normal stimulus to thirst, as is the dehydration used in our experiments.

Our experiments do not indicate the source of the endogenous angiotensin blocked by P-113. However, since both angiotensin (*7*) and its analogs (*15*) in plasma can cross portions of the blood-brain barrier and gain access to dipsogenic sites in the brain, we believe that angiotensin from the plasma of the dehydrated rats crossed the blood-brain barrier, and that this was the source of the endogenous angiotensin blocked by the intraventricular P-113. Consistent with this hypothesis are the recent findings in rats that 24-hour dehydration increases the plasma concentration of angiotensin 2½ times and that the individual increments in plasma angiotensin correlate positively with water intake (*16*).

While it is clear that blocking endogenously generated angiotensin attenuates the thirst induced by water deprivation, it is also evident that angiotensin receptors blocked by P-113 cannot be the sole regulators of thirst because most of the rats receiving P-113 did finally begin to drink; thus, other receptor mechanisms are also involved.

RICHARD L. MALVIN
DAVID MOUW
ARTHUR J. VANDER
Department of Physiology, University of Michigan, Ann Arbor 48109

References and Notes

1. J. T. Fitzsimons, *J. Physiol. (London)* **201**, 349 (1969).
2. ——, *Physiol. Rev.* **52**, 468 (1972); W. B. Severs and J. Summy-Long, *Life Sci.* **17**, 1513 (1975).
3. S. F. Abraham, R. M. Baker, E. H. Blaine, D. A. Denton, M. J. McKinley, *J. Comp. Physiol. Psychol.* **88**, 503 (1975).
4. R. L. Malvin, D. R. Mouw, A. J. Vander, C. Gregg, in *Proceedings of Symposium, January 12 to 15, Houston, Texas: Central Actions of Angiotensin and Related Hormones* (Pergamon, New York, in press).
5. A. Epstein, *Am. J. Physiol.* **199**, 964 (1960).
6. M. Tang and J. L. Falk, *Pharmacol. Biochem. Behav.* **2**, 401 (1974); S. A. Malayan and I. A. Reid, *Endocrinology* **98**, 329 (1976).
7. J. Summy-Long and W. B. Severs, *Life Sci.* **15**, 569 (1974).
8. A. K. Johnson and J. E. Schwob, *Pharmacol. Biochem. Behav.* **3**, 1077 (1975).
9. S. F. Abraham, D. A. Denton, M. J. McKinley, R. S. Weisinger, *ibid.* **4**, 243 (1976).
10. J. E. Schwob and A. K. Johnson, *Neurosci. Abstr.* (1975).
11. K. Olsson, *Acta Physiol. Scand.* **94**, 536 (1975).
12. J. R. Blair-West, A. H. Brook, P. A. Simpson, *J. Physiol. (London)* **226**, 1 (1972).
13. H. F. Oates and G. S. Stones, *Clin. Exp. Pharmacol. Physiol.* **1**, 495 (1974).
14. D. J. Ramsey, I. A. Reid, W. F. Ganong, *Fed. Proc. Fed. Am. Soc. Exp. Biol.* **25**, 620 (abstr.) (1976).
15. W. E. Hoffman and M. I. Phillips, *Brain Res.* **109**, 541 (1976).
16. A. E. Abdelaal, P. F. Mercer, G. J. Mogenson, *Pharmacol. Biochem. Behav.* **4**, 317 (1976).
17. We thank J. Hoogland and S. Schock for technical assistance, and Norwich Products, Norwich, N.Y., for providing the P-113. This work was supported by grants from the National Science Foundation (BMS 74-20455), the National Institutes of Health (1R01-NS12825-01), and the Michigan Kidney Foundation.

27 October 1976; revised 4 January 1977

Siamese Cats: Abnormal Responses of Retinal Ganglion Cells

Abstract. *Comparison of optic tract recordings in Siamese and ordinary cats reveals that Siamese cats have a significantly lower percentage of Y-cells than of X-cells. In addition, Siamese cats show depressed responses to a contrast-reversal stimulus, a result that supports the lower spatial contrast sensitivity demonstrated behaviorally by these animals. Both physiological findings suggest neurophysiological anomalies in the Siamese retina.*

It has been well documented that some of the retinogeniculate fibers in the Siamese cat's visual pathway are misrouted (*1–4*). Furthermore, the geniculocortical pathway of these animals is also different from that of ordinary cats (*5–7*), and this aberrance may involve more than just the lateral geniculate nucleus (LGN) and the cortex (*8*).

