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GROWTH PATTERNS IN *PROCTOTHYLACOCRINUS LONGUS* KIER

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VOLUME 22

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ABSTRACT—In thirteen selected specimens of *Proctothylacocrinus longus* Kier, growth of individual calyx plates was measured by constant differential growth ratios of width, height, and width × height compared with the average width of BB plates. These ratios show distinct changes in growth rate between the smaller five and the larger eight specimens; the changes are considered to mark the boundary between early ontogeny (probably juveniles) and late ontogeny (probably adults). When values are plotted and contoured on plate diagrams of the species, growth patterns of width, height, and area are graphically shown for the two ontogenetic stages.

INTRODUCTION

GROWTH PATTERNS in *Proctothylacocrinus longus* Kier were investigated by the same methods used recently in *P. esseri* Kesling. Thirteen specimens were carefully selected to avoid crushed and distorted calyces. In each plate which appeared to be well preserved, measurements were made of width and height. This data was plotted against standards to give constant differential growth ratios of each dimension in each kind of calyx plate. Values of these ratios were entered and contoured on plate diagrams to show graphically the patterns of growth in young and in old specimens of width, height, and area (as estimated from width × height).

Mr. Richard J. Greenwood, Research Assistant at the Museum of Paleontology, made the basic measurements early in 1968. Mrs. Gladys Newton typed the manuscript, and Professor E. C. Stumm and Professor C. A. Arnold critically reviewed it. Mr. Karoly Kutasi helped in photographic preparation of text-figures. To all who assisted I offer sincere thanks.

PROCEDURE

Specimens.—Only calyces with complete circlets of BB and no serious distortion in other areas were selected. Most had all the plates well preserved, but some lacked clear outlines in one dimension or the other of a few plates.

All specimens are catalogued in the Museum of Paleontology. Most were illustrated in an earlier publication (Kesling, 1965). The numbers and previous illustrations are listed, from smallest to largest specimens, in table 1.

TABLE 1—SPECIMENS OF *PROCTOTHYLACOCRINUS LONGUS* USED IN GROWTH STUDY AND THEIR STANDARD MEASUREMENTS

Specimen UMMP	Illustration (1965)	Standard measurement (mm)
51727	Pl. 5, figs. 5, 6	1.33
51724	Pl. 5, figs. 1, 2	1.73
51658	Pl. 5, figs. 9, 10	2.07
51659	Pl. 3, figs. 1, 2	2.11
51726	Pl. 5, figs. 7, 8	2.28
51725	Pl. 4, figs. 3, 4	2.34
51655	Pl. 3, figs. 6, 7	2.41
51657	Pl. 3, figs. 4, 5	2.48
51660	Pl. 5, figs. 3, 4	2.55
27694	Pl. 4, figs. 5, 6	2.68
51662	Pl. 5, figs. 11, 12	2.81
27693	———	3.05
51656	Pl. 3, fig. 3	3.13

Measurements.—Measuring was done with a Gaertner Scientific Corporation measuring microscope, which operates as a vertical monocular with crosshairs moved along a straight path by screw threads connected to a graduated drum. Two basic measurements were made of each plate, height and width. Height was measured as the greatest extent of the plate in a direction perpendicular to the dorsal edge of the nearest BB plates, with the plate surface flat and normal to the line of sight through the scope. Width was measured as the greatest extent of the plate in a direction perpendicular to that of height. The Gaertner instrument is particularly suited for such measurements.

Height and width were measured in all thirteen specimens for each of the five IBB, five BB, five RR, RA, X_1, and RX_1, except for those plates which were obviously chipped, out of position, or otherwise imperfectly fossilized. Of the 468 possible measurements in these crinoids, 375 were considered reliable. Most omissions were of IBB; these small plates seem especially prone to damage.

For a standard of comparison, the average width of BB was chosen because the BB circlet shows less distortion than any other set of plates in the calyx. Standard measurements of specimens are shown in table 1. Width was regarded as accurate in all BB of all specimens used. As an estimate of plate area, the product of width × height was used.

Constant differential growth ratios.—As in my study of growth in *Proctothylacocrinus esseri* Kesling (see Kesling, 1968), constant differential growth ratios (CDGR's) were determined by plotting each measurement against the standard measurement of the specimen (the average width of BB) on double-logarithm paper by the method presented several years ago (Kesling, 1951).

For plotted points, the line of best fit was drawn. It was soon apparent that growth did not continue throughout the ontogeny of this crinoid at a fixed CDGR (text-fig. 1). Instead, the line for each dimension showed a difference in slope below 2.3 mm standard and above 2.3 mm standard. This deflection or bend in the line occurred for both height and width in nearly all plates (text-figs. 1–8). Separate CDGR's were measured, therefore, for early ontogeny (below 2.3 mm) and late ontogeny (above 2.3 mm). Five specimens were in the early category, and eight in the late.

Although CDGR's were determined for all plates (table 2), only certain plates are illustrated (text-figs. 1–8). In each text-figure the width is plotted as small circles, the height as black dots, and the area (actually, width × height) as concentrically encircled circles; to emphasize each dimension, the scales are offset. For direct comparison with width and height, the scale for area is the square of values in the other two scales. Lines of best fit are labeled in CDGR values.

