It should be noted that enhanced secretion was always accompanied (and usually preceded) by an increase in blood flow to the gland, without measurable change in dorsal aortic blood pressure. An increase in blood flow, however, was not the primary stimulus for secretion, since when glandular blood flow was increased by a pump, there was no change in secretory rate (Figure 1). Although an increase in blood flow is not sufficient to cause an increase in duct secretion, it seems to enhance the response (Figure 2), possibly because oxygen supply becomes rate-limiting at high rates of secretion.

In isolated rectal glands perfused with shark Ringer's solution, both vasoactive intestinal peptide and adenosine have been identified as humoral substances capable of stimulating secretion. The present experiments suggest that VIP, but not adenosine, is a factor in mediating the secretory response to volume expansion in vivo. Somatostatin, which inhibits stimulation by VIP (but not by adenosine) of isolated rectal glands, also inhibited secretion by the explanted gland when infused into the gland at a concentration of only 1.4×10^{-7}M. On the other hand, theophylline ($10^{-6} \times 10^{-5}$M) which blocks adenosine stimulation of isolated glands, did not prevent secretion by explanted glands. Furthermore, adenosine (10^{-4}M) produced no change in blood flow or secretory rate when infused directly into the explanted gland. The mechanism of the local vasodilatation induced by volume loading, which permits blood flow to the gland to rise greatly without an increase in perfusion pressure, remainds to be determined.

(4 EFFECT OF GANGLIONIC BLOCKADE ON RESPONSE OF DOGFISH BLOOD PRESSURE, HEART AND RESPIRATORY RATES TO INJECTION OF A GANGLIONIC STIMULATOR AND POTASSIUM ION

David F. Opdyke, Nancy E. Keller and Karen E. Holmes, Department of Physiology, CMDNJ-New Jersey Medical School, Newark, N.J.

The systemic arterial pressor response of dogfish (Squalus acanthias) to both a ganglionic stimulator, 1,1-dimethyl-4-phenylpiperazinium (DMPP) and potassium ion (K^+) is catecholamine (CA) mediated (Opdyke et al., Comp. Physiol. Biochem., 42A:611-620, 1972; Opdyke et al., Am. J. Physiol., 241:R228-232, 1981). This poses the question: Is the release of CA initiated by each of these treatments caused by neurogenically mediated stimulation of chromaffin cells, or, are the mechanisms of inducing CA release basically different? The following experiments were undertaken to illuminate this question.

Materials and Methods

The dorsal aortae of unanesthetized, healthy dogfish caught by gill-netting in Frenchman Bay, Maine were catheterized via the caudal artery. The fish were placed in a long and narrow restraining box provided with a flow-through of cold sea-water. Phasic dorsal aortic blood pressure (DAP) was monitored by a P23AA Statham gage and transcribed on an E for M CRO recorder. Heart rates were obtained from the blood pressure records. A sea-water filled P260 polyethylene catheter was inserted into the pharyngeal cavity through a spiracle and the changes in pressure associated with gill ventilation were recorded by another P23AA Statham gage. All drug injections and infusions (Harvard infusion pump) were made through the dorsal aortic catheter during a brief interruption of pressure recording. All drugs were prepared in the appropriate dose and delivered in 1 ml elasmobranch saline with allowance for catheter dead space. Control injections of 1 ml saline were made in 10 dogfish. The responses to injections of DMPP (0.2 mg/kg) and K^+ (0.05 mEq/kg) were observed before and after a 10 min continuous infusion of hexamethonium (0.83 mg/kg/min). Twenty min were allowed for recovery between the injections of DMPP and K^+, which were given in alternating order. The significance of the results was assessed by the application of Student's paired t test ($\alpha = 0.05$) with the aid of a programmed calculator.

Results and Discussion

Table 1 presents the results of these experiments. Both DMPP and K^+ gave highly significant pressor responses before infusion of hexamethonium. Infusion of hexamethonium did not result in a sustained change in DAP, although a small but significant increase did occur early on during the infusion period. DAP did not increase significantly in response to DMPP following hexamethonium infusion, but the pressor response to K^+ was not attenuated. No significant changes in heart rate or respiratory movement rate occurred in response to injections of DMPP or K^+ either before or after hexamethonium injection. A progressive increase in heart rate occurred during hexamethonium infusion which was not accompanied by any significant decrease in DAP or change in respiratory rate. The ability of the fish to respond to direct catecholamine stimulation after hexamethonium infusion was tested by injecting norepinephrine (2 μg/kg). A pressor response was obtained that was consistent with the dose of norepinephrine administered.

