that although the nonhistone chromosomal proteins synthesized and associated with chromatin during G_1 may be responsible for regulating the expression of genetic information during this phase, the synthesis of these "regulatory" macromolecules may be controlled at the transcriptional as well as at the translational level.

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26 February 1973

Sand Dollar: A Weight Belt for the Juvenile

Abstract. *Juvenile sand dollars* (Dendraster excentricus) *selectively ingest heavy sand grains from the substrate and store them in an intestinal diverticulum which may function as a weight belt, assisting the young animal to remain in the shifting sandy environment. The sand disappears from the diverticulum when the animal reaches the length of 30 millimeters.*

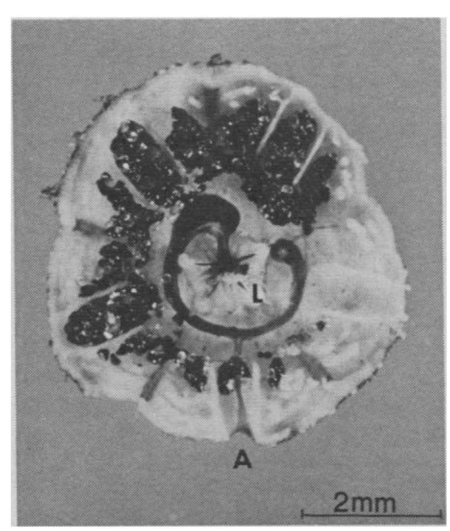
Gregory (*1*) described an intestinal diverticulum in a sand dollar, *Echinarachnius parma*, and noted that this organ was distended with sand in juveniles but not in adults. Similar situations have been observed in several other sand dollars (*2*). This suggests the question, What is the adaptive significance for the young animal of storing sand in the diverticulum? I report here that in the Pacific sand dollar, *Dendraster excentricus*, the juvenile stores specifically heavy sand grains in the diverticulum, thus increasing the body weight, enabling the animal to maintain its position in the sandy substrate.

Thirty-seven young specimens of *Dendraster* (5 to 32 mm long) and ten adult specimens (70 to 80 mm long) were collected from Puget Sound, at the south side of Alki Point, Seattle, Washington, in August 1972, and were fixed immediately in 75 percent ethanol. Each animal was then weighed (alcohol wet weight), and was dissected by removing the aboral half of the test. In this way the entire digestive tract and the diverticulum were exposed (Fig. 1).

All animals examined possessed the diverticulum but only the juveniles, when less than 30 mm long, contained sand. The diverticulum sand in all juveniles was extracted and the dry weight was measured. The amount of sand in each animal varied from 0.2 to 12 mg; it equaled 0.2 to 23 percent of the total body weight. Animals about 9 to 10 mm long contained more sand than both bigger and smaller ones. Small animals in general contained proportionally more sand (Fig. 2).

Grain types were separated and identified for sand from diverticula and from the substrate. The results are summarized in Table 1. There are eight grain types in the substrate; only two of these were found in the diverticula. The interesting point is that 78 percent of the diverticulum sand is iron oxide, which is heaviest of all grain types but constitutes only 9.8 percent of the substrate sand. This indicates that young sand dollars store heavy sand grains selectively. The density of the sand dollar itself is about 2 g/cm^3, which is less than half of the density of the ingested sand. Therefore the storage of heavy sand in the diverticulum will considerably increase the density of the animal. This may be necessary for the survival of the juveniles in the shifting substrate. In other words, the young sand dollar has, in fact, equipped itself with a weight belt which enables it to remain in the sand. Moreover, it should be noted that the diverticulum with its radial pouches is essentially located at the anterior half of the animal. This arrangement may be important for enabling the animal to maintain an oblique position with the anterior end downward, which is the natural position of the adult (*3*).

At present I can offer no explanation



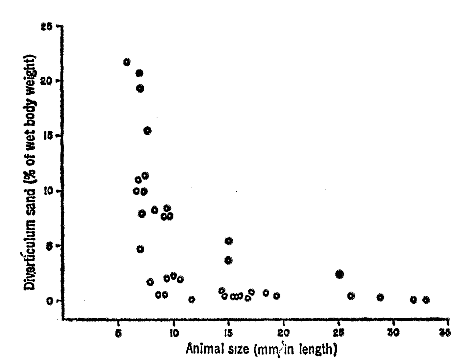


Fig. 1 (left). Aboral view of a young sand dollar after removal of the aboral half of the test, showing Aristotle's lantern (*L*), the digestive tract, and the intestinal diverticulum, which is filled with sand. The dark sand grains are iron oxide and the clear ones are feldspar and quartz. Area *A* is the anus, which marks the posterior end of the animal. The length of the animal was measured from the anus to the anterior margin of the test by crossing the mouth. The length is slightly greater than the width. Fig. 2 (right). Diverticulum sand expressed as percentage of wet body weight and also as a function of the size of the animal.

