierry, Stinus, Blanc & Glowinski, 1973; Lindvall, Björklund, Moore & Stenevi, 1974). Using a sensitive radioenzymatic assay for dopamine (DA) and noradrenaline (NA) (Cuello, Hiley & Iversen, 1973) we have mapped the distribution of these two catecholamines in the areas and layers of the prefrontal and cingulate cortex. In particular, we investigated the response of these two catecholamines to lesions designed to deplete selectively either DA or NA in the frontal cortex.

The quantities of DA and NA in the dorsal, and medial prefrontal and cingulate cortical areas are indicated in Table 1. The unilateral injection of 6-hydroxydopamine (6OHDA) 8 μg in 2 μl saline (ascorbic acid 1 mg/ml) into the ascending NA projections in the central tegmental tract (Mason & Iversen, 1975) resulted in an almost complete depletion of the frontal cortex NA. In contrast the content of DA was increased in those areas of frontal cortex believed to contain DA terminals and reduced in areas which contain mainly NA. Thus in the dorsal prefrontal cortex area DA is probably a precursor of

Table 1 The effects of various lesions on the catecholamine content of the rat frontal cortex

	Cortical area assayed	*Dopamine content ng/g*	*% change relative to control*	*Noradrenaline content ng/g*	*% change relative to control*
Control samples	+DPFC	24.6 ± 3.7 (6)	—	134 ± 21 (6)	—
	+MPFC	74.5 ± 11.6 (6)	—	137 ± 23 (6)	—
	+CgFC	48.0 ± 6.4 (5)	—	114 ± 29 (6)	—
6-hydroxydopamine (8 μg/2 μl saline) into ascending noradrenaline bundle	DPFC	14.5 ± 5.6 (7)	−41%	3.2 ± 3.3* (7)	−97.2%
	MPFC	104 ± 25* (7)	+39%	8.2 ± 3.6* (7)	−95.4%
	CgFC	72.4 ± 22.3* (7)	+50%	14.8 ± 7.1* (7)	−87.0%
Electrolytic lesion in ventral tegmental area	DPFC	20.3 ± 14.4 (6)	−6.7%	146 ± 7 (6)	+8.9%
	MPFC	24.8 ± 13.4* (6)	−63%	136 ± 19 (6)	+0.7%
	CgFC	32.2 ± 3.9* (6)	−33%	125 ± 14 (6)	+9.6%
6-hydroxydopamine (4 μg/μl saline) into lateral substantia nigra	DPFC	23.1 ± 3.9 (6)	−7%	138 ± 21 (6)	+2.1%
	MPFC	76.3 ± 41.4 (6)	+3%	120 ± 19 (6)	−13.5%
	CgFC	36.3 ± 2.5* (6)	−25%	109 ± 22 (6)	−4.4%

+ DPFC—Dorsal prefrontal cortex, MPFC—Medial prefrontal cortex, CgFC—Cingulate cortex. Numbers of determinations given in brackets. Statistical analysis by paired *t*-test. Significance (*) taken at $P < 0.05$.

NA. Electrolytic lesions in the ventral tegmental area resulted in a significant depletion of DA from both the medial prefrontal and cingulate cortex but produced no change in cortical NA. The depletion of DA from the cingulate cortex was not complete and indicated the possible presence of a separate group of DA terminals whose cell bodies of origin were outside the ventral tegmentum. Unilateral injections of 6OHDA (4 μg/1 μl) into the substantia nigra produced a small but significant depletion of DA from the superficial layers of the cingulate cortex. These results are consistent with previous fluorescent histochemical findings (Lindvall *et al.*, 1974).

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The actions of cholinomimetics and catecholamines on rat substantia nigra neurones

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Acetylcholine and choline acetylase occur in the substantia nigra (Cheney, Le Fevre & Racagni, 1975) and acetylcholine excites nigra cells (Crossman, Walker & Woodruff, 1974a; Dray & Straughan, 1976). Recent evidence suggests that dopamine is released from dopamine-containing zona compacta neurone dendrites (Geffen, Jessell, Cuello & Iversen, 1976) and iontophoretically applied dopamine produces inhibition or excitation (Dray, Gonye, Oakley & Tanner, 1976). Although there is little noradrenaline in the substantia nigra, histochemical studies reveal a small population of noradrenaline-containing terminals in the zona reticulata. In this study we have examined the characteristics of the acetylcholine and catecholamine receptors of nigra neurones.

Experiments were performed on 150 g female Wistar rats, anaesthetized with urethane (1.5–2 g/kg i.p.). Extracellular recordings were made from single substantia nigra neurones using multibarrel glass microelectrodes (Crossman *et al.*, 1974b). Drugs were applied iontophoretically. The iontophoretic barrels contained acetylcholine, nicotine, carbachol, furtrethonium, atropine, physostigmine, dopamine, adrenaline and noradrenaline, all 0.2 M, pH 4–5.

Acetylcholine has predominantly excitatory effects applied iontophoretically to nigra cells. Of 190 cells tested, acetylcholine (20–60 nA) excited 105 and inhibited 20. Nicotine (30–60 nA) excited 41 and inhibited 2 of 70 cells tested. Furtrethonium (20–60 nA) excited 11 and inhibited 3 of 19 cells tested. Carbachol (20–60 nA) excited 15 and inhibited one of 19 cells tested. All four carbachol responses tested with atropine (40 nA for 45 s) were reversibly inhibited. Atropine blocked two of three actylcholine excitations and both nicotine excitations on which it was tested. Physostigmine (50 nA) applied prior and concurrently with acetylcholine potentiated the acetylcholine response on all five occasions.

Close correlation occurred between the effects following application of noradrenaline and adrenaline to nigra cells. Of 14 cells tested both adrenaline (30–60 nA) and noradrenaline (30–60 nA) excited three cells, inhibited five cells and three gave biphasic responses to both compounds; three cells were unaffected by adrenaline and two of these were similarly unaffected by noradrenaline while the third gave a biphasic response. No such correlation occurs between dopamine and noradrenaline responses. Of 13 cells excited by dopamine (30–60 nA), noradrenaline (30–60 nA) excited four, inhibited three, one was biphasic and five were unaffected. Of eight cells inhibited by dopamine, noradrenaline inhibited five, excited one and had no effect on two. Of 12 cells unaffected by dopamine, noradrenaline inhibited three, excited two, two were biphasic and five were unaffected.

It is suggested that cholinergic excitations are produced by stimulation of a mixed nicotinic/muscarinic receptor while inhibitions may be muscarinic. The catecholamine results are consistent with two populations of adrenergic receptors, one stimulated by dopamine and one by noradrenaline and adrenaline.

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