in the eelpout, flounder, and sea raven than in the dogfish (urine samples for eelpout and sea raven were obtained from Dr. A. Devries). Analysis of kidney enzymes in these species revealed that while glutaminase levels were fairly constant there were large differences in glutamine synthetase activities which correlated with the difference in ammonia excretion between marine teleosts and the dogfish. The skate was found to have a urine pH approximately 1 unit lower than the other fishes. Because acidification of the skate urine occurs primarily in the kidney (Holliday et al., Bull. MDIBL 19:52-53, 1979), a 10-fold increase in ammonia excretion due to nonionic diffusion alone would be expected. When the urinary ammonia excretion is corrected for this difference in pH, the ammonia concentration of the skate urine decreases from .64 μEq NH_3/kg·hr to approximately .06 μEq NH_3/kg·hr. Thus, as in the dogfish, the skate's corrected low renal ammonia production would be coincident with a high glutamine synthetase activity. Comparing the glutaminase and glutamine synthetase activities among the teleost species, it can be seen that an increasing glutaminase/glutamine synthetase ratio is associated with an increasing urinary ammonia excretion and indicates the potential for control of renal ammoniagenesis via the modulation of these two enzymes. Finally, the high glutamine synthetase activities in the dogfish and skate could also be related to the urea retaining characteristics of the elasmobranchs. Anderson (Science 208:291-293, 1980) has proposed that the biosynthesis of urea in the elasmobranch liver occurs via carbamoyl phosphate synthetase III, a form of CPS that utilizes glutamine as the nitrogen-donating substrate and thus requires that the fish have the capacity for adequate glutamine synthesis.

In conclusion, glutamine appears to be an important source of renal ammonia in the dogfish. Our results indicate that the ammonia production depends on the relative activities of glutaminase and glutamine synthetase and that in dogfish a substrate cycle between glutamine and glutamic acid plus ammonia may exist. This cycle most likely does not operate in teleosts due to the low levels of renal glutamine synthetase found for these species. The tissue slice experiments also suggest that aspartate may be an important renal ammonia source for the dogfish and aspartate amino transferase activities in kidney tissue should be investigated. This work was supported by NSF Grant PCM 79-22476.

EXCHANGE OF RADIOLABELLED POLYETHYLENE GLYCOLS BETWEEN BRAIN AND EXTRADURAL FLUID IN SKATES

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The elasmobranch brain is surrounded by extradural fluid (EDF). This fluid differs in ionic composition from cerebrospinal fluid (CSF) and has a protein concentration approaching that of plasma. Whether there is communication between EDF and the underlying central nervous system is unclear. In a previous communication we presented qualitative evidence for exchange of protein tracers between brain and EDF in skates (Cserr et al., The Bulletin 19:21, 1979). We have now extended our studies of brain-EDF exchange to two radiolabelled tracers: ^{3}H-PEG (polyethylene glycol; 900 daltons) and ^{14}C-PEG (4,000 daltons).

To examine the possible distribution of tracer from brain to EDF, an isotonic solution of the two polyethylene glycols was microinjected into the skate telecephalon (Raja erinacea or Raja ocellata) through a guide cannula implanted several days previously (~0.2 μCi ^{3}H and ~0.03 μCi ^{14}C in 0.4 μl). Radioactivity of various fluid and tissue samples was then determined 0, 1, 4 or 24 hrs after injection into brain. Results at all time periods indicate tracer movement from brain to EDF. Values for samples collected 4 hrs after intracerebral tracer injection are summarized in Tables 1 and 2. Tracer concentration in EDF is higher than in plasma showing that PEG did not enter EDF via the plasma. In higher vertebrates, patent perivascular spaces around the cerebral blood vessels provide a pathway for exchange between brain and its surrounding fluid (CSF in mammals). The high concentration of tracer in vessels sampled from the dorsal surface

TABLE 1

CONCENTRATIONS OF RADIOLABELLED POLYETHYLENE GLYCOLS (NORMALIZED TO THOSE IN EDF) IN VARIOUS TISSUES AND FLUIDS 4 HOURS AFTER MICROINJECTION OF ISOTOPE INTO SKATE TELENCEPHALON

Isotope	Whole brain	Blood Vessels		EDF	Plasma
		from dorsal telencephalon	intracranial carotids		
PEG-900	1,060	1,640	69	100	10
PEG-4,000	1,270	2,400	95	100	7

Values are means and N = 4 or 5.

TABLE 2

CONCENTRATIONS OF POLYETHYLENE GLYCOLS (NORMALIZED TO THOSE IN EDF) IN VARIOUS TISSUES AND FLUIDS 4 HOURS AFTER INJECTION INTO EDF

Isotope	CSF	Medulla oblongata					EDF	Intracerebral carotids	Plasma
		1	2	3	4	5			
PEG-900	0.12	0.76	0.47	0.45	0.58	0.83	100	23	1.2
PEG-4,000	0.03	0.49	0.21	0.17	0.25	0.45	100	23	0.7

Values are means and N = 3 for CSF, 6 for tissue samples, and 10 for plasma.

of the skate telencephalon suggests that perivascular spaces may also perform a similar function in elasmobranchs. There was also significant radioactivity in other intracranial vessesl (e.g., the carotids), although the activity was always highest in vessels located closest to the injection site.

Movement of tracer in the opposite direction, from EDF to brain, was studied 4 hrs following injection of tracer solution into the rostral portion of the extradural fluid cavity (3 μCi ^{14}C and 22 μCi ^{3}H in 25 μl). Comparison of the radioactivity of three EDF samples withdrawn from different portions of this fluid compartment indicate some tracer inhomogeneity. However, as the samples did not differ in a consistent manner, mean CSF tracer concentration was taken as the average of the three samples. The whole brain was rinsed in sea water to remove adhering fluid and a core of tissue taken from the medulla oblongata and telencephalon. These were sectioned at 1/2 mm on a freezing microtome. Results are summarized in Table 2. The first medullary slice includes the dorsal (CSF facing) surface of the medulla; the last (EDF facing) includes the ventral meninges. Both tracers penetrated from EDF into brain; however, the concentration of the smaller tracer (PEG-900) is consistently larger in the tissue slices. Similar results were obtained for the telencephalon.

These results indicate bidirectional exchange between EDF and brain tissue in the elasmobranch central nervous system and provide additional support for the role of perivascular spaces as preferential channels of material exchange in the central nervous system. This work was supported by U.S. Public Health Service Grant NS11050.