Growth patterns.—To graphically portray growth gradients in the calyx, CDGR values were plotted at plate centers on a plate diagram of *Proctothylacocrinus longus*, one diagram each for early and late ontogeny of width, height, and area (text-figs. 9–14). Contours based on these values show patterns of growth and the location of growth gradients.

RESULTS

Differences in CDGR's are greater from dorsal to ventral than from anterior to posterior in the calyx. General patterns of growth, therefore, can be discussed primarily as the differences among the three circlets (the IBB, the BB, and the RR + RA + X_1 + RX_1 circlets) and secondarily as differences within each circlet.

TABLE 2—CONSTANT DIFFERENTIAL GROWTH RATIOS IN *PROCTOTHYLACOCRINUS LONGUS*

Width

	Early Ontogeny										Late Ontogeny									
Location (Ray)	E		D		C		B		A		E		D		C		B		A	
X_1, RA, RX_1				1.02		0.94		0.80						1.18		0.97		1.04		
RR	0.92		1.00		1.08		0.99		0.90		1.12		1.08		1.15		1.12		1.23	
BB		0.80		0.92		1.18		1.05		0.95		1.13		0.89		1.02		0.99		1.04
IBB	1.43		0.70		0.89		1.29		1.30		1.06		1.43		1.57		1.37		1.25	

Height

	Early Ontogeny										Late Ontogeny									
Location (Ray)	E		D		C		B		A		E		D		C		B		A	
X_1, RA, RX_1				1.30		1.04		1.05						0.85		1.04		1.19		
RR	0.89		0.77		0.85		0.83		0.91		0.99		1.16		1.38		1.18		1.14	
BB		0.64		0.79		0.57		0.71		0.88		1.23		0.93		1.35		1.13		1.03
IBB	1.32		0.90		1.11		1.43		1.29		1.43		1.63		1.56		1.65		2.00	

Area

	Early Ontogeny										Late Ontogeny									
Location (Ray)	E		D		C		B		A		E		D		C		B		A	
X_1, RA, RX_1				1.15		0.98		0.93						1.05		1.00		1.10		
RR	0.84		0.80		0.80		0.86		0.89		1.09		1.11		1.18		1.14		1.09	
BB		0.74		0.87		0.79		0.93		0.89		1.12		0.92		1.19		1.10		1.05
IBB	1.40		0.83		1.09		1.26		1.33		1.14		1.35		1.37		1.49		1.52	

During early ontogeny, the IBB plates grew more in width than plates in the other two circlets (text-fig. 9). Growth (as shown by CDGR values) reached a maximum in the IB of the E-ray (1.43), and was strong in IBB of the A-ray (1.30) and B-ray (1.29) and in B of the BC-interray (1.18); it reached a minimum in IB of the D-ray (0.70) and was weak in RX_1 (0.80). Compared with the standard (average width of BB), less-than-average growth occurred along a diagonal through the posterior region, the trough of low values crossing from RX_1 to a depression in IB of the D-ray. Positive gradients formed a ridge rising from R of the C-ray (1.08) to IBB of the B-ray (1.29) and A-ray (1.30).

During the late ontogeny (text-fig. 10) the same general plan of width increase prevailed although there were minor changes. The only plates which showed less-than-average growth were the BB of the CD-interray (0.89) and the AB-interray (0.99). Strongest growth occurred in the IBB plates, which, from A- through E-rays, had ratios of 1.25, 1.37, 1.57, 1.43, and 1.06. The only area of somewhat weak growth during this period of the crinoid's life was central posterior.

In early ontogeny, growth in height of plates (text-fig. 11) was strong in IBB, notably weak in BB, and intermediate in the RR circlet except for a local concentration in X_1 (1.30). The IBB of the A-, B-, and E-rays reached CDGR's of 1.29, 1.43, and 1.32. In late ontogeny (text-fig. 12) height increased in all plates at a faster rate than in early ontogeny, with two exceptions: RA increased at the same CDGR (1.04) and X_1 slowed up (from 1.30 to 0.85). Particularly strong increases in height characterized IBB with CDGR's (A- through E-rays) of 2.00, 1.65, 1.56, 1.63, and 1.43. In the BB circlet, height centered on the BC-interray (1.35); and in the RR plates it centered on the C-ray (1.38). During ontogeny of the crinoid, the growth pattern of height changed remarkably little, except for the slower growth of X_1 with age.

Area, as estimated from the product of width × height, shows similarities both to width and to height in its growth pattern. The IBB grew more than other plates in early (1.33, 1.26, 1.09, 0.83, and 1.40) and in late ontogeny (1.52, 1.49, 1.37, 1.35, and 1.14). In early ontogeny (text-fig. 13) and in late ontogeny (text-fig. 14), the BB and RR circlets grew at about the same rate; in early ontogeny, CDGR's of RR ranged from 0.80 to 0.89, whereas in late ontogeny, they ranged from 1.09 to 1.18. The only notable change in the pattern of plate area growth was the slowing up of growth in X_1; in early life, this plate grew faster than the average, but in late life it grew at about the same pace as other plates.

The greatest changes in calyx plates of *Proctothylacocrinus longus* during its lifetime were concerned with the relative sizes of plates in the circlets. The IBB grew drastically more in height and in width than the other plates. Hence, the IBB circlet expanded more rapidly than the BB circlet, and the taper of the cup toward the columnar facet became less and less. In early ontogeny, X_1 grew more than the RR in all dimensions, but in late ontogeny these differences disappeared. It seems possible that the high CDGR in area of X_1 (1.15) early in life was correlated with the establishment of the anal chimney atop this plate.

