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BLOOD PERFUSION OF THE KIDNEY OF *LOPHIUS PISCATORIUS* L.

IV. MAGNESIUM EXCRETION

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(Text-figs. 1–3)

From our previous publications (Brull & Nizet, 1953; Brull, Nizet & Verney, 1953; Brull & Cuypers, 1954), it appears that the power of concentration of the aglomerular kidney of *Lophius* is rather low, the density of the urine being usually less than that of the plasma concentration. Most individual urinary constituents do not reach concentrations that are more than once or twice those in the plasma, magnesium being an exception.

The kidney of *Lophius* possesses a high power for concentrating magnesium, to a degree approaching a hundred-fold. The plasma Mg usually increases after the fish has been caught, and therefore it seems likely that trauma is a factor in increased Mg absorption.[2] We referred in our previous work (1953) to other authors who had already noticed that urine secreted by *Lophius* in the aquarium is not the same as that secreted by fishes living under normal conditions. Yet, as *Lophius* kidneys are endowed with a particular power for excreting Mg, we thought it would be interesting to investigate this function further. What is the normal amount of Mg in *Lophius* plasma? Is it higher or similar to the figures found in mammals? Is there a threshold below which the secretion stops? Is exogenous Mg excreted in the same manner as the Mg that enters the blood stream through normal channels? These are the first questions which arise and seem worthy of investigation.

Methods

The problem was studied with isolated kidneys perfused with heparinized blood, according to the method described by Brull & Cuypers (1954). As we demonstrated that there is a maximum or optimum perfusion pressure above which no further increase of urine secretion is obtained (250–300 mm water), our perfusions were made at pressures of about 250–300 mm of water, at

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[2] In dialysis experiments on *Lophius* skin E. Nizel (unpublished) found that rubbing the skin increases its permeability to minerals.

room temperature and with oxygenated blood (in July–August). Leaving aside a first series of experiments, in which the initial plasma level of Mg was high, we shall describe briefly three experiments only in which, during prolonged perfusion of the kidney, total exhaustion of the plasma Mg was reached.

Determinations of Mg were made by the method of Fister (1950), with a modification described by M. Orange & H. C. Rhein (1951).

Some of the determinations were checked with the ammonium magnesium phosphate method, and the figures agreed. Trichloracetic deproteinization was used. When the plasma figures were low, 2 ml. of plasma were used instead of 0·5 ml. Urine samples were diluted.

Experimental Results

Figs. 1–3 illustrate three perfusion experiments in which, with the use of two kidneys, the plasma Mg could be exhausted in 3–5 h, Mg being added afterwards.

In Expt. 54B (Fig. 1) a perfusion was started with 300 ml. of blood with a cell volume of 16%, and an initial plasma Mg of 16·2 mg. Two kidneys, weighing 12·5 and 12 g respectively, were perfused. As usual, there was an initial rise in urinary Mg, probably due to the fact that the kidneys came from a *Lophius*, the plasma Mg of which was lower than that of the pool of blood contained in the reservoir, the first two samples of urine being a wash-out.

Owing to the progressive exhaustion of the Mg reserve in the plasma, there is a regular drop of Mg, down to 0·47 mg % at the fifth hour of perfusion. With a delay of about 80 min, there is a parallel drop in the Mg concentration in urine and in plasma. In 80 min each kidney gives ±2·5 ml. urine. When a total amount of 15 ml. of urine have been excreted by the two kidneys, the plasma Mg has dropped to 0·47 mg %, showing that excretion continues even when practically all the available Mg has been removed. Some blood was lost during the perfusion, so that it is impossible to compare the available Mg with the excreted amount.

In Expt. 54C (Fig. 2) the initial level of Mg in the plasma was 13 mg %, with a pool of blood of 300 ml., and a red-cell volume of 15·8%. (Loss of blood during perfusion: 10 ml., sampling: 30 ml., total: 40 ml.)

After perfusing two kidneys weighing 12 and 11 g respectively, for 4 h 37 min, the Mg level in the plasma is down to 0·9 mg; there is a parallel drop of Mg in the urine (one kidney only is represented in the diagram) with a delay of 140 min. Of the 33·8 mg of Mg contained in the pool of blood (minus the losses and samples), 29·1 mg had been excreted after that time; thus ±4·7 mg are left in about 218 ml. of plasma, which would represent 2·1 mg % against 0·9 actually found. This means an error of 2·6 mg in all measurements and determinations involved. 73 min later, when two more ml.

