Table 2. Cadmium in soil, commercially grown grains and seeds, and grains grown in an abandoned pasture (in micrograms per 100 g wet weight). N.D., not detected.

Grain	Commercial feed	Commercial seed	Pasture grown
Rye	N.D.	N.D.	N.D.
Oats	8.1 to 12.7	N.D.	N.D.
Wheat	5.7 to 13.0	1.0	4.6
Barley	1.0	1.0	N.D.
Millet	*	4.0	N.D.
Buckwheat	7.2	N.D.	N.D.
Soil†			N.D.

* Not available. † Soil of the long-abandoned pasture had been limed 2 years previously; the *p*H was 5.5. The subsoil undoubtedly contained Cd.

of the composted wood chips and manure, and the third received a heavy application of superphosphate, approximately 10 percent by volume. Four vegetables were planted and watered with doubly deionized water. Growth was lush in the box treated with superphosphate but poor in the others. The mature vegetables were analyzed for Cd (Table 1).

In order to grow grains in a cadmium-free environment, a long-abandoned pasture in a remote forest was cleared, plowed, limed, and planted with rye. Both the soil and the crop were free of cadmium. The next year five plots, each 10 by 40 m, were rototilled and planted heavily with buckwheat, wheat, oats, barley, and Hungarian millet. No fertilizer was applied. The mature grain was threshed by hand, metallic contamination being carefully avoided. Commercial feed, the seed planted, and the grain grown by us were analyzed (Table 2).

Our experiments indicate that superphosphate can be a source of the cadmium in certain vegetables. Several of the commercial vegetables which do not ordinarily contain detectable cadmium can absorb it in the presence of high concentrations of phosphate. Other vegetables usually containing cadmium can be grown without it appearing in the mature plant. Furthermore, certain grains ordinarily containing cadmium can be grown free of this trace metal, although wheat appears to be an exception. Presumably the cadmium in most commerical grains and many vegetables comes partly from that in marine phosphorite deposits, for phosphate fertilizers are widely used on grain-producing lands and truck gardens (*4*). Although the ultimate source was the sea, sea water now contains little cadmium (1 part in 10^9) (*9*). We could not find cadmium in water samples from Cape Cod, although a commercial sea salt from Texas contained 0.13 ppm.

Cadmium is undoubtedly present in the subsoil of our area, for we have found it in leaves, twigs and bark of forest trees (*2*). The earth's crust contains 0.18 ppm Cd (*6*), an amount comparable with that in our forest soil. Although it was not detected in untreated garden and pasture soils, a small amount must have been available since it was absorbed by parsnips and wheat. The area cultivated is one of heavy rainfall and excessive leaching of trace metals from exposed soils.

The amount of cadmium in vegetables exposed to phosphate appears to be small. The mean daily dietary intake of Americans, however, has been estimated as only 23 μg of Cd, of which 3 μg is retained in the body, mainly in kidney and liver (*2*). An institutional diet (2500 calories per day) contained 18 μg. By comparison the concentrations of 1 to 4 μg/100 g in these vegetables are relatively large.

There seems to be no evidence at this time that cadmium is an essential trace metal for mammals. Rats and mice were reared successfully on a cadmium-free diet, none being found in their tissues; others given small amounts of cadmium have had considerably higher mortalities when renal concentrations were approximately one-fourth those of adult Americans (*10*). Female rats fed cadmium in small doses have exhibited hypertension, often severe (*11*) at these same renal concentrations. The mammalian body apparently has no homeostatic mechanism for cadmium (*12*), unlike the "essential" trace metals. Pathways by which cadmium enters food and the body of man are therefore important to explore (*13*).

HENRY A. SCHROEDER
JOSEPH J. BALASSA
Brattleboro Retreat, Brattleboro, Vermont, and *Department of Physiology, Dartmouth Medical School, Hanover, New Hampshire*

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Helicoplacoidea: A New Class of Echinoderms

Abstract. *A fusiform, spirally coiled and pleated, free-living, heavily placate echinoderm with an expansible test has been discovered in the Lower Cambrian* Olenellus *zone of California. It is characterized by 10 "interambulacral" areas, a single principal endothecal ambulacrum with a short branch, and oral and apical regions at opposite poles. A new class, the Helicoplacoidea is proposed for the new genus* Helicoplacus, *with two new species,* H. gilberti (*type species*) *and* H. curtisi.

