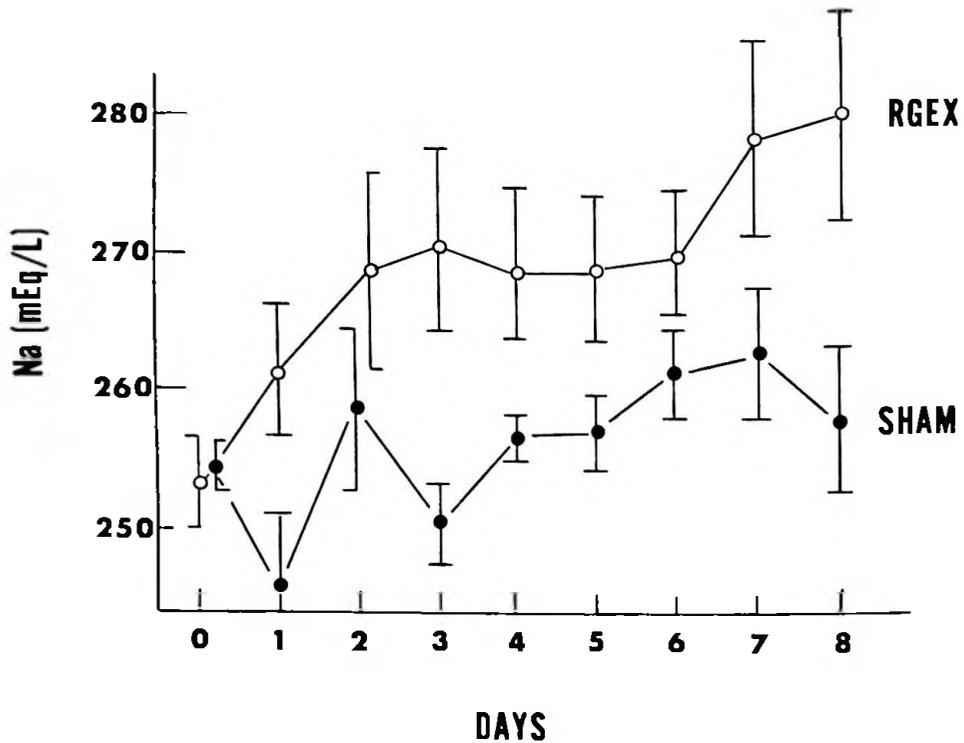


## PLASMA SODIUM



The present series of experiments emphasize the importance of the rectal gland in the maintenance of a normal serum sodium in *Squalus acanthias*. It is apparent that homeostasis requires the presence of both the rectal gland and kidney and that in the absence of the rectal gland the kidney is not capable of excreting the normal daily load of sodium without the development of hypernatremia.

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### TRANSPORT OF FLUID AND ELECTROLYTES BY URINARY BLADDER OF THE AGLOMERULAR MARINE TELEOST *Lophius americanus*

Roy P. Forster and John W. Danforth, Dartmouth College, Hanover, New Hampshire

This study is a continuation of preliminary investigations of the osmoregulatory role of the urinary bladder. We showed that Na is actively extracted from bladder urine in stenohaline marine teleosts and that its transfer to plasma is coupled with the reabsorption of a solute-linked essentially isosmotic fluid from which free water presumably is generated eventually by the excretion of univalent ions at the gills (Bull. MDIBL 12:35-37, 1972). The model to be tested in our current experiments on aglomerular goosefish calls for the formation of a tubular urine that is hypertonic to plasma

The hypothesis assumes that the gills ultimately perform most of the work by the active extrusion of sodium chloride thereby gaining water to balance osmotic loss (Smith, H.W. Am. J. Physiol. 93: 480-505, 1930; Maetz, J. Phil. Trans. R. Soc. Lond. B 262:209-249, 1971).

Freshly captured goosefish taken by otter trawl were maintained in rapidly running aerated seawater. The fact that in this species the right and left kidneys are entirely separate permitted us to conduct "bypass" experiments in which the ureter on one side was cannulated and urine from it collected exteriorly in a detachable rubber balloon. Urine formed in the contralateral kidney was allowed to drain through its intact ureter into the characteristically large urinary bladder where it was allowed to remain usually for 12-hour collection periods before the indwelling cannula placed in the urinary papilla was unplugged. Experiments were conducted on 12 goosefish with right and left ureters alternately exteriorized. Blood samples were taken by syringe from caudal vessels. Three or four urine collections were made in each experiment but because of the progressive "laboratory diuresis" that these animals characteristically undergo in acute experiments such as these the results reported here are from data taken from the first collection period only. Na and K determinations were made by flame photometry, Ca, Mg and SO<sub>4</sub> by atomic absorption spectrophotometry, Cl by coulombmetric titration, and osmometry by freezing point depression.

