that these granules were the major site of zein storage. *Floury-2* mutant, also known to be low in zein and high in lysine (*4*), presented a subcellular pattern of storage protein deposition similar to that of o_2; that is, mainly amorphous matrix protein was present. However, no zein granules were detectable in the electron microscope.

A change in size of the protein granules represents a corresponding change in zein content, and the protein granules are largely the site of zein storage in maize endosperm. Our studies provide a visual basis for the observations of Mertz *et al.* (*1*) that changes in protein composition of opaque and floury maize mutants as compared with normal corn are accompanied by a reduction in the amount of zein deposited. Our work also suggests that, while the mechanism for deposition of subcellular bodies in which zein is stored is greatly impaired in high-lysine mutants, deposition of nongranular storage protein high in lysine content is simultaneously increased.

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Negative Growth and Longevity in the Purple Sea Urchin Strongylocentrotus purpuratus (Stimpson)

Abstract. *Purple sea urchins were tagged, measured, and placed in a tidepool at Sunset Bay, Oregon. After 1 year, many animals had decreased in size. Accordingly, size is not necessarily a reliable index of age in* Strongylocentrotus purpuratus; *however, it is possible to conclude that these animals are relatively long-lived.*

Critical studies of the growth of echinoids under natural conditions have been few. Most have been based on shifts in size distributions over periods of one or more years (*1*); these shifts can be fairly accurately observed and used for determining the growth of small animals, but they become questionable for large individuals. The development of a suitable marking method for urchins (*2*) has allowed information concerning growth to be gathered in the field on all but very small individuals.

Since 1962, an intertidal population of the purple sea urchin *Strongylocentrotus purpuratus* (Stimpson) has been studied at the south side of Sunset Bay, Coos County, Oregon, 43°21′ north latitude. This side of the bay, formed of tipped beds of sandstone dipping sharply to the east and striking north and south, has been differentially weathered to produce a series of ridges, flat areas, and channels. Growth of urchins in two pools on one of these flat areas was examined. One pool was at approximately 3.5 feet (1.1 m) above 0 tide and had a surface area of 1.2 m^2, and a maximum depth of 0.25 m. This was used to hold tagged individuals and will be called the "experimental" pool. The other, the "control," was larger (approximately 5 m^2), 7 m south of the experimental pool and intertidally 0.9 m lower; it had a maximum depth of 0.65 m. Size distributions were examined for 3 years in this pool, and shifts in the modal classes of small animals were used to check for gross effects of marking on small urchins. Within the pools, urchins lived in cavities of their own construction (*3*) and apparently moved about only rarely. The dominant vegetation surrounding the pools was the eel grass *Phyllospadix Scouleri* Hook. Maximum tidal excursion at this region of the Oregon coast is roughly 9.5 feet (2.9 m) in June (*4*) which then makes the relative intertidal positions of the two pools "Zone 2" of Ricketts and Calvin (*5*).

In 1964, 141 urchins were marked and placed in the experimental pool; 72 with test diameters between 3 and 7 cm came from the pool itself, 7 large animals with test diameters between 7 and 9 cm were collected at about 0 tide from a boulder field 45 m northeast of the experimental pool, and 62 (1.2 to 7 cm) came from the control pool. After they were marked, the animals were measured to the nearest 0.01 cm with knife-edge vernier calipers. The five possible diameters were measured from the center of an ambulacrum to the opposite interambulacrum. Urchins under 2 cm in diameter were measured only three times. Standard errors of measurement ($S/\sqrt{N}$, where S is the standard deviation and N is number) in all cases were about 0.01 cm and were independent of size. After 1 year, 71 marked individuals were recovered from the experimental pool, and all were measured five times. Standard errors of measurement after 1 year were inversely proportional to size: about 0.02 cm in animals 2 cm wide and 0.01 in animals 4 cm wide and larger. The increase in error in small urchins was apparently due to a slower growth rate of the marked ambularcum relative to other areas of the test. The change in test diameter is expressed as a function of the original diameter (Fig. 1) with all points derived from the means of the original measurements and the five measurements after 1 year. Not all 71 points are on the graph; those not shown fall within the major cluster. The least-squares regression, however, included all points. The fate of the 70 animals not recovered after 1 year is only partially known. Migration did not appear to be significant. Some early mortality occurred after the marking; but after the 1st month, tag loss and mortality could not be separated.

A striking feature of Fig. 1 is the large number of individuals which decreased in size during the year. That this was a real negative change is evident from the very small standard errors of measurement. Since only hard

Table 1. Analysis of size distribution of urchins in the control pool. Means and standard deviations were determined graphically (*9*). S.D., standard deviation; *N*, number of urchins.