I presume that the division between early and late ontogeny, clearly indicated as the level at which the average width of BB = 2.3 mm, marks a significant change in the physiology of the crinoid. Logically, this may be interpreted as the onset of maturity.

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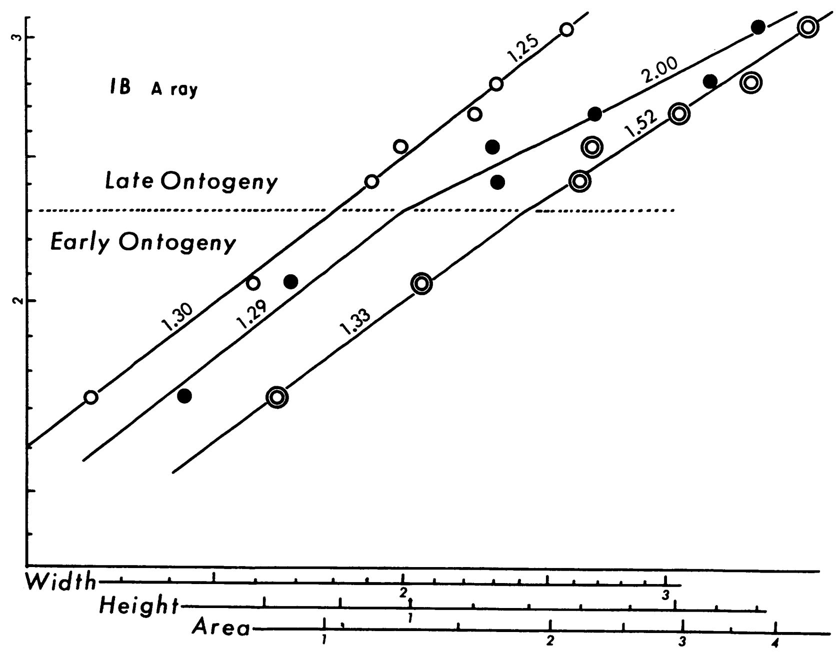
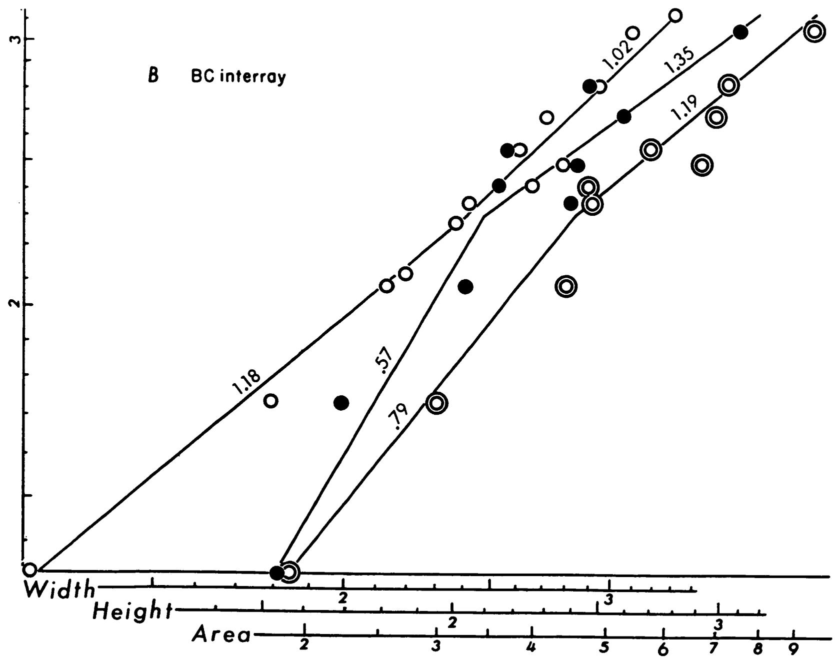
——— 1968, Note on ontogeny of the Middle Devonian crinoid *Proctothylacocrinus esseri* Kesling: *Ibid.,* v. 22, no. 9, p. 133–138, 2 pls., 4 text-figs.