The physiological consequences of abnormal projections in the central visual pathways of Siamese cats include not only suppression of certain inputs (*7*) but also the apparent loss of binocularity in cortical neurons (*6, 7, 9*), in which binocular excitation is routinely demonstrated in ordinary cats (*10*). This latter finding has been used to explain the apparent lack of stereopsis (*11*), as well as the existence of a convergent squint in Siamese cats (*6*).

Table 1. Relative frequency of X- and Y-units in the optic tract of Siamese and ordinary cats. Corrected $\chi^2 = 19.38$; $P < .001$.

Type of units	Siamese cat		Ordinary cat	
	N	Percent	*N*	Percent
X-cells	125	92	57	68
On-center	85		43	
Off-center	40		14	
Y-cells	11	8	27	32
On-center	4		9	
Off-center	7		18	
Totals	136	100	84	100

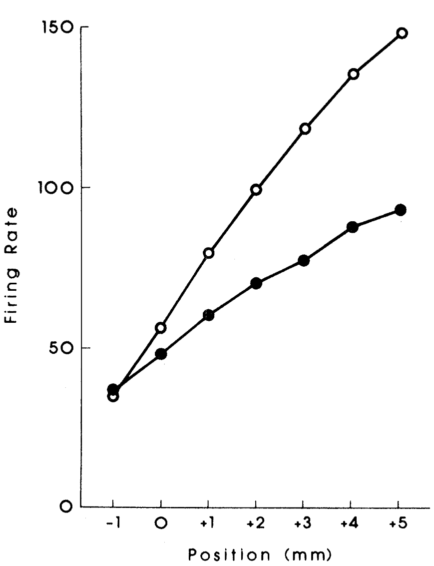

Fig. 1. Responses of optic tract fibers in Siamese (●) and ordinary (○) cats to contrast. Averaged maximum firing rate (impulses per second) to an edge pattern turned on and off in various positions across the receptive field. Position 0 indicates the null position for X-cells and the equal-response position for Y-cells. Contrast of target, 82 percent; background luminance, 0.86 cd/m²; 1 mm = 4.3′ of arc.

Siamese cats display depressed spatial contrast sensitivity compared to that in ordinary cats (*12*), a phenomenon which implies that the physiological characteristics of neurons in the visual system of these animals may be different in some respects. Since certain properties of retinal ganglion cells (for example, classification as X- or Y-cells) may be related to visual acuity (*13, 14*), we felt it important to begin our studies at the retinal level.

We have been investigating the responses of the Siamese cat's retinal ganglion cell, and now report observations on 136 optic tract fibers obtained from three Siamese cats and 84 optic tract fibers obtained from three ordinary cats. We have found that (i) the ratio of Y- to X-cells in the Siamese cat is significantly lower than that in ordinary cats; and (ii) the response to contrast in Siamese ganglion cells, as measured electrophysiologically, is depressed.

Conventional techniques were used to record extracellular action potentials from optic tract fibers. A 3° bipartite field whose contrast reversed every 0.5 second was used to classify all of the cells into X- and Y-types (*15*). The same stimulus configuration, electrodes, and recording conditions were used in the experiments on ordinary cats.

Table 1 shows the relative numbers of X- and Y-cells in Siamese and normal cats. Only 8 percent of the Siamese units are classified as Y-type compared with 32 percent of ordinary cat units. This lower percentage of Y-units is not specific to either on- or off-center cells nor to normally routed or misrouted fibers (*16*). Furthermore, more than 90 percent of the receptive fields encountered in these experiments were located no more than 30° from the area centralis for both breeds. After determining the null position for the bipartite field with respect to the receptive field center, the alternating stimulus was moved by small increments (1 mm = 4.3′ of arc) to either side of the null position, and the responses were measured. In Fig. 1, the maximum firing rate is plotted as a function of eccentricity from the null position. Lower firing rates exhibited by Siamese units support the behavioral findings of Blake and Antoinetti (*12*) that Siamese cats exhibit reduced overall contrast sensitivity.