Year	Mode I (cm)	S.D.	*N*	Mode II (cm)	S.D.	*N*
1964	1.65	.48	200	5.13	.59	111
1965	2.44	.69	145	5.70	.52	93
1966	3.50	.57	72	5.37	.57	34

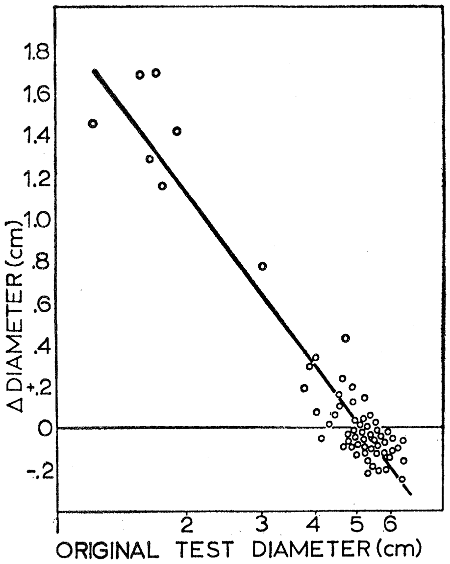

Fig. 1. Diameter changes (Δ diameter) of marked sea urchins in the experimental pool. The regression equation is $y = -2.77\ x + 1.97$, where x is the original diameter in logarithms and y is the change in diameter. Time is 1 year from June 1964 to June 1965.

parts are involved in the estimate of size, the fact that the animals shrink suggests that calcite was resorbed. The general growth of echinoid tests by addition of material around individual plates has long been known (*6*). Resorption of plates at the peristome has been experimentally determined in cidarids (*7*), and a highly precise deposition and resorption in spines has been suggested (*8*). Mechanisms for reworking calcite are obviously present and could lead to controlled decreases in test size.

In 1963, large numbers of newly settled animals were observed. By following these during the year, I knew that the small individuals collected from the control pool and marked in 1964 were all 1 year old. Size distributions were constructed from samples from the control pool during the summers of 1964 through 1966. Animal densities exceeded 200 individuals per meter squared, and sampling consisted of simply collecting all individuals within a small area and measuring one diameter with vernier calipers. Distributions for all 3 years were distinctly bimodal. Graphic analysis (*9*) was used to determine means and standard deviations of the distribution (Table 1).

The growth equation which can be derived from the regression in Fig. 1 is:

$$-x_t^{2.77} + x_t + 1.97 = x_{t+1} \qquad (1)$$

where t is years and x is test diameter in centimeters. If in Eq. 1 x equals 1.65 cm and t equals 1 year (Table 1), then test diameters of urchins 2 years old would be 3.02 cm; those of 3-year-olds, 3.66 cm; and those of 10-year-olds, 4.95 cm. .

Shifts in the modes of the 1963 class (Table 1) indicate mean sizes of 2.44 cm for 2-year-old urchins and 3.50 cm for animals 3 years old; these values are in general agreement with the sizes suggested from marking. Settling was apparently poor from 1964 to 1966; so the first mode, even in 1966, represented an almost pure 1963 class. The underestimate of the true mean of the 1963 class in 1966 is accordingly considered to be insignificant. Because of the agreement between growth of small marked animals and apparent growth of small animals in the control pool, I conclude that marking did not seriously affect the growth of small individuals. It would also then be expected that growth of larger individuals would not be affected by marking. The apparent shift of the second mode in the size distributions from 1964 to 1965 (Table 1) is much greater than that observed for marked animals of comparable sizes, as is the decrease from 1965 to 1966. Differences between large individuals in the experimental and control pools could be simply artifacts due either to sampling or to the graphic method of determination of mean size. It is also possible that there are environmental differences or that marking affects large animals differently than it does small ones. The latter explanation, however, appears to be unlikely. General growth form of *S. purpuratus*, as indicated by Walford's method (*10*), with size at $t + 1$ plotted as a function of size at t, is unlike graphs which can be drawn for other urchins (*1*), fish (*10, 11*), or pelecypods (*12*).

An implication of shrinking in large animals is that periods of decrease in size may be interspersed with periods of net gain, when environmental conditions change from year to year. Perhaps sea urchins grow to the limit allowed by the environment and adjust as the environment fluctuates.

The growth of animals in this study indicates that *S. purpuratus* may attain an age of at least 10 years. If settling observed since 1963 was normal, the large standing populations must represent recruitment over many years; the average age is possibly more than 10 years. The growth equation and the suggested relationship between size and age must of course be considered as representative only for the period 1964 to 1965 at the high area of Sunset Bay having eel grass; they cannot be considered as the only ones possible for this urchin.

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Stabilization of Hydrated Electrons in Irradiated Frozen Sugar Solutions

Abstract. *Yields of free radicals in irradiated aqueous solutions of saccharides at 77°K are larger and qualitatively different from those observed in the components alone. In addition, a blue color results only with the solution. The mechanism proposed to explain the observations is the stabilization of hydrated electrons by the solute.*

Irradiation of frozen solutions of sucrose and the monomers forming it—fructose and glucose—results in phenomena which are specific to the solution and which do not occur in either the solvent or solute alone. The electron spin resonance spectrum exhibits a strong narrow single line in addition to the absorption due to the components by themselves. Irradiation effects on the