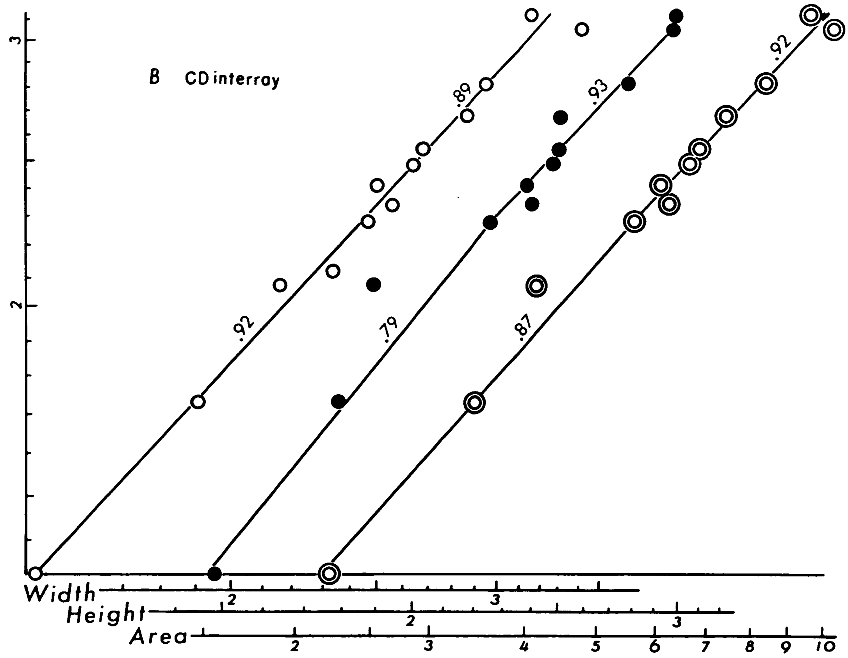
MANUSCRIPT RECEIVED NOVEMBER 6, 1968



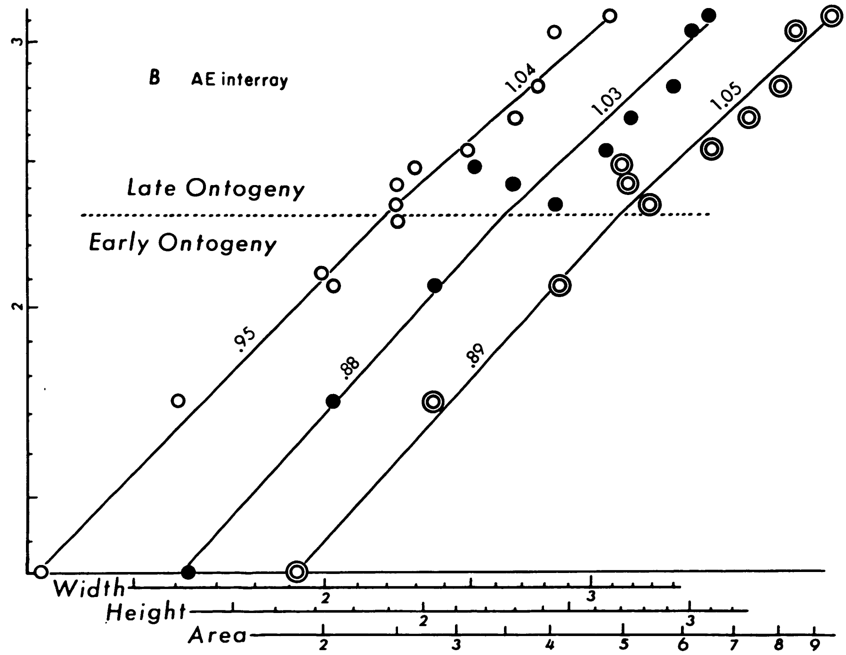
TEXT-FIG. *1—Proctothylacocrinus longus* Kier. Constant differential growth ratios of width, height, and area in IB of the A-ray. Standard for comparison is average width of BB plates. Separate values computed for early and late ontogeny.



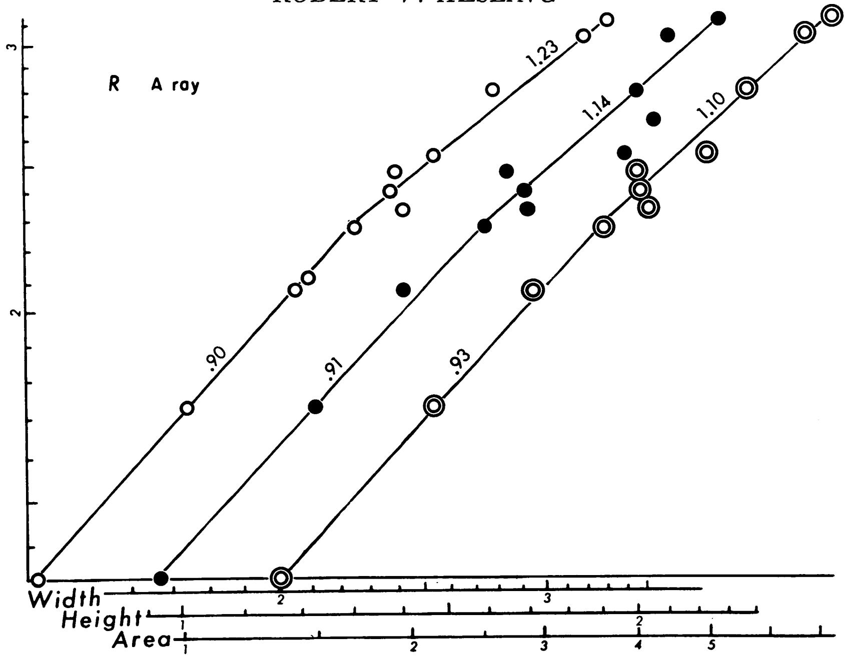
TEXT-FIG. *2—Proctothylacocrinus longus*. Constant differential growth ratios in B of the BC-interray.



