The Role of the Gills in Seawater Adaptation in *Anguilla dieffenbachii*

III. The Relative Significance of the Gills

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Summary. A comparison of results obtained in studies of serum concentrations in the whole fish with those obtained from preparations of isolated, perfused gills indicates that the rate at which ions are entering the gills of freshwater *Anguilla dieffenbachii* on being placed in sea water may only amount to some 10% or less of the calculated rate of addition of ions to the fish as a whole. An additional major route for the entry of ions into the fish on being placed in sea water, other than via the gills, is therefore indicated and, from a consideration of the functioning of the main effector organs of ionic regulation in teleosts, it is concluded that the intestine is the major site of the initial addition of ions to the fish on transfer to sea water.

The subsequent reduction and eventual stabilisation of serum ionic concentrations following transfer can be largely explained on both a qualitative and temporal basis by the changes in functioning of the gills, as demonstrated by the isolated, perfused preparations.

Introduction

The two previous papers in this series have described the changes occurring in the composition of the internal medium (both extracellular and intracellular) and in the net fluxes of ions across the gills of *A. dieffenbachii* during adaptation to sea water. There remains to be considered the general nature of seawater adaptation in *A. dieffenbachii* and, in particular, the ways in which the measured net fluxes of ions in the isolated gills may relate to the recorded changes in the concentration of the blood during adaptation to sea water.

Results and Discussion

From the results presented in the first paper in this series (Shuttleworth and Freeman, 1973a), it was deduced that the initial rises in serum sodium and chloride concentrations and serum total osmotic pressure occurring during the first 12 hours of seawater adaptation were caused by both removal of water from, and addition of ions to,

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the extracellular body fluids. The total increases in serum sodium and chloride concentration during these first 12 hours amount to some 46% and 64% of the respective freshwater values for these ions. Taking account of the simultaneous reduction in the extracellular volume it was calculated that only about 22% of this increase in concentration could be accounted for by removal of water from the body fluids. Therefore, the remaining increases in concentration of some 24% (for sodium) and 42% (for chloride) must be caused by the addition of ions. The measured concentrations of sodium and of chloride in the serum of freshwater eels are 140.4 mmol l⁻¹ and 114.0 mmol l⁻¹ respectively, and the actual increases in these concentrations produced as a result of the addition of ions will amount, therefore, to 33.7 mmol l⁻¹ for sodium and 47.9 mmol l⁻¹ for chloride. Assuming that the blood serum occupies a volume equivalent to 15 ml kg⁻¹ (see the review by Holmes and Donaldson, 1969) the total amounts of sodium and chloride added to the blood during the first 12 hours of adaptation to sea water can be calculated and amount to 506 µmol kg⁻¹ and 719 µmol kg⁻¹ respectively. These values are equivalent to mean hourly rates of addition of 42 µmol kg⁻¹ hr⁻¹ for sodium and 60 µmol kg⁻¹ hr⁻¹ for chloride.

The net influxes of sodium and chloride into the perfused gills of freshwater eels in an external medium of artificial sea water amounted to 4.7 µmol kg⁻¹ hr⁻¹ and 4.3 µmol kg⁻¹ hr⁻¹ respectively (Shuttleworth and Freeman, 1973b). There is then an evident discrepancy between the rate at which ions are entering the gills of a freshwater eel on being placed in sea water and the calculated rate of the addition of ions to the internal medium of the fish as a whole. This conclusion derives from the comparison of results obtained in studies of serum concentration in whole fish with those obtained from preparations of isolated, perfused gills. Of course the dynamic nature of the osmoregulatory changes occurring in a whole, living fish may be expected to produce somewhat different results from the far more static situation of an isolated perfused gill preparation and it is necessary to consider the experimental situations in which the measurements were made.

In the isolated perfused preparation a gill is removed from a freshwater eel, placed in an artificial seawater solution and is continuously perfused with an artificial fluid having sodium and chloride concentrations approximating those in the serum of a freshwater eel. In the intact fish the specimen is transferred directly from fresh water to sea water but the concentration of the internal medium does not remain constant. It has, in fact, been shown that there is a very rapid increase in the concentration of the blood serum during the first 12 hours of seawater adaptation (Shuttleworth and Freeman, 1973a, Fig. 1). This increase in the concentration of the internal medium will have the effect of