



Figure 1.

or no PD and  $I_{sc}$  across the intestinal membrane was observed. However, in choline chloride Ringer, a negative PD and  $I_{sc}$  were observed and these were usually greater than those observed in  $\text{NaCl-HCO}_3^-$  Ringer as well as being sensitive to the presence of  $\text{HCO}_3^-$  ion.

Measurement of the flux of Na and Cl ions during the short circuit period was performed with the use of the radioactive isotopes,  $^{22}\text{Na}$  and  $^{36}\text{Cl}$ . Ratio  $\frac{M_{m \rightarrow s}}{M_{s \rightarrow m}}$  for Cl ion was found to be 2.20, and 3.3 for Na ion. Addition of glucose to both sides of the chamber or only to the mucosal side increased the negativity of PD and  $I_{sc}$ . These data suggest that Na and Cl ions are actively transported from mucosal to serosal side of flounder intestine with a PD negative to the serosal side which is contrary to data from observations of mammalian intestine.

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1969 #12

#### OXYGEN CONSUMPTION IN THE INTESTINAL MUCOSA AND GILL FILAMENTS OF FRESH-WATER AND SALT-WATER TELEOSTS

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In teleosts, osmotic regulation is largely mediated by the intestines and the gills. Although the intestine plays no role in this respect in fresh-water species; marine species drink and transport monovalent ions and water across the intestinal epithelium. The gills of fresh-water species absorb ions from the water against a concentration gradient; whereas the gills of their marine counterparts actively secrete ions. The gills and intestines of euryhaline teleosts have

the remarkable ability to adapt to either environment. In this study, oxygen consumption was compared with ion transport in these tissues.

Mucosa was scraped from the intestines; and filaments were dissected from the gill arch. The tissues were placed in teleost Ringers containing 10mM Na<sup>+</sup> succinate. Oxygen consumption (QO<sub>2</sub>) was measured in an Oxygen Monitor (Model 53, Yellow Springs Instrument Co.) at 25°C. The QO<sub>2</sub> was calculated as  $\mu\text{l O}_2/\text{gram tissue}/\text{min}$ . The results are presented in Table 1.

Table 1

QO<sub>2</sub>\* IN INTESTINAL MUCOSA AND GILL FILAMENTS OF FRESH-WATER (F.W.) AND SALT-WATER (S.W.) TELEOSTS

Species	Environment	QO <sub>2</sub>	
		Mucosa	Gill
<u>E. lucius</u>	F.W.	1136 ± 167	774 ± 96
<u>Notropicus</u>	F.W.	1117 ± 196	823 ± 115
<u>A. rostrata</u>	F.W.	1396 ± 166	909 ± 190
<u>A. rostrata</u>	S.W., 3 days	1298 ± 148	937 ± 173
<u>A. rostrata</u>	S.W., 1 wk	1582 ± 246	Not assayed
<u>A. rostrata</u>	S.W., 3 wks	2914 ± 374	1060 ± 154
<u>A. rostrata</u>	F.W. & hydrocortisone†	1271 ± 242	868 ± 138
<u>F. heteroclitus</u>	S.W.	1917 ± 178	1241 ± 93
<u>F. heteroclitus</u>	F.W., 3 wks	945 ± 273	827 ± 177
<u>M. scorpius</u>	S.W.	2159 ± 403	896 ± 58
<u>P. americanus</u>	S.W.	716 ± 16	947 ± 136

\*  $\mu\text{l O}_2/\text{gram}/\text{min}$  at 25°C; values are the Mean ± SE, with six fish in each group.

† Hydrocortisone: intramuscular injections, 400  $\mu\text{gm}/\text{kg}/\text{day}$ , for two weeks.

Mucosal QO<sub>2</sub> was about twice as high in two species captured in salt-water (Fundulus heteroclitus and Myoxocephalus scorpius) than in three species captured in fresh-water (Notropicus, Esox lucius and Anguilla rostrata). However, the mucosal QO<sub>2</sub> of the marine Pseudopleuronectes americanus resembled that seen in fresh-water species. Therefore, it remains unclear whether high mucosal QO<sub>2</sub> is a factor in salt and water movement in teleost intestine.