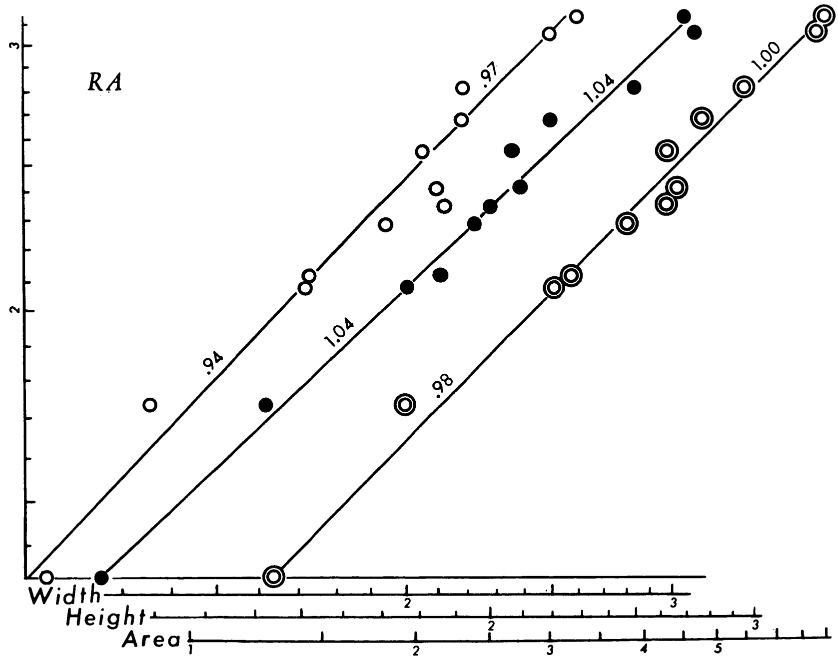
TEXT-FIG. 3—*Proctothylacocrinus longus*. Constant differential growth ratios in B of the CD-interray.



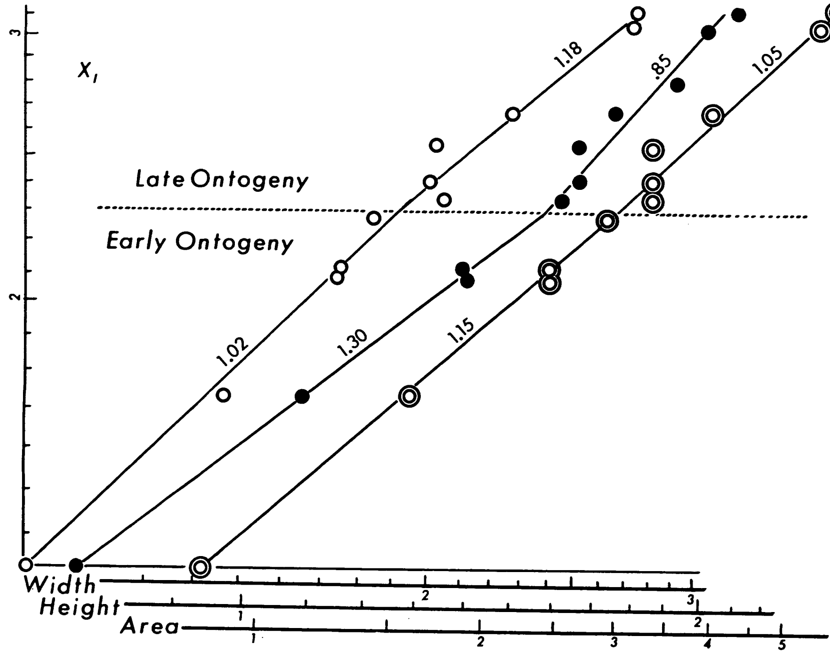
TEXT-FIG. 4—*Proctothylacocrinus longus*. Constant differential growth ratios in B of the AE-interray.



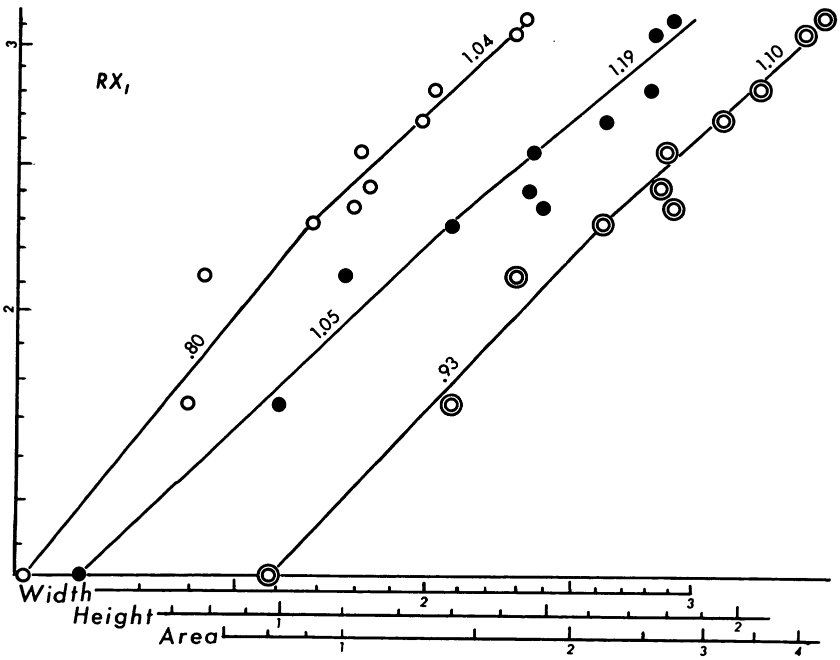
TEXT-FIG. 5—*Proctothylacocrinus longus*. Constant differential growth ratios in R of the A-ray.