The decreased Y/X ratio we found is not easily explained, but it conflicts with the hypothesis that the "visual system of the Siamese cat is composed predominantly of Y-cells" (*12*, p. 110). The significance of this ratio and visual acuity in Siamese and normal cats has not yet been established, although several studies have suggested a possible relationship between X-cell properties and visual acuity in ordinary cats (*13, 14*). Since Siamese retinal ganglion cells reveal no reduction in the percentage of X-cells, compared with ordinary cats, the data are consistent with an earlier finding (*11*) that the two kinds of cats have similar acuity. It is not clear, however, whether the Y/X ratio can account for the lower spatial contrast sensitivity found behaviorally in Siamese cats, or whether this phenomenon is simply a function of the lower firing rates exhibited by the Siamese retinal ganglion cells in response to contrast.

The lack of pigment in the retinal epithelium in Siamese cats is well known (*17*). Our results indicate that the retinal neurophysiology of these animals may also differ from that of ordinary cats. The ultimate source of this difference probably lies distal to the ganglion cells.

YUZO M. CHINO
MICHAEL S. SHANSKY
Division of Visual Science, Illinois College of Optometry, Chicago 60616
D. I. HAMASAKI
Bascom Palmer Eye Institute, William L. McKnight Vision Research Center, University of Miami, Miami, Florida 33136

References and Notes

1. The optic-nerve fibers that originate primarily from a vertical strip of retina about 20° to 25° in width lying just temporal to the area centralis are misrouted in the optic chiasm so that they project to the LGN of the contralateral side of the brain. As a result of this misrouting, the sequential representation of the visual field within lamina A1 of the LGN is not only disrupted, but the visual field representation by the abnormal segment of lamina A1 is reversed.
2. R. W. Guillery, *Brain Res.* **14**, 739 (1969); ——— and J. H. Kaas, *J. Comp. Neurol.* **143**, 73 (1971).
3. R. W. Guillery, V. A. Casagrande, M. D. Oberdorfer, *Nature (London)* **252**, 195 (1974).
4. R. E. Kalil, S. R. Jhaveri, W. Richards, *Science* **174**, 302 (1971).
5. Some investigators [for example, (*6*)] report that the fibers, originating from the abnormal part of lamina A1 of the LGN are rerouted and project to a separate location in the visual cortex, resulting in the displacement of the zero vertical meridian representation from the border between areas 17 and 18. Others (*3, 7*) have not found such rerouting.
6. D. H. Hubel and T. N. Wiesel, *J. Physiol. (London)* **218**, 33 (1971).
7. J. H. Kaas and R. W. Guillery, *Brain Res.* **59**, 61 (1973).
8. N. Berman and M. Cynader, *J. Physiol. (London)* **224**, 363 (19→ R. H. Lane, J. H. Kaas, J. M. Allman, *Brain Res.* **70**, 413 (1974).
9. S. J. Cool and M. L. J. Crawford, *Vision Res.* **12**, 1809 (1972).
10. H. B. Barlow, C. Blakemore, J. D. Pettigrew, *J. Physiol. (London)* **193**, 327 (1967); P. O. Bishop, G. H. Henry, C. J. Smith, *ibid.* **216**, 39 (1971); D. H. Hubel, T. N. Wiesel, *ibid.* **160**, 106 (1962); D. E. Joshua. P. O. Bishop, *Exp. Brain Res.* **10**, 389 (19→ T. Nikara, P. O. Bishop, J. D. Pettigrew, *ibid.* **6**, 353 (1968); J. D. Pettigrew, T. Nikara, P. O. Bishop, *ibid.* **6**, 373 (1968); ———, *ibid.*, p. 391.
11. J. Packwood and B. Gordon, *J. Neurophysiol.* **38**, 1485 (1975).
12. The animals of R. Blake and D. Antoinetti [*Science* **194**, 109 (1976)] exhibited (i) a lower overall spatial contrast sensitivity, (ii) a lower high-frequency cutoff point, and (iii) less falloff in sensitivity at low spatial frequencies.
13. C. Enroth-Cugell and J. G. Robson, *J. Physiol. (London)* **18**, 517 (1966).
14. K. B. Franklin, H. Ikeda, S. G. Jacobson, W. I. McDonald, *ibid.* **254**, 114p (1975); H. Ikeda and M. J. Wright, *Vision Res.* **12**, 1465 (1972); *Brit. J. Ophthalmol.* **58**, 165 (1974).
15. Those cells which showed a null position (linear spatial summation) in the receptive field were classified as X-cells according to the designation of Enroth-Cugell and Robson (*13*); those cells which failed to show a null position (nonlinear spatial summation) were classified as Y-cells. However, because most units do not show perfect linear spatial summation, a more objective method had been used to segregate cells. From the responses obtained with the stimulus at the null or equal response position, the firing rate at the time of the maximal response was compared with the firing rate 300 msec later. When the distribution of the ratios of the two firing rates was plotted for all cells, two groups of cells were found; those with high ratios ($\bar{X}$ = 0.68) were classified as X-cells by their histograms, and those with low ratios ($\bar{X}$ = 0.04) were classified as Y-cells (two-tailed *t*-test, $P < .001$). The two groups of cells can be shown to arise from two populations (D. I. Hamasaki and V. Sutija, in preparation). For surgical details, see R. N. Winters and D. I. Hamasaki [*Vision Res.* **16**, 36 (1976)].
16. Nine percent (3/35) of misrouted fibers compared to 8 percent (8/101) of normally routed fibers were classified as Y-units. In addition, the Siamese cats in these experiments all exhibited a convergent strabismus (optic disk separations of 16.2°, 21.6°, and 24°) when compared with a control group of ten normal cats (optic disk separations ranging from 33.5° to 48.2°) (Y. M. Chino, M. S. Shansky, and D. I. Hamasaki, in preparation).
17. R. W. Guillery and J. H. Kaas, *Science* **180**, 1287 (1973); K. J. Sanderson, R. W. Guillery, R. M. Shackelford, *J. Comp. Neurol.* **154**, 225 (1974).
18. Supported by NIH grants EY01444 and EY00701. We thank O. Navarro for technical assistance, H. Cohen for assistance in data collection, and J. M. Lelko for manuscript preparation.