Adaptations in mucosal QO<sub>2</sub> were studied in two euryhaline species, F. heteroclitus and A. rostrata. Three weeks after F. heteroclitus was transferred to fresh-water, mucosal QO<sub>2</sub> was about one-half that seen in salt-water (P < 0.01). Three weeks after A. rostrata was transferred to salt-water, mucosal QO<sub>2</sub> was twice that seen in fresh-water (P < 0.01). In another study (Mackay, Bull. MDIBL, this volume) intestinal salt and water transport in A. rostrata was increased after three days of salt-water adaptation. Furthermore, hydrocortisone treatment also increased intestinal salt and water transport. In this study, mucosal QO<sub>2</sub> remained unchanged during the first week of adaptation, and after hydrocortisone treatment. There is, consequently, no clear relationship between mucosal QO<sub>2</sub> and salt and water transport.

Left unstudied is an obvious hypertrophy of the intestinal mucosa in A. rostrata during the

early stages of salt-water adaptation. The development of a thicker mucosal layer per unit length of intestine may be a critical factor in salt and water transport.

Three weeks after F. heteroclitus was transferred to fresh-water, gill filament  $QO_2$  had decreased 30% ( $P < 0.05$ ). Otherwise, there was no relationship between  $QO_2$  and ion transport in the gill.

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1969 #13

#### REFLEX CONTROL OF GILL RESISTANCE AND HEART RATE IN S. acanthias

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A vagally mediated cardio-inhibitory response to a wide variety of stimuli has been of interest for many years (Biol. Bull. Woods Hole 59:170, 1930). Hypoxia and hypercapnia are known to be effective in producing this response in the dogfish (J. Exptl. Biol. 38:531, 1961). More recently it has been postulated that changes in  $O_2$  or  $CO_2$  in the sea water delivered to the gills induce vascular changes in the gill itself as well as bradycardia (J. Exptl. Biol. 39:503, 1962). In previous studies the interpretation of pressure and heart rate changes have been limited by the lack of cardiac output data. In this investigation, flow was measured, and the hemodynamics of a reflex response to elevated  $pCO_2$  were described.

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Twenty-five dogfish weighing between 1.5 and 6 kg were used; the preparation was the same as that described in Bull. MDIBL 8:20, 1968. Ventral aortic pressure (VAP) and dorsal aortic pressure (DAP) were recorded from appropriately placed cannulas and stroke volume was recorded from a 20 or 25 mm electromagnetic flow probe placed around the conus arteriosus. Flow ( $\dot{Q}_B$ ) was calculated by integrating the stroke volume curve and was expressed in L/kg/hr. Gill resistance ( $R_G$ ) was calculated from  $(\overline{VAP} - \overline{DAP})/\dot{Q}_B$  and expressed in peripheral resistance units (PRU). In three fish an index of cardiac contractility was measured as described in Bull. MDIBL 8:20, 1968.

Seventeen of the fish were vagotomized, via an oro-pharyngeal approach, by section of the vagi at the medullary junction; nine of these were excluded from the study either because on autopsy the vagotomy was found to be incomplete, or because of rapid deterioration of the preparation after vagotomy. In eight fish the vagi were blocked pharmacologically with a 2.0 mg/kg dose of atropine. The fish were exposed to 10 minute periods of hypercapnia before and after either vagotomy or atropine by perfusing their gills with sea water equilibrated in a bubble equilibrator with 5%  $CO_2$  in air as described in Bull. MDIBL 8:28, 1968. It is assumed that the elevated  $pCO_2$  caused some desaturation of the blood due to a large Bohr effect and hypercapnia was most probably accompanied by some hypoxia.

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Hemodynamic changes occurring when the intact dogfish was exposed to sea water equilibrated with 5%  $CO_2$  in air, are shown in Figure 1, 1st panel.  $\overline{VAP}$  rose although total cardiac output fell with a drop in heart rate and no change in stroke volume. The pressure drop across the gills widened as a result of both an increase in  $\overline{VAP}$  and a decrease in  $\overline{DAP}$ . The calculated