At least 31 specimens of a striking new type of echinoderm, some essentially complete, others fragmentary and exceedingly numerous dissociated plates have been collected from a shale with graded bedding near the base of the upper member of the Poleta Formation, Lower Cambrian (*1*) in the Westgard Pass area of the White-Inyo Mountains, about 15 miles southeast of Bishop, California. The new form is found at three localities (*2*) scattered over an area of perhaps a square mile, about 1 mile west of the highway. The specimens occur in beds in which trilobites are common (occasionally on the same bedding surface) and which are perhaps 25 feet above the lower, archaeocyathid-bearing limestone of the Poleta Formation. Archaeocyathids are also found in overlying beds. The pedunculate echinoderm *Eocystites* occurs at approximately the same stratigraphic position and may possibly occur in the same bed. The beds in which the new form occurs fall within "beds with the very abundant *Nevadella gracile* (Walcott) fauna, approximately 2500′ above

the base of the 6700′ [thick section] of olenellid-bearing strata" (*3*).

The free-living character and the distinct oral and aboral poles suggest that this echinoderm is related to the "subphylum Echinozoa" (*4*). The flexible character of the test suggests the holothurians, but it differs from them by the spiral arrangement of the columns and the presence of only a single ambulacrum with one branch. The fusiform shape likewise suggests some elongated echinoids but the spiral pleating and the unique method of expanding the test separate it from that class. The imbrication of the external (medial) "interambulacral" columns when in the retracted state and the gross character of the ambulacra recall the edrioasteroids, but the presence of internal lateral columns of the "interambulacra" and the method of expanding the test readily separate it from them.

The unique method of expanding the test appears unlike any known condition in other echinoderms. Only one specimen (see cover photograph) of the present collection, an incomplete oral region, obliquely flattened, is in the fully expanded state, but the edges of the lateral interambulacral columns can be observed between the medial columns in several incompletely retracted specimens and their internal, infolded condition can be clearly observed (Fig. 1*B*) in one cross-sectioned individual. This mechanism necessitates a complex internal muscle system or else a retractor muscle system working against an internal water vascular system that was capable of expanding the organism.

No trace of an attachment area has been observed on the five specimens on which the apical pole (or part of it) can be observed. Unfortunately, all details of this pole are not clearly preserved on any specimen, but the shape of the pole and character of the apical plates that are preserved do not suggest an attachment area. Likewise no columnals have been noted among the thousands of dissociated plates available. Finally, the rock matrix in which the fossils are preserved contains no clastic particles large enough for an organism of this size to adhere to.

The free-living habitat of this animal, the ten "interambulacral" areas, the single branching ambulacrum, and the early Cambrian age lead to speculation about its immediate ancestry. The newly found form, if not in the direct