Table 1. Comparison of mineral types between the substrate and diverticulum sand. The percentage (by weight) of each mineral type was determined on 500 mg of substrate sand and on 120 mg of diverticulum sand extracted from 34 sand dollars.

Sand mineral type	Color	Density (g/cm^3)	Percentage in sand in	
			Substrate	Diverticulum
Oxidized iron oxide	Red	5.0	0.2	0
Shell fragments		2.7	0.4	0
Oxidized silicates	Orange	2.9	1.4	0
Iron oxide	Black	5.2	9.8	78
Hydrolyzed feldspar and quartz	Translucent	2.7	10.4	0
Highly altered feldspar	Opaque	3.0	18.5	0
Highly altered silicates	Gray	2.8	28.2	0
Feldspar and quartz	Clear	2.7	31.1	22

as to why the diverticulum sand contains 22 percent of clear feldspar and quartz (Table 1), but not other minerals such as silicates, which are also abundant in the substrate.

The particle size of the sand was analyzed by sieving it through a set of Nitex nylon monofilament screen cloths; it was found that the young sand dollar stores only particles smaller than 500 μm in diameter, which constitute about 83 percent of the substrate. However, 70 percent of the sand extracted from the sand dollars is less than 300 μm in diameter, and this constitutes only about 20 percent of the substrate. This suggests that particle size is also a limiting factor. But considering the density and the size of sand particles together, it is still seen that the heavy sand grains are much preferred by the juveniles.

The distribution of *Dendraster* in the Puget Sound area is rather patchy and the population density varies greatly from place to place (*4*). If we assume that the storage of heavy sand is important in the survival of the juveniles, then it follows that the nature of the substrate is essential for the success of the newly recruited juveniles. Thus, differences in particle size and composition of the substrate may have a profound effect on the patterns of distribution and the differences in population density.

At the study site, 10-mm individuals are about 1 year old while 30-mm ones are 2 years old (*4*). This study indicates that at 2 years of age the animals are perhaps sufficiently large to withstand the shifting substrate and no longer need to store sand in the diverticulum. It is also noted that at this stage the gonads begin to grow; they will certainly compete with the diverticulum for coelomic space.

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23 February 1973

Capacitor Electrode Stimulates Nerve or Muscle without Oxidation-Reduction Reactions

Abstract. *Porous tantalum disks, available as "slugs" from the capacitor industry, have large available surface area and a thin insulating coating of tantalum pentoxide. When implanted, they fill with extracellular fluid and operate as capacitor-stimulating electrodes having high capacitance per unit volume. Capable of stimulating excitable tissue without generating electrochemical by-products, these electrodes should provide a safer interface between neural prosthetic devices and human tissue.*

During electrical stimulation of muscle or nervous tissue with conventional metal electrodes, charge transfer across the electrode-tissue interface occurs by a combination of oxidation-reduction reactions and double layer charging. Some of the products of the oxidation-reduction reactions are toxic to tissue and must not be allowed to accumulate. Also, these reactions may corrode the electrodes themselves. Clearly such reactions must be minimized or eliminated for long-term electrical stimulation.

Biphasic stimulating waveforms with zero net charge flow, or "balanced" waveforms, have been proposed by Lilly (*1*) and others to minimize electrochemical damage with metal electrodes. However, the particular anodic and cathodic reactions occurring during these waveforms are often asymmetrical and may yield net quantities of harmful products (*2*).

If a metal electrode is completely insulated with a very thin layer of perfect dielectric material, oxidation-reduction reactions are essentially eliminated. Even though electrons cannot pass through the insulating barrier, ions in the tissue can be attracted or repelled by charge on the electrode, and current pulses sufficient for stimulation may be delivered. Although a perfect dielectric layer on the electrode can never be achieved, residual electron leakage can be made so negligible that no significant oxidation-reduction reactions occur.

A capacitor-stimulating electrode was first described by Mauro (*3*) in 1960 and recently improved by Schaldach (*4*). Neither of their electrodes is suitable for such applications as selective stimulation of cerebral cortex. Mauro's design is too bulky, and a small electrode of Schaldach's design will not hold the necessary charge. One method of increasing the amount of charge a miniature capacitor electrode will hold is by using a porous electrode material with a large accessible surface area. We have used a porous disk of tantalum for this purpose. Such a disk is termed a "slug" in the capacitor industry and is formed by fusing loosely packed tantalum powder into a conducting meshwork by a sintering process (see Fig. 1). Available surface area is increased to many times that of a smooth-surfaced electrode of comparable size. The insulating dielectric is tantalum pentoxide, a highly inert material. This dielectric layer is formed by anodization, and its thickness is directly proportional to the anodizing or forming voltage, about 20 Å per volt. When implanted, these electrodes fill with extracellular fluid and behave as electrolytic capacitors with extremely low leakage when operated at positive potentials. Our prototype electrodes were obtained as anodized slugs directly from the production lines of commercial capacitor manufacturers (*5*).

An important consideration in using a porous electrode is that organic ma-