5 November 1976; revised 11 January 1977

Efflux of Cyclic Nucleotides from Rat Pineal: Release of Guanosine 3′, 5′-Monophosphate from Sympathetic Nerve Endings

Abstract. *Potassium and norepinephrine stimulate the efflux of adenosine 3′,5′-monophosphate (cyclic AMP) and guanosine 3′,5′-monophosphate (cyclic GMP) from intact pineal glands. The postsynaptic β-adrenergic receptor mediates the efflux of cyclic AMP. In contrast, the efflux of cyclic GMP requires calcium and intact nerve endings. It appears that sympathetic nerve endings may release cyclic GMP into the synaptic space.*

Adenosine 3′,5′-monophosphate (cyclic AMP) has been shown to act intracellularly as a second messenger in the action of several hormones (*1*). In addition, the release of cyclic AMP into perfusates or culture media by a variety of tissues (*2*) and cells (*3*), including brain (*4*), has been described. Although extracellular cyclic AMP plays an important role in intercellular communication in slime molds (*5*), its roles in mammalian systems have not been elucidated.

Guanosine 3′,5′-monophosphate (cyclic GMP) has been shown to increase in response to neurotransmitters and depolarizing agents in several tissues (*6*), including brain (*7*). It has been proposed that cyclic GMP may act intracellularly to elicit effects which oppose, or differ from, those of cyclic AMP (*8*). Extracellular cyclic GMP has been shown to increase in plasma in response to norepinephrine (*9*). Recently, Kapoor and Krishna demonstrated the secretagogue-stimulated elevation of both intracellular and extracellular cyclic GMP in the exocrine pancreas (*10*).

In the rat pineal gland, cyclic AMP mediates the postsynaptic effects of the neurotransmitter norepinephrine (*11*). The gland is innervated exclusively by noradrenergic nerves whose cell bodies lie in the superior cervical ganglia (*12*). Stimulation of the β-adrenergic receptors leads to the induction of serotonin *N*-acetyltransferase and ultimately to the synthesis and secretion of the hormone melatonin (*11*). In addition, norepinephrine and depolarizing agents increase the concentration of cyclic GMP in the pineal gland (*13*). A major component of the effect on cyclic GMP concentrations depends on the presence of intact nerve endings in the gland (*13*). We therefore examined the possibility that cyclic nucleotides might be released by the rat pineal, and, in particular, by the sympathetic nerve endings which it contains. Our results indicate that the efflux of both cyclic nucleotides can be elicited from intact glands. However, the release of cyclic AMP differs from that of cyclic GMP. Cyclic AMP appears to be released from postsynaptic sites on paren-