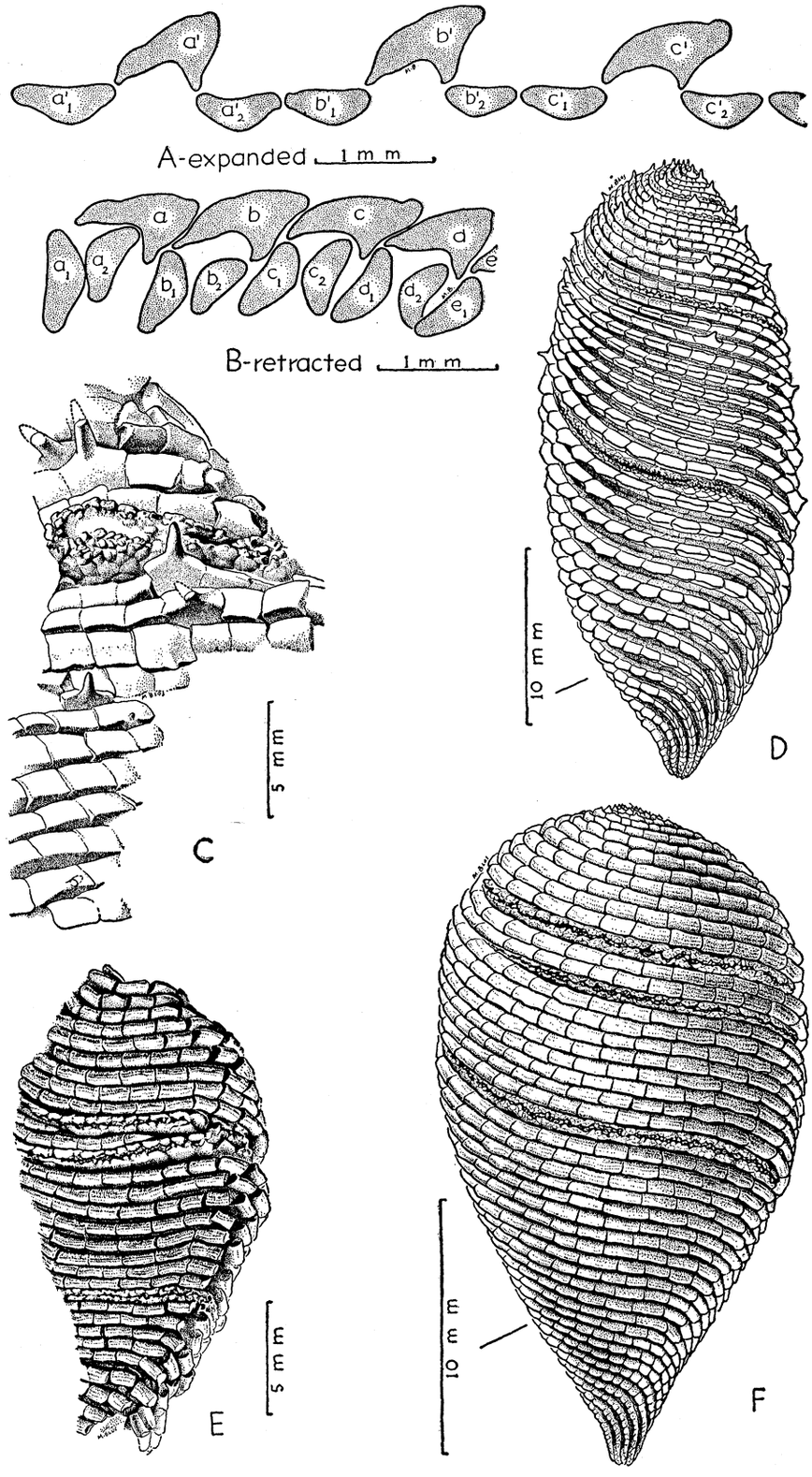

Fig. 1. *A, B, E, F, Helicoplacus gilberti* n. sp.: *A*, section parallel to axis and normal to surface, exterior surface up (based on paratype No. 37849); *B*, orientation as in *A* (from paratype No. 37854); *E*, holotype (incomplete) No. 37847; *F*, restoration (retracted state, oral pole up) based on holotype and paratypes. *C, D, Helicoplacus curtisi* n. sp.: *C*, holotype (incomplete) No. 37844; *D*, restoration (semiexpanded state, oral pole up) based on holotype, paratype, and other specimens.

ancestry of some later echinoderm, must be a descendant of an ancestor which had the potential to give rise to both stalked and free-living types. Inasmuch as representatives of both conditions are present in the Lower Cambrian and are already differentiated, they must have arisen and diverged a considerable time before the beginning of the Cambrian. The free-living character of the new form suggests that the common ancestor may not have been a stemmed (or pelmatozoic) echinoderm. Of all classes hitherto known, the edrioasteroids would seem to be closest to the helicoplacoids and may well be closely related to them.

The new class Helicoplacoidea may be diagnosed as follows:

Free living, fusiform placoid echinoderms with spirally pleated, expansible test; apical and oral poles at opposite extremities; columns of plates arranged in a spiral; ambulacra and "interambulacra" present; new "interambulacral" plates originating at apical pole and becoming more oral in position as subsequent plates are added (origin of ambulacral plates obscure). Lower Cambrian, California.

