SUBLETHAL EFFECTS OF CADMIUM ON SCORPIONFISH: CYTOSOLIC DISTRIBUTION

Concern about coastal water quality in the 1970s led to the start of pollution monitoring programs in many parts of the U.S. coast. In a number of these programs, measurements were made not only of concentrations of pollutants in the environment but also in the tissues of marine organisms. While this made it possible to compare the availability of pollutants to organisms at different sites, such measurements of "body burden" of pollutants did not shed any light on harmful effects to the organisms themselves.

Research in physiology was beginning to show, however, that not all of an accumulated toxicant is necessarily biologically active — that is, harmful — to the organism. Instead, some proportion of the substance may be detoxicated by binding to specific agents such as metallothionein in the case of heavy metals and glutathione for certain toxic organic compounds. This has been confirmed both for mammals and fish.

In this study, David A. Brown, Steven M. Bay, Darrin J. Greenstein and G. Patrick Hershelman report on the partitioning of the metal cadmium between enzyme-associated and metallothionein-associated fractions of the cytosol (the cytoplasm of a cell minus its organelles; see Figure 1) in different tissues of the scorpionfish, *Scorpaena guttata*. Previous work by Brown and others has shown that cadmium and other metals in the metallothionein pool are rendered nontoxic, while cadmium in enzyme pools coincides with toxic effects. (Report on enzyme effects, p. 41 this volume)

Scorpionfish were exposed to several levels of cadmium in seawater in both acute (4-day) and chronic (28-day) exposures. The researchers used column chromatography to separate tissue extracts by molecular weight. The metallothionein pool is a medium molecular-weight fraction; the enzyme pool is a high molecular-weight fraction.

The findings of the scorpionfish cadmium study break some new ground: Brown and his co-workers show that different tissues of the same organism do not have the same detoxifying capability. And they confirm what many bioassays have also shown — that chronic effects of a toxicant cannot be predicted from acute exposures.

Several important principles relating to the toxicology of cadmium are suggested by these results with scorpionfish:

Although the liver may be a major site of accumulation of cadmium, it may not be the major site of toxicity of cadmium. Although the liver accumulated the highest cytosolic- and metallothionein-cadmium concentrations of the four tissues examined, it showed no increases of enzyme-cadmium for any exposure regimen (Figure 2).

During high acute exposures to cadmium (i.e., 50 mg Cd/L; this is 80 percent of the 96-hour LC50, which is the concentration that kills 50 percent of organisms in 96 hours), *kidney is the most sensitive tissue,* followed by gill, intestine, liver. The order of accumulation of enzyme-cadmium is kidney>gill>intestine>liver and the order of accumulation of metallothionein-cadmium is kidney<gill<intestine<liver.

Following low sublethal exposure, the intestine may be the most sensitive tissue. Only the intestine showed a significant increase of enzyme-cadmium at an exposure of 1.0 mg Cd/l. In addition, the intestine accumulated almost as much metallothionein-cadmium at 1.0 mg/L as at any of the higher exposure levels, suggesting that its capacity to produce metallothionein has been reached at this exposure level. The other three tissues showed much higher metallothionein-cadmium levels at 10 and 20 mg Cd/L exposure levels than at 1.0 mg Cd/L.

Detoxication and toxication mechanisms operate differently during chronic and acute exposures. In all four tissues examined, much higher concentrations of metallothionein-cadmium and lower concentrations of enzyme-cadmium occurred following chronic exposure to 20 mg Cd/L compared with acute exposure to 25 mg Cd/L.

Copper and zinc levels are frequently altered in cadmium-exposed fish. For example, concentrations of copper and zinc were markedly decreased in intestine enzyme and metallothionein pools of fish exposed to 10 and 20 mg Cd/L.

Brown notes that this approach can be used to examine sublethal toxicity in organisms exposed in their natural environment. Since it is based on the actual mechanisms of internal detoxication or toxic action, it can be used to measure accurately the portion of accumulated contaminants that is causing toxicity. In organisms from a multiple-contaminated environment, it can be used to ascertain which contaminant(s) are causing an observed toxic effect.

In addition to underscoring the differences in responses to acute and chronic exposure, the study's results point to the variation in response of different tissues. These subtleties in organism physiology need to be considered, both in bioassays and in field programs for monitoring contaminants.