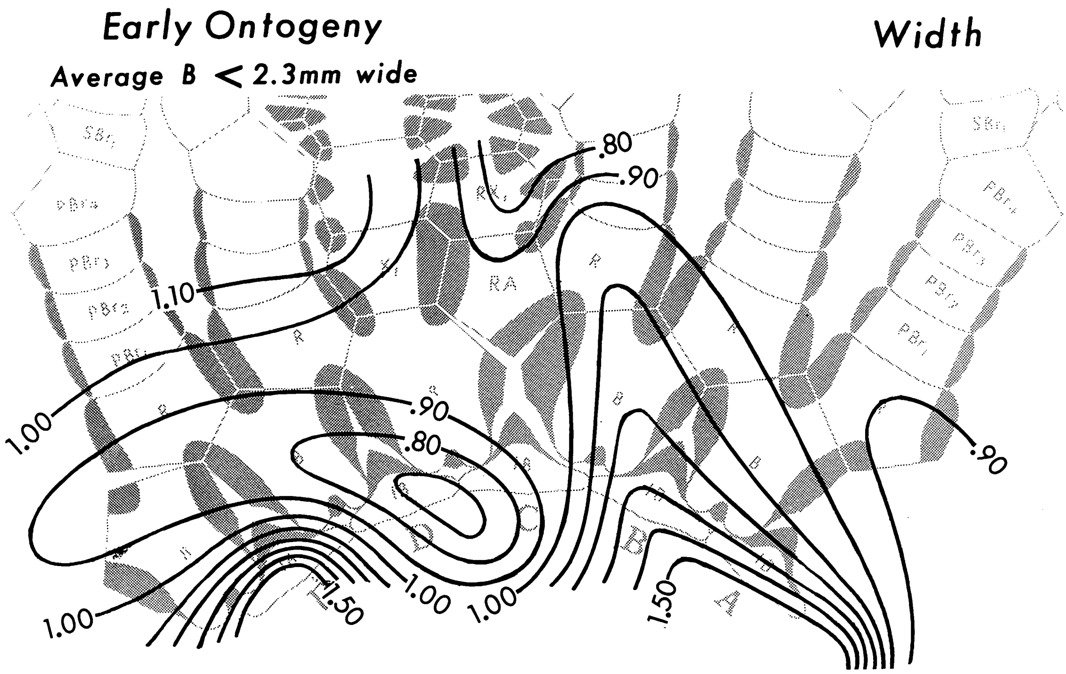
TEXT-FIG. 6—*Proctothylacocrinus longus*. Constant differential growth ratios in RA.



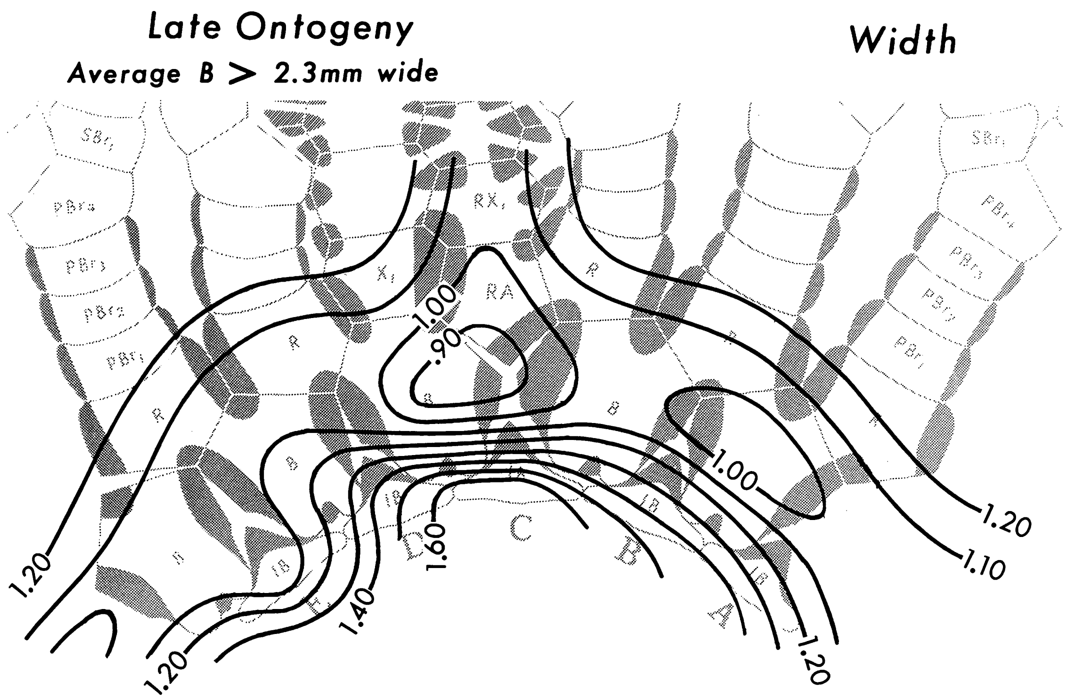
TEXT-FIG. 7—*Proctothylacocrinus longus.* Constant differential growth ratios in X_1 (anal *x*).