The "interambulacral" areas are formed of three columns of plates. In the retracted slate (Fig. 1 *B*) the central column is external and the two lateral columns folded internally; to expand (Fig. 1*A*) the lateral columns fold out laterally and floor the "valleys" adjacent to the ridge-like medial column. The three columns of an area appear to originate from a single center. In the species here described there are 10 "interambulacral" areas. The principal ambulacrum makes at least two full spiral turns, starting at the mouth, but does not reach to the apical pole. The secondary ambulacrum first appears about 180° along the spiral from the mouth and then continues for approximately another 180°, being separated from the first by two "interambulacral" areas throughout most of its length. In one specimen (Fig. 1*E*) the two ambulacra clearly join, apparently adapically and the principal ambulacrum continues. In the retracted state the medial "interambulacral" column imbricates adapically posterior to the branching of the ambulacrum, and slightly adorally anterior to this point. The ambulacra are composed of several rows of small plates. As yet no podial pores nor anal and genital orifices have been recognized. The structure of the peristome is uncertain but the mouth apparently was not more than 1 mm in diameter. Grossly, the symmetry of the test at least as far as the interambulacra are concerned, should be considered as radial, modified by torsion to spiral.

The new genus *Helicoplacus* consists of helicoplacoid echinoderms, in which the primary ambulacrum has a single branch. From Greek *helix*, a spiral, and *plakos*, a flat plate. Type species:

Helicoplacus gilberti, n. sp. (*5*). "Interambulacra" with about four turns; plates of medial column slightly longer than those of lateral columns; rounded external edges of medial plates with fine longitudinal ribs, and intermittently developed nonarticulated spines adorally (on every fourth to ninth plate); spines not present medially or adapically on test; adult specimens about 35 mm long.

Helicoplacus curtisi, n. sp. (*6*). Similar to *H. gilberti* but plates of medial "interambulacral" columns without longitudinal ribs and with outer edge sharply angled; large, elongated, nonarticulated spines locally present medially on test; spines becoming reduced adapically but adapical margin of plates with an angle suggesting incipient spines; "incipient spines" may be present on adjacent plates near apical pole; adult specimens larger than *H. gilberti*, possibly attaining a length of about 75 mm.

Helicoplacus curtisi (Fig. 1, *C*, *D*) may be distinguished from *H. gilberti* (Fig. 1, *A*, *B*, *E*, *F*) by the nonribbed, prominently spinose plates on the medial portion of the test. In the type specimen the ambulacrum either has more columns of plates than in *H. gilberti* or else it is expanded so as to show columns that are hidden in the type of that species.

There may well be signal phylogenetic implications in these new-found organisms, even though it has been said that "the original echinoderm must have been very different from those that we know today and that we can scarcely hope to unravel the history of the phylum" (*7*).

Inasmuch as the Helicoplacoidea and the contemporary eocrinoid *Eocystites* (on which Caster is currently working) are the most ancient echinoderms yet discovered, are both free-living, and yet are morphologically widely separated from one another, it is apparent that considerable doubt is cast upon the generally accepted view (*8*) that the ancestral echinoderm was attached. Need for a reconsideration of all subphyla of the Echinodermata hitherto proposed is also indicated.

J. W. DURHAM
University of California, Berkeley
K. E. CASTER
University of Cincinnati, Cincinnati, Ohio

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Methodological Questions in the Study of One-Trial Learning

Abstract. *The substitution method may lead to poorer learning than the customary repetition method when learned pairs are eliminated after each trial. This results from a procedure in which the subject is required to spell the response. Spelling leads to greater difficulty in learning the response item but repetition tends to counteract it.*

Recent experiments have led to the conclusion that, in the learning process, associations are formed either completely or not at all in one trial (*1*). The number of trials to criterion is the same when missed pairs are replaced by new ones after each trial as it is when the same pairs are presented on every trial. Although these results have been confirmed when the same procedure is followed (*2*), certain variations have led to different results (*3*, *4*, *5*). One such variation arose from a possible difference in interference between learned and unlearned pairs and learned and new pairs (*6*). Kristofferson tried to eliminate this possible flaw by discarding correct items after each trial for both groups instead of retaining them. Although this is an adequate test of the all-or-none hypothesis it was not used in the original experiment; by discarding correct items after every trial, the list becomes in-