TABLE  
COMPARISONS OF "RENAL" AND "BLADDER" URINE IN  
COMPARABLE EXPERIMENTS ON FOUR GOOSEFISH

Sample	Volume (ml)	Na <sup>+</sup>	Cl <sup>-</sup> (mmoles/L)	Mg <sup>++</sup>	Osmolarity (mosmoles/L)
Lophius #5, 0.9 Kg					
Plasma		190	184	0.7	367
"Renal"	29.0	140	257	50.0	448
"Bladder"	17.8	48	196	78.5	335
Lophius #7, 3.05 Kg					
Plasma		172	176	0.6	341
"Renal"	32.5	135	270	93.0	458
"Bladder"	21.5	33	205	124.0	345
Lophius #10, 3.16 Kg					
Plasma		182	193	0.3	367
"Renal"	53.0	145	279	78.0	520
"Bladder"	37.5	25	195	88.0	392
Lophius #11, 2.2 Kg					
Plasma		186	-	0.8	333
"Renal"	29.0	183	-	99.0	554
"Bladder"	22.0	18	-	132.0	382

The principal findings in these bladder "bypass" experiments are as follows. The volume of "bladder urine" was reduced by almost 40 percent during the 12-hour collection periods. Plasma osmolar concentrations were approximately 350 milliosmoles per liter. Renal urine collected from ureteral catheters which had been advanced up close to the collecting ducts was significantly hyper-

osmotic to plasma averaging 495 milliosmolar. This is presumably due to the establishment by divalent ion secretion of a hypertonicity in or between the tubular cells which drives the fluid volume flow. Bladder urine was approximately isosmolar with plasma. The high water permeability of urine bladder epithelium in this stenohaline marine fish stands in contrast to the bladders of all fresh water fishes which are relatively impermeable to water. In the latter the osmotic gradient is reversed and impermeability to water prevents osmotic back-flow into plasma from the characteristically large volume of very dilute urine that is generated by distal tubule activity and by the additional salt-saving operation of bladder epithelium. In fresh water teleosts bladder urine is approximately one-tenth of the plasma osmolarity (Hickman, C.P., Jr. and B.F. Trump. *The Kidney in Fish Physiology*, Hoar, W.S. and D.J. Randall, eds., Vol. 1:91-239, 1969. Academic Press, N.Y.). Euryhaline fishes seem able to modify the water permeability of the urinary bladder from the more permeable sea water state to the relatively impermeable fresh water state depending upon environmental salinity. The hormone prolactin is involved in these adaptive modifications (Hirano, T., D.W. Johnson, H.A. Bern and S. Utida. *Comp. Biochem. Physiol.* 45A:529-540, 1973).

Sodium concentrations were markedly reduced in bladder urine and other univalent ions to a somewhat lesser degree. In goosefish with plasma sodium concentrations averaging 183 meq per liter "renal urine" contained 151 and "bladder urine" had only 31 meq per liter. The bladder epithelium is quite impermeable to divalent ions; Mg concentrations for example show corresponding rises accompanying the simultaneous reabsorption of Na and the associated reduction in volume of bladder fluid. In plasma the average Mg concentration was 0.60 mmoles per liter, while the average concentration in "renal urine" was 80 and bladder urine contained 111 mmoles per liter. The bladders of euryhaline teleosts, including the aglomerular toadfish *Opsanus* are also capable of avidly reabsorbing Na and Cl and it has been shown that on occasions concentrations of the latter may be reduced to nondetectable levels while urine is stored in the bladder (Lahlou, B., I.W. Henderson and W.H. Sawyer, *Am. J. Physiol.* 216: 1266-1272, 1969). Essentially chloride-free urine hypotonic to plasma is characteristic of residual samples obtained from fish bladders immediately after capture in both glomerular and aglomerular marine teleosts (Forster, R. P. *J. Cell. and Comp. Physiol.* 42:487-510, 1953).

In summary the reduction of urine volume during storage in bladders of marine stenohaline teleosts appears to play an osmoregulatory role by providing an approximately 0.5 osmolar fluid (in *Lophius*) for absorption into plasma and desalination subsequently at the gills. Use of this device makes the generation of free water thermodynamically "cheaper" than by the derivation of fluid from its principal source in these forms, i.e., via ingestion of sea water and the absorption of an osmolar solution of salt and water from the gut. Whatever the mechanism may be whereby tubular urine is generated in this aglomerular fish (probably divalent ion "pumps") it appears that aqueous channels in its blind-ended, exclusively "proximal segment" nephron are quite permeable to univalent ions and that these (probably Na) provide the means for bladder epithelium actively to extract solute-linked fluid from urine that is essentially isosmotic to plasma and considerably hypotonic to sea water.

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