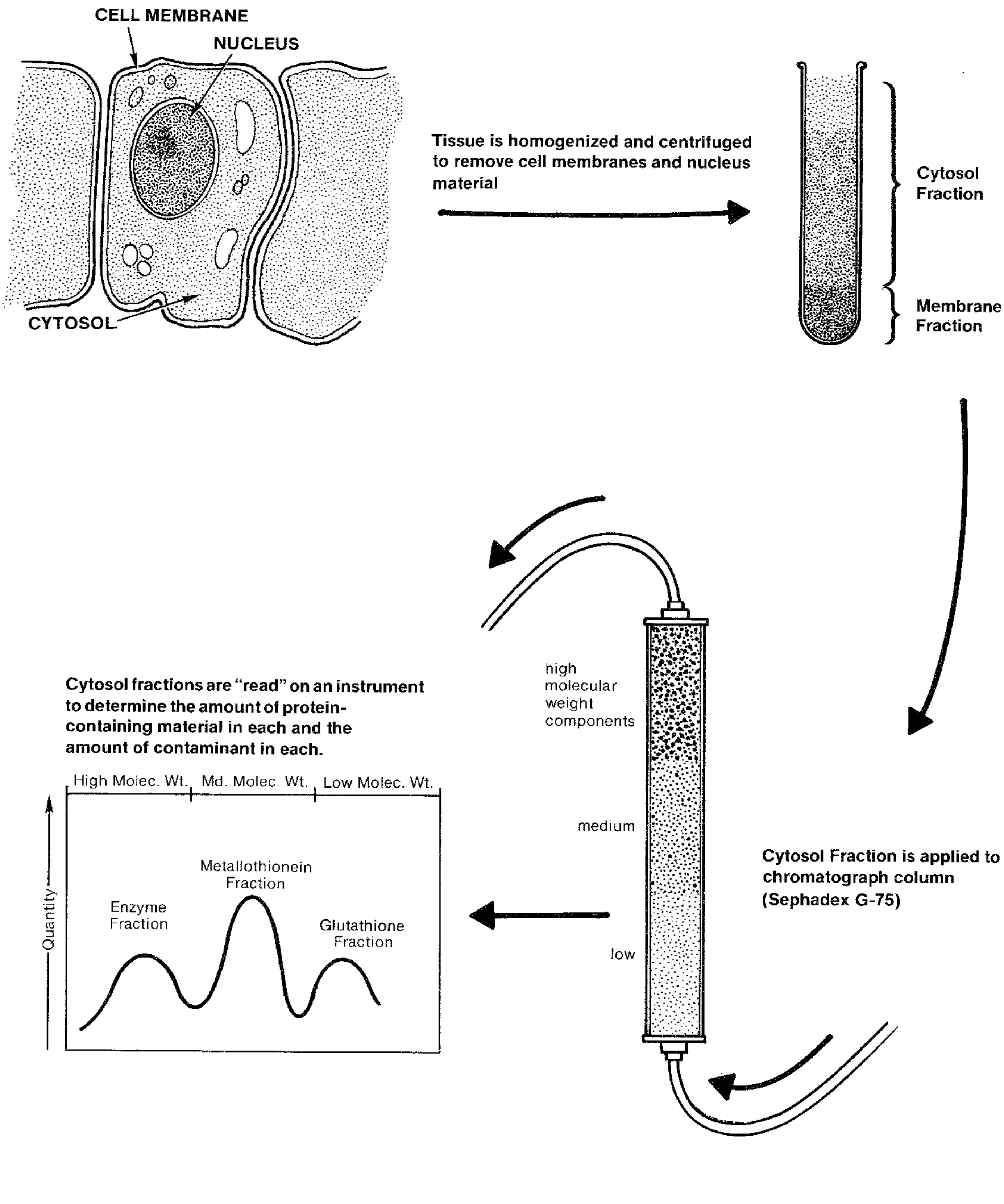

Figure 1. Schematic diagram outlining procedures used to separate tissue cytosol into high, medium, and low molecular weight components.