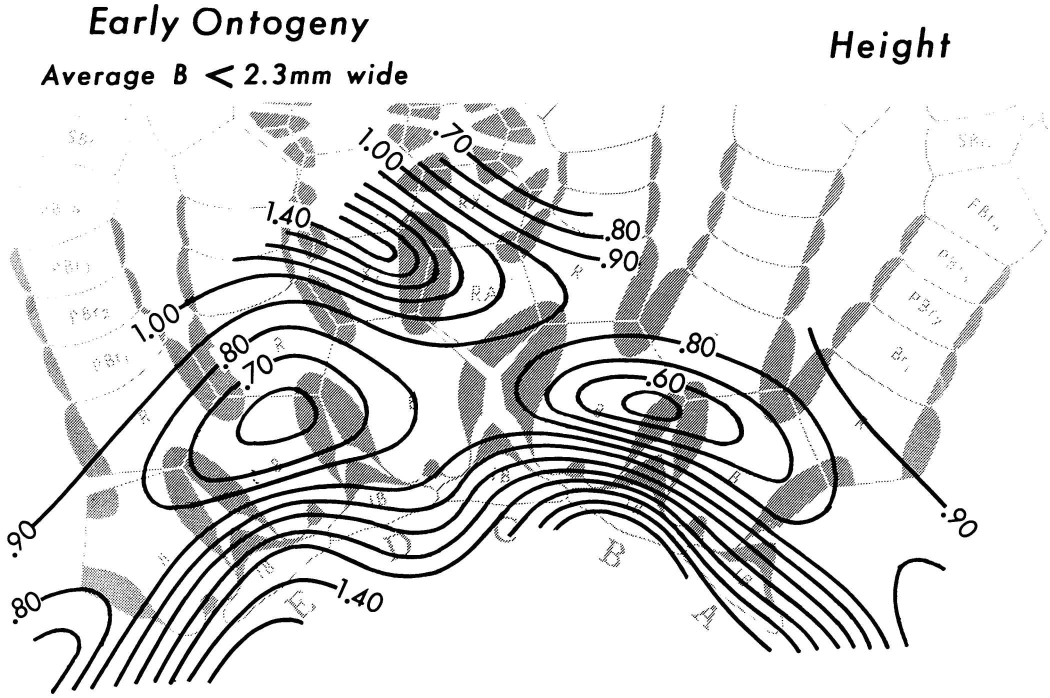
TEXT-FIG. 8—*Proctothylacocrinus longus.* Constant differential growth ratios in RX_1.



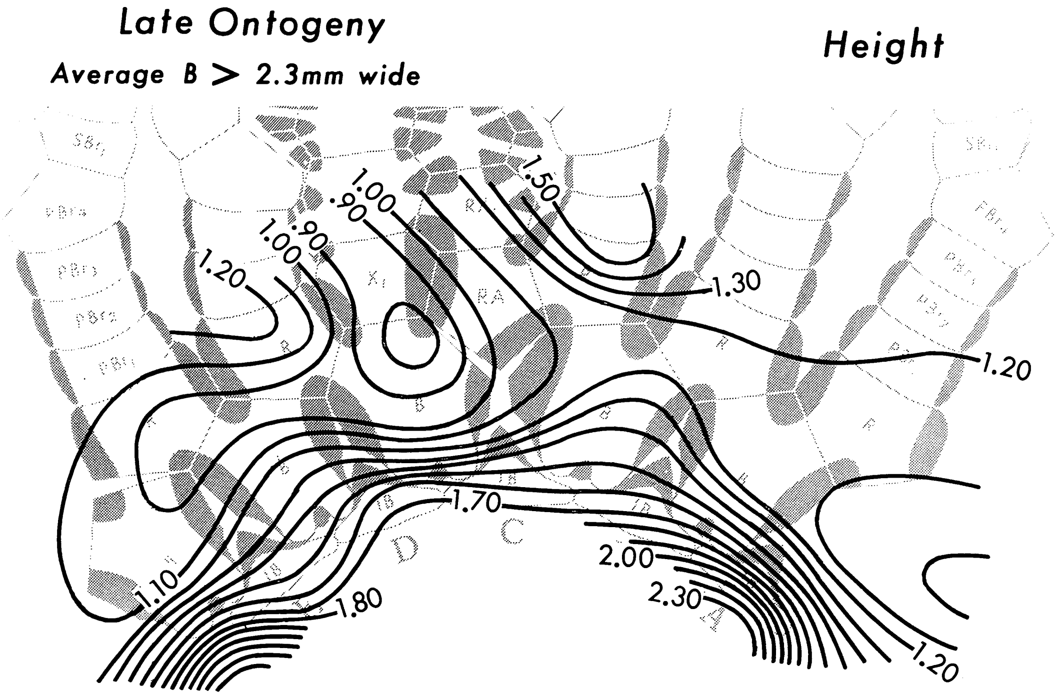
TEXT-FIG. *9—Proctothylacocrinus longus.* Growth pattern of width in early ontogeny. Contours labeled with values of constant differential growth ratios.