TABLE 1

RESPONSE TO 1,1-DIMETHYL-4-PHENYLPIPERAZINIUM (DMPP) AND K^+ BEFORE AND AFTER HEXAMETHONIUM INFUSION

TREATMENT	DORSAL AORTIC BLOOD PRESSURE ± SE Systolic/Diastolic mm Hg	HEART RATE ± SE	RESPIRATORY RATE ± SE
DMPP before hexamethonium 0.2 mg/kg n = 13	Control		
	25.4 ± 1.3/16.8 ± 0.9	18.6 ± 1.5	37.8 ± 1.9
	Response		
	41.9 ± 2.0/26.7 ± 1.3**	18.7 ± 1.8	38.4 ± 1.9
K^+ before hexamethonium 0.05 mEq/kg n = 13	Control		
	25.5 ± 1.7/17.0 ± 0.5	20.1 ± 1.4	40.0 ± 1.3
	Response		
	40.0 ± 1.6/24.0 ± 1.2**	20.3 ± 1.1	39.1 ± 1.6
Before & after hexamethonium infusion 0.83 mg/kg/min n = 13	Control		
	31.3 ± 1.5/20.6 ± 0.9	20.7 ± 1.1	38.2 ± 1.8
	1 min infusion		
	33.6 ± 1.7/22.2 ± 1.0*	23.1 ± 1.5*	38.4 ± 1.8
	5 min infusion		
	29.5 ± 1.4/21.3 ± 1.2	25.2 ± 1.3*	37.5 ± 1.8
	10 min infusion		
	31.0 ± 1.8/21.2 ± 1.0	26.5 ± 1.2**	37.6 ± 1.8
DMPP after hexamethonium infusion n = 13	Control		
	31.6 ± 1.7/21.6 ± 0.9	26.5 ± 1.2	37.2 ± 1.8
	Response		
	43.8 ± 1.6/29.8 ± 1.2**	28.3 ± 1.1	37.0 ± 1.6
Norepinephrine 2 μg/kg after hexamethonium n = 13	Control		
	35.4 ± 1.4/25.2 ± 0.6	27.3 ± 0.8	38.4 ± 1.5
	Response		
	42.6 ± 1.4/28.5 ± 0.7**	27.5 ± 0.9	38.7 ± 1.5
1 ml saline control injection n = 10	Control		
	26.1 ± 1.6/16.7 ± 0.8	18.6 ± 1.9	38.5 ± 1.7
	Response		
	26.5 ± 1.6/16.4 ± 0.9	18.8 ± 1.8	38.8 ± 1.6

*$p<0.05$; **$p<0.005$

Since DMPP is a sympathetic ganglionic stimulator and hexamethonium is a specific ganglionic blocker, these results strongly suggest that the release of CA by DMPP is neurogenically mediated. This is a curious finding, since the presence of a functional sympathetic nervous system affecting the peripheral circulation in the dogfish has not been proven. Embedded in the kidney are what appear to be ganglion cells intertwined with the

chromaffin cells. This is not surprising, since these cells have a common embryological origin. The fact that hexamethonium blocks CA release by DMPP, but not by K^+, suggests that the ganglion cells are involved in a release mechanism, but it does not necessarily imply that a sympathetic reflex pathway for initiating CA release from chromaffin cells exists in the dogfish. This research was supported by a grant from the American Heart Association-New Jersey Affiliate, Central New Jersey Chapter.

15 THE FEEDING AND BURROWING MECHANISM IN THE SAND DOLLAR ECHINARACHNIUS PARMA

Joe Ghiold, Institut f. Geologie und Paläontologie der Universität Tübingen, Tübingen, Germany-W.

Microarchitectural and experimental studies of the echinoid Echinarachnius parma show the importance of spines and podia in the feeding and burrowing process. Scanning electron photographs reveal five structurally distinct spines. These include club, miliary, marginal, locomotive and geniculate spines. Aboral spines (club and miliary) form a two-tiered canopy which acts like a sieve to sort and dismember particles. Potential food matter that is passed posteriorly by these spines (and ambulacral podia) can fall between the spine canopy where they are swept away by ciliary currents flowing continuously past the spine bases towards the test martins. Pores at the distal ends of miliary spines and from small domes on the animal's epidermis are the sites of mucus secretion. Food is loosely aggregated by the mucus secretions to facilitate handling of microscopic particles in the ciliary currents. At the food grooves, aggregated food particles are passed towards the mouth by geniculate spines and podia on and within the groove. Aboral ambulacral tube-feet form five complicated radial bands extending from the petalloid region to the marginal fringe. They actively gather and draw particles to the test edge and then bring them aborally. They assist the aboral spines in moving particles posteriorly over the test.

Sand dollars are found mostly in 2-3 ϕ sand grains. When placed in artifically sorted sand fractions, the sand dollars tolerated a wider range of substrata than that reported for other sand dollar species. It is the podia that are chiefly responsible for the wider geographic distribution of this echinoid. When marginal spines are surgically removed the animals continue to burrow in all sediment grades suggesting that the podia are chiefly involved in the burrowing process.

E. parma occurs intertidally and to depths of about 1600 meters. Distribution and sediment type in the intertidal and in the shallow subtidal range was studied at 3 sites in Frenchmen's Bay, Maine. Within these two zones distribution was influenced by sand grain size; lower densities of E. parma were found in the silty-mud bottom of the subtidal zone while greater numbers were reported for the medium-fine sand regions (intertidally).

E. parma could right itself in artificial and control sediments using a combination of spine and podia movements. The righting reaction is completed in anywhere from 10 minutes to 3 hours. A thick layer of sediment is required under the animal to falicitate righting. Sand dollars can burrow in 8 - 15 minutes in the host sediment. Burrowing is achieved by the action of the ventral locomotive spines and the movement of particles over the test by the aboral spines and podia.

Burrowing and feeding are accomplished by the echinoid simultaneously through spine and podia manipulation. This works was funded by the Sonderforschungsbereich 53 ("Palökologie"), Tübingen, whose financial support by the Deutsche Forschungsgemeinschaft is acknowledged. I thank Ms. Maria Durig for assistance in the field and in the laboratory.