blood flow. The dogfish was approached within this ideological framework.

BSP-Na was measured colorimetrically, and as S^{35} will be measured later. In 12 experiments BSP was given intravenously (lateral abdominal vein) in a single dose, and in 10 experiments, as a constant infusion (calibrated Harvard pump). Arterial blood from the caudal artery was sampled. Fish were free in a small tank, as experiments indicated that fish tied to a "shark-board" were depressed. Bile was taken repetitively directly from the gall bladder following ligation of the bile duct. Plasma volume was measured by the T-1824 method.

The results show that BSP is removed from the blood less rapidly than in mammals, averaging 1.56% per minute for 3 fish in contrast to 15% per minute in man. BSP storage and transfer gave preliminary values for transfer maxima from 0.42 to 0.51 mgm per minute, approximately one-third those observed in man. Definition of storage proved difficult due to loss of dye into non-hepatic tissues. S^{35} data should clarify this area.

BSP concentration in the bile was as much as 1000 times greater than that in the plasma, with low bile flows of 0.4-13 lambda per minute, tending to vary inversely with biliary BSP concentration. Because of the time required to establish an equilibrium between infusion and biliary excretion, accurate BSP clearances were difficult to obtain. In one case with nearly 24 hours of perfusion with a fish in excellent condition, biliary clearance averaged 1.78 ml per minute, with average bile flow of 3.92 lambda per minute. Terminal plasmas were: arterial, 1.23 mg%, indicating an extraction (E) of 32.8%, which gave an estimated hepatic blood flow (EH^{BF} = BSP clearance/E) as 5.35 ml per minute. It seems that the liver of the dogfish is relatively ischemic since perfusion per unit weight of liver amounts to no more than 1.8 ml per 100 grams per minute in contrast to man and dog in whom perfusion is 1/ml per gram per minute. Even allowing for the high hepatic fat content, the hepatic blood flow is low compared to a mammal.

1965 #6

SODIUM TRANSPORT BY THE RED BLOOD CELLS OF THE DOGFISH (Squalus acanthias) UNDER AEROBIC AND ANAEROBIC CONDITIONS*

N. S. Bricker, S. Klahr, L. Holle, and S. Mayer, Washington University, St. Louis, Mo.

The characteristics of sodium transport by the nucleated red blood cells of the dogfish shark, Squalus acanthias, have not yet been studied. Definition of these characteristics should be of considerable interest not only because the sodium concentration of dogfish plasma is approximately 250 mEq/L, but because active sodium transport, as well as all other endergonic biologic processes, in this species must be sustained in vivo at temperatures ranging from 12 to 16°C. Experiments were performed on washed red blood cells after overnight incubation in Na^{22} containing dogfish Ringer's at 4°C. Na^{22} efflux rates and net sodium transport were measured during a 4 hour period at room temperature (16-22°C). Measurements were made under both aerobic and anaerobic conditions. Anaerobiosis was obtained by using 100% nitrogen as the gas phase; the nitrogen was passed through an oxygen trap en route to the incubation flasks. In

*Supported by U. S. Public Health Service Research Grant No. AM-02667 and Dept. of the Interior, Office of Saline Water Grant No. 14-01-0001-686.

addition to chemical sodium measurements, chloride and potassium concentrations were measured in red cell water and in the Ringer's solutions.

If chloride is in thermodynamic equilibrium across the dogfish red blood cell membrane, both sodium and potassium are maintained in a state removed from equilibrium. Presumably therefore both of these cations are actively transported against an electrochemical gradient.

In contrast to non-nucleated mammalian red blood cells, the sodium concentrations of cell water were lower after prolonged incubation at 4°C without substrate than after incubation with substrate at approximately 20°C. When the cells were incubated in an oxygenated environment, Na^{22} efflux rates were greater by several fold than values reported for mammalian red blood cells. Sodium transport was maintained under anaerobic conditions although the efflux rates were approximately half of those observed in the aerobic system. Nevertheless, anaerobic sodium transport in the dogfish red blood cells at 16-22°C still appreciably exceeded values reported for mammalian red blood cells at 37°C. Strophanthin (1×10^{-5} mM) inhibited sodium transport under both aerobic and anaerobic conditions. After overnight incubation without substrate, lactate formation measured during flux studies ranged from approximately 50 to 250 μmoles/Kg red blood cells per hour in an oxygenated environment. In the anaerobic system, lactate formation was increased by over 100%; hence a brisk Pasteur effect was demonstrable.

The present studies define certain of the characteristics of sodium transport by the dogfish red blood cell. The data indicate that brisk transport occurs in these nucleated cells under aerobic conditions very much as it does in the nucleated red blood cells of the duck. In contrast to the duck cells however the rate of anaerobic transport by the dogfish red blood cells is somewhat less than aerobic transport rates. Nevertheless the dogfish appears equipped to sustain active cation transport by means of glycolytic metabolism. It therefore could serve as a valuable model for the study of the inter-relationships between glycolysis and a key endergonic biologic process.

1965 #7

THE EFFECTS OF OLIGOMYCIN AND 2-4 DINITROPHENOL ON ANAEROBIC SODIUM TRANSPORT BY THE RED BLOOD CELLS OF THE DOGFISH SHARK (Squalus acanthias)*

N. S. Bricker and S. Mayer, Washington University, St. Louis, Mo.

The red blood cells of the dogfish shark have been found to transport sodium from cell water to extracellular fluid under anaerobic as well as aerobic conditions. This cell type therefore could serve as a model for the investigation of certain of the inter-relationships between metabolism and transport in the elasmobranch under conditions wherein metabolic energy production is provided via the Embden-Meyerhof pathway. We previously have studied the coupling between anaerobic metabolism and anaerobic sodium transport in the isolated urinary bladder of the turtle. From these studies evidence emerged that suggested the possible existence of a high energy intermediate of glycolysis (Bricker, N. S., and Klahr, S. J. Gen. Physiol. To be published January 1966). This evidence consisted of the fact that 2-4 dinitrophenol, a classic un-

*Supported by U. S. Public Health Service Research Grant No. AM-02667 and Dept. of the Interior, Office of Saline Water Grant No. 14-01-0001-686.