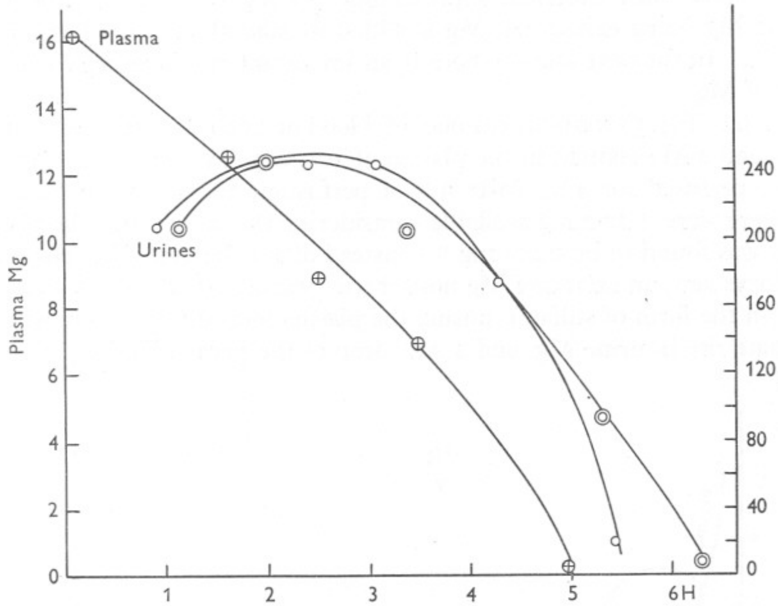

Fig. 1. Two kidneys are perfused until the plasma Mg is exhausted. All figures are given in mg per 100 ml.

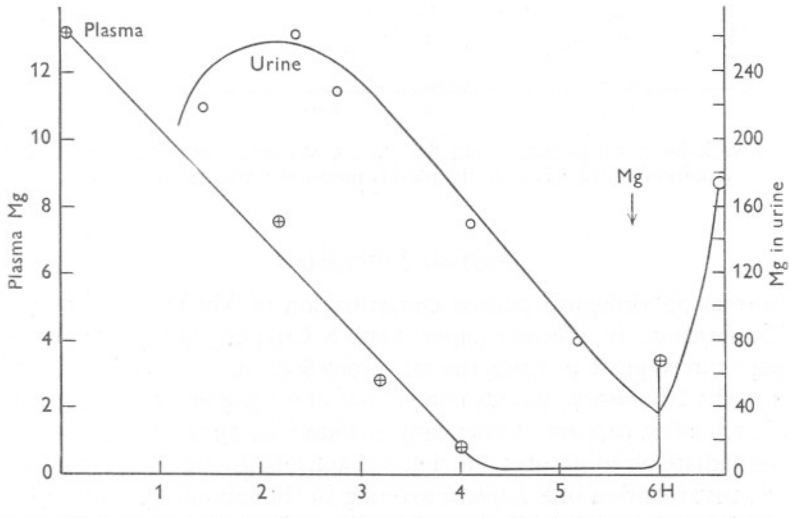

Fig. 2. Two kidneys are perfused until the plasma Mg drops down to 0·9 mg %. After addition of Mg sulfate to the blood, there is a rise of Mg in the urine.

of urine have been excreted, representing ±2 mg of Mg, and the total available Mg being exhausted, Mg is added to raise the plasma level up to 3·3 mg %. In the next sample there is an important rise in urinary concentration of Mg.

Expt. 54L (Fig. 3) starts with a pool of blood of 260 ml., a red-cell volume of 8 %, and a Mg content in the plasma of 10·1 mg. Two kidneys of 13 and 11 g are perfused for 4 h. After 3 h of perfusion, 20·6 mg were excreted, while there were ±22·2 mg available (considering the sampling). The plasma content was found to be 0·225 mg %, instead of 1·1 theoretically. However, the kidneys kept on excreting Mg until it was practically exhausted. Mg was added (in the form of sulfate), raising the plasma level up to 2·5 mg with an immediate rise in urine Mg, and a new drop of the plasma level.