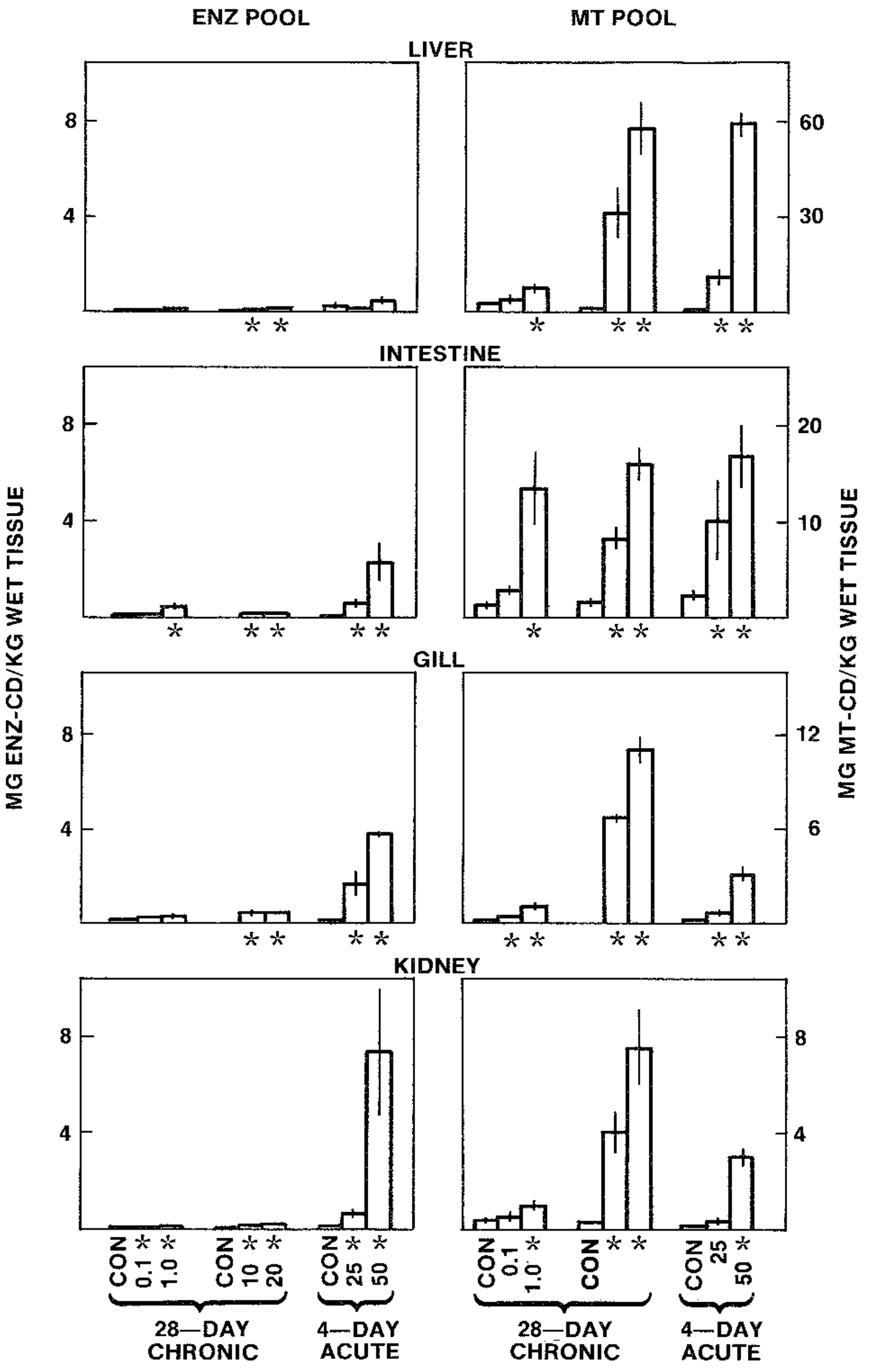

Figure 2. Concentrations of Cd (mg/wet kg) in the enzyme-containing (ENZ) and metallothionein-containing (MT) pools in tissues of scorpionfish exposed to a range of Cd concentrations dissolved in seawater. Mean + standard error. N = 7 for 0.1 and 1.0 mg Cd/L exposures; N = 5 for 10 and 20 mg Cd/L exposures; N = 3 for 25 and 50 mg Cd/L exposures. Asterisk denotes statistically significant difference from control.

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