

How are Kings and Marine Algae Alike?

As early as A.D. 822, objects called bezoar stones were credited by Persian pharmacists with life-saving powers. The name bezoar, meaning "to protect against poison," was also given to the goats from whose stomachs they were originally obtained. The stones, found in the stomachs of many ruminant animals, such as antelopes, gazelles and llamas, are actually bits of hair and other indigestible substances around which minerals accumulate. They were thought to remedy a whole slew of miseries, not the least being arsenic poisoning. This last-imbued power held particular attraction for royalty, who believed the stones could absorb arsenic when dipped in wine. They became portable insurance policies for kings and princes: King Eric XIV of Sweden and Queen Elizabeth I allegedly set the stones in silver rings; other cautious sovereigns wore them on filigreed gold necklaces.

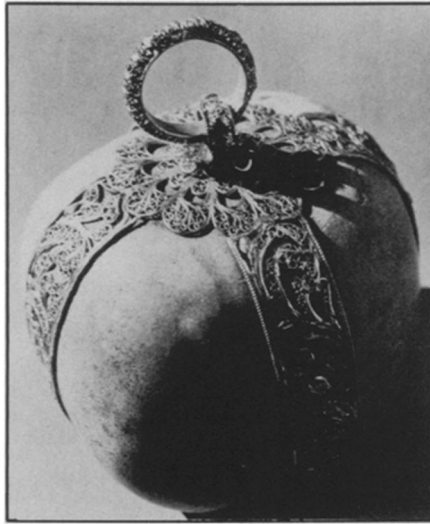
Since then, science, as it is sometimes wont to do, has turned the magic of the stones to chemistry. About ten years ago, Gustaf Arrhenius of Scripps Institution of Oceanography showed that the stones are made of a mineral called brushite, or sodium hydrogen phosphate. And, indeed, by the less-than-romantic process of ion exchange, the brushite will switch phosphate for arsenate in solution, thus "absorbing" the poison. But arsenate is only one form of the poison; arsenite is the other. Now, Andrew A. Benson, also of Scripps, adds the final scientific blow: The sulfur in the protein of the partly digested animal hair picks up the arsenite like a "chemical sponge." So much for magic stones.

But that's not the end of the story for arsenic. Benson's discovery about bezoar stones was actually the spin-off of other, albeit less glamorous, research on arsenic metabolism in the ocean, which he described in a recent lecture at Georgetown University in Washington, D.C. Royalty only had to worry about arsenic in their wine; marine life is surrounded, literally, by a sea of it. Most arsenic in the ocean is natural, resulting from volcanic activity, submarine hot springs and the slow dissolution of sediments, although industrial waste, particularly from smelting, is also a source. Larger marine animals that do not absorb nutrients directly are not immediately threatened by arsenic. However, marine algae, such as diatoms and dinoflagellates, which form the base of the food chain, absorb all their nutrients directly from the ocean. And whatever they take in, sooner or later, ends up as part of a larger creature.

The problem, Benson says, is that, like the brushite of bezoar stones, marine algae absorb both phosphate ions, which they need as a nutrient, and arsenic (in the form of arsenate ions), which poisons by

Answer: Both can be poisoned by arsenic. But marine algae, unlike royalty, have a built-in antidote.

BY SUSAN WEST

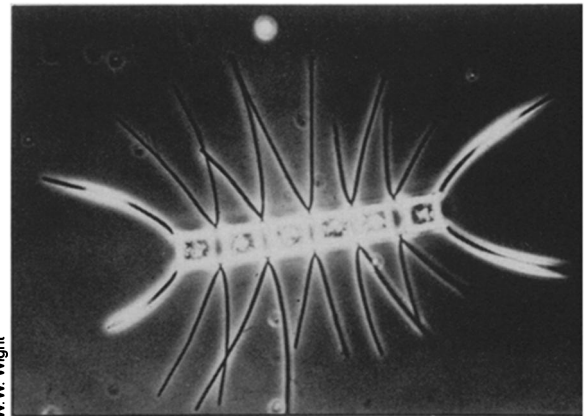


The kingly solution to arsenic poisoning: a variety of "magic" bezoar stones (right) and a royal version (above).

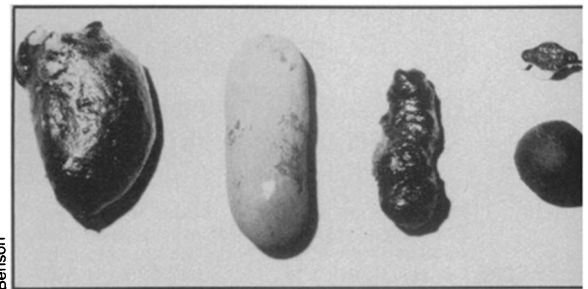
clamping onto enzymes and changing their structure, thus disrupting cell functions. Because 60 to 80 percent of the oceans — mostly in the tropics — are phosphate "starved," Benson explains, the concentration of arsenate ions may often outstrip that of phosphate ions by a factor of four. At best, he says, the algae may take in one arsenate ion for every three phosphate ions.

The high arsenic content of oceans and marine life had been known for at least two decades, but nothing was known about how marine organisms coped with it and if it was passed along, in some toxic form, to humans. The breakthrough came in 1977 when a group of Australian chemists, led by J.R. Cannon of the University of West Australia in Nedlands, isolated from a ton of lobster tails a nontoxic, lipid form of arsenic called arsenobetaine. Clued that a lipid form might be their goal, Benson, graduate student Robert Cooney and Ralph Mumma of Pennsylvania State University started to track the arsenic from the beginning. They fed radioactively labeled arsenic to diatoms, extracted the cells and combined paper chromatography and X-ray to detect the structure of the resulting compounds. Their approach was unique, Cooney says; other researchers had recovered only ambiguous, impure compounds.

Among the assortment of labeled products, which probably represent intermediates, they found a larger amount of an arsenic-containing phospholipid, Cooney told SCIENCE NEWS. In a phospholipid



Algae with an arsenic antidote: Diatom Chaetoceros decipiens used by Cooney and Benson.



form, an arsenic-containing compound would most likely be shunted into fats or lipid membranes, out of the cellular mainstream. Once they determined the structure of the lecithin-like compound (which is phosphatidyltrimethylarsoniumlactate), Cooney and Benson synthesized it in the lab.

Provided diatoms follow the same organic text as that of Cooney and Benson, the procedure for detoxifying arsenic goes like this: Arsenate, presumably enzymatically distinguished from phosphate once it enters the cell, is reduced to arsenite and methylated. With three methyl groups attached to an arsenic, the compound becomes an analog to nitrogen (which is also in short supply in tropical waters) and replaces it in cellular reactions. As a nitrogen analog, the methylated arsenic eventually becomes an arsenophospholipid, which is safely packed off to become part of a membrane. The arsenic, in this defused form, is passed through the food chain, only a short reaction away from the arsenobetaine recovered from the lobster tails.

Thus, the diatoms' arsenic metabolism has two functions: It acts as an algal "bezoar stone" — also insuring those higher up the food chain against poisoning — and satisfies a structural need for nitrogen. Says Benson: "Like the bezoar stone, nature's process for transforming arsenate solves the problem of arsenic poisoning in tropical algae." □