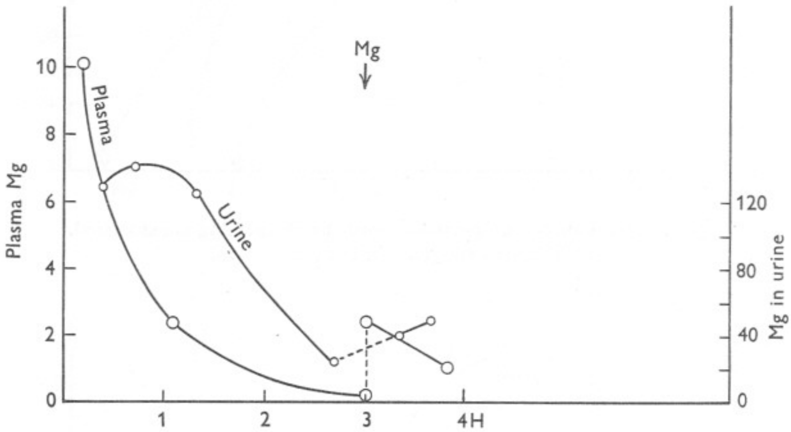

Fig. 3. Two kidneys are perfused until the plasma Mg drops from 10·1 to 0·225 mg %. Addition of Mg sulfate to the plasma produces a rise in urinary Mg.

General Discussion

The normal physiological plasma concentration of Mg has not been established in *Lophius*. In a former paper (Brull & Cuypers, 1954) we gave figures showing an average of 12·1 mg/100 ml. (from 6·32 up to 16·7), in fish bled on arrival in the laboratory, and also one figure of 6·5 mg in a fish bled on board immediately after capture. Other figures found in 1954 aboard the *Sarsia*, after immediate bleeding, are: 2·6, 3·2, 7·2, 3·4, 8·6, giving an average of 5 mg, and we must mention one *Lophius* arriving in the laboratory with 1·98 mg.

It is well known that mammalian plasma contains an average Mg content of about 2 mg/100 ml. It is likely that while the fish are being trawled, unusual quantities of sea water are swallowed and absorbed, thereby increasing the Mg concentration in the plasma on the way to the laboratory. We may however suppose, from the above figures, that the normal concentration is about 2 mg or less.

As long as the plasma figures are higher than, let us say, 5 mg, the percentages in urine are high, up to 200 or even nearly 300 mg/100 ml. This concentration seems to be the maximum attainable for Mg concentration by *Lophius* kidneys. At first sight, when we performed perfusions with high initial plasma figures, and lasting only for 3–4 h, it looked as if urinary percentages of Mg were independent of the plasma concentration; this is true down to a certain level. But it is clear, from the three experiments reported, that when the plasma Mg drops down to 4, 3 or 2 mg, there is a parallel drop in urinary percentage.

But the most striking fact of all is that, while we believe we may consider Mg as a normal constituent of the plasma, the perfused *Lophius* kidneys keep on excreting Mg until its total, or practically total exhaustion, as if there were no threshold.

In our opinion, this finding is capable of two explanations. (1) The isolated perfused kidney of *Lophius piscatorius* lacks some (hormonal?) control to maintain its Mg threshold. (2) *Lophius* is a very greedy fish in the stomach of which enormous amounts of sea animal food can be found; sea water may be unavoidably ingested with the food, thus producing a continuous inflow of Mg, the latter to be neutralized by a very active power of excretion the kidney possesses. No mechanism for the preservation of Mg is required. On the contrary, the problem of its constant removal is by far more urgent. The plasma level may be more variable than in terrestrial or freshwater animals, in which Mg may eventually be lacking.

Under normal conditions of life, a minimum amount of sea water is swallowed, and the excess Mg is easily excreted by the kidneys. After trawling, there is a surfeit of Mg in the blood, representing up to 16 or 17 mg %.

As far as we know, in mammals, there is a very accurate homeostatic mechanism for minerals. One of us demonstrated in 1927 a threshold for phosphates (Brull, 1927), which is under control of the hypophysis (Brull, 1928), and of the parathyroids (Brull, 1936). This author also produced evidence that usually protein-bound and ionized Ca is not excreted by the kidney, but that a small quantity of Ca combined in a complex form with organic acids, is the origin of the urinary leakage of Ca (Brull, 1930).

It is the first time we come across conditions under which a normal inorganic constituent of the plasma is excreted by the kidney until exhaustion. Further research will have to show whether this phenomenon, observed in the perfused kidney, may be confirmed with the whole animal.

Moreover, exogenous Mg, added to the plasma, seems to be excreted in the same way as absorbed Mg.

SUMMARY

Kidneys of *Lophius piscatorius*, perfused with heparinized *Lophius* blood, concentrate magnesium up to one hundred times. This degree of concentration is independent of the plasma level as long as the blood contains high amounts of magnesium, as occurs in the hours following capture of the fish. Below 5 mg % or less, there is a parallel drop in urinary concentration of magnesium and in plasma level. When kidneys are perfused with a limited pool of blood, they excrete magnesium until total exhaustion of this substance. Under such conditions there is no threshold for magnesium in *Lophius*. Exogenous magnesium added to the plasma is excreted in the same manner as endogenous (absorbed) magnesium.

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