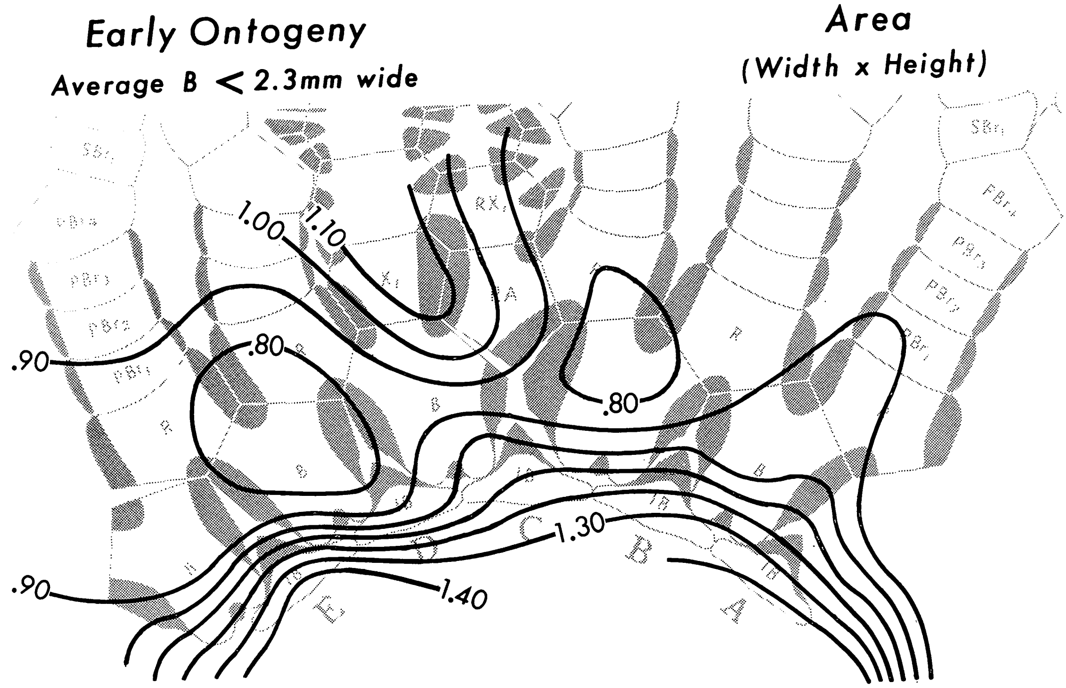
TEXT-FIG. *10—Proctothylacocrinus longus.* Growth pattern of width in late ontogeny.



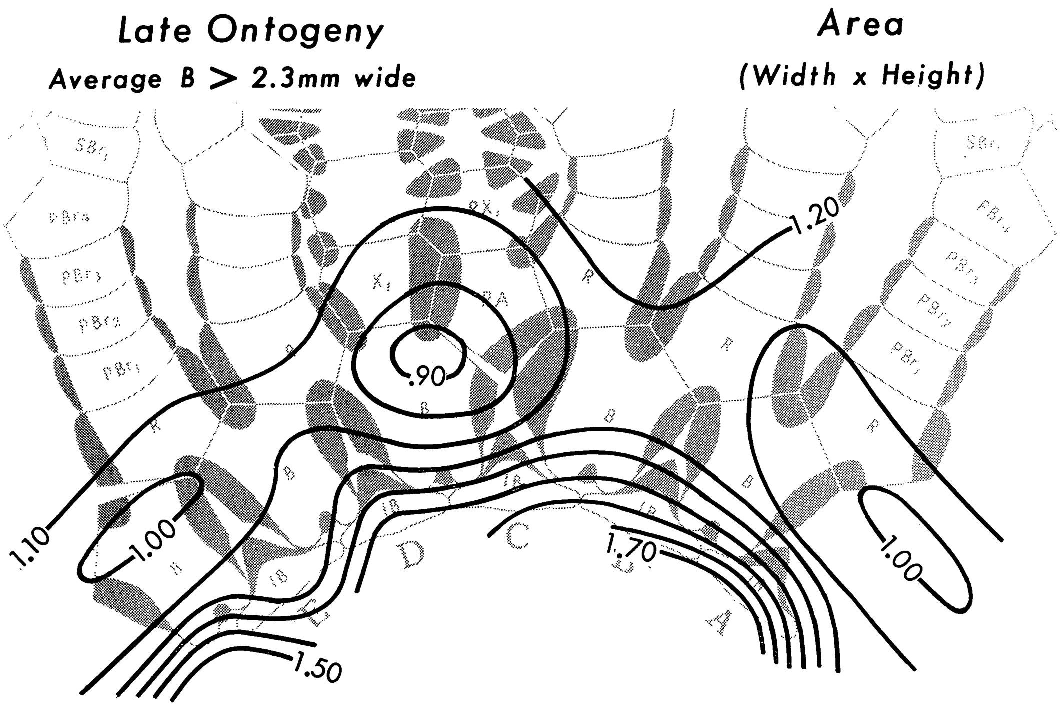
TEXT-FIG. *11—Proctothylacocrinus longus.* Growth pattern of height in early ontogeny.



TEXT-FIG. *12—Proctothylacocrinus longus.* Growth pattern of height in late ontogeny.



TEXT-FIG. *13—Proctothylacocrinus longus*. Growth pattern of area in early ontogeny.



TEXT-FIG. *14—Proctothylacocrinus longus*. Growth, pattern of area in late ontogeny.