Carbohydrate and Lipid Levels in the Intestine of *Holothuria atra* (Echinodermata, Holothuroidea)[1]

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ALTHOUGH THE NUTRIENT COMPOSITION of the intestinal tract of many echinoderms has been analyzed (see Giese, 1966 *a,b* for summaries), little attention has been given to possible differences in the different regions of the intestine. This situation exists despite numerous studies showing that the regions vary structurally and functionally (see Hyman, 1955, and Anderson, 1966, for summaries). Apparently only Doezema (1967) has made a biochemical analysis of the various parts of the echinoid gut. He found that glycogen was located primarily in the second circuit of the intestine.

This paper reports the levels and content of carbohydrate, total lipid, and neutral lipid in the small intestine, large intestine, and rete mirabile of the sea cucumber *Holothuria atra* Jäger.

MATERIALS AND METHODS

Specimens of *Holothuria atra* were collected intertidally at Eniwetok Atoll, Marshall Islands (lat 11°21′ N, long 162°21′ E). Ten animals were collected on 31 July and again on 23 August 1968.

The tissues from the small and large intestines, and the rete mirabile were pooled and the animals analyzed by the methods given in Lawrence (1970).

RESULTS

The animals in both groups sampled were of the same size, as indicated by the wet weights of the body wall. The sizes of the intestines and rete mirabile in both groups were similar (Table 1).

The levels of carbohydrate, neutral lipid, and total lipid in the intestines are given in Table 2. Values for the two groups of animals corresponded closely. The small intestine had low levels of total lipid and neutral lipid. Even lower levels of total lipid and neutral lipid occurred in the large intestine.

The carbohydrate levels were higher in the large intestine than in the small intestine. The carbohydrate levels were much lower than total lipid levels in the small intestine, while the levels of both were similar in the large intestine.

The rete mirabile contained higher levels of total lipid and neutral lipid than either portion of the intestine. It also had a relatively high level of carbohydrate.

The small intestine was 12 percent dry tissue and the large intestine 9 percent dry tissue. These values were used to calculate the absolute amounts of nutrients in the intestine of one group (31 July).

The small intestine contained twice as much lipid as the large intestine (15 mg to 7 mg, respectively). This difference was reflected in the level of neutral lipid (8 mg to 3 mg, respectively). The carbohydrate content of the small intestine (5 mg) was the same as that of the large intestine (6 mg).

DISCUSSION

The total lipid levels in the small and large intestines of *Holothuria atra* from the field were similar to those reported for the entire intestine of *H. mexicana* (Giese, 1966 *a*), and less than that reported for the entire intestine of *Parastichopus californicus* (Giese, 1966 *b*). The lipid levels in these holothurians were lower than those found in intestinal tissue of asteroids and echinoids (Giese, 1966 *a,b*). A low level of neutral lipid, found here in *Holothuria atra,* was also found in the intestine of *H. mexicana*

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TABLE 1

WET WEIGHTS OF THE BODY WALL, SMALL AND LARGE INTESTINES, AND THE RETE MIRABILE OF *Holothuria atra*

	31 JULY		23 AUGUST
REGION	WET WEIGHT	% WATER	WET WEIGHT
Body Wall	28 ± 14	87 ± 3	28 ± 3
Small Intestine	1.4 ± 0.4	88 ± 1	1.5 ± 0.4
Large Intestine	1.5 ± 1.2	91 ± 1	1.3 ± 0.1
Rete Mirabile	3.4 ± 1.3	89 ± 3	3.4 ± 1.1

NOTE: Water content of the organs is given for one group. The values represent the mean ± one standard deviation. Weights given in grams.

(Giese, 1966 *a*). Again, these levels are lower than those reported for the intestinal tissue of several species of echinoids (Giese et al., 1964; Lawrence, Lawrence, and Giese, 1966; Lawrence, 1967; Lawrence, 1970). The general direct relation between levels of neutral lipid and total lipid found in the gut of an echinoid by Lawrence, Lawrence, and Giese (1966) is apparent in *H. atra* also.

The carbohydrate levels in the small and large intestines of *H. atra* were much higher than those reported for the intestine of *Parastichopus californicus* (Giese, 1966 *b*). The carbohydrate level in the small intestine of *Holothuria atra* was similar to, and the level in the large intestine higher than, that reported for intestinal tissue of asteroids and most echinoids (Giese, 1966 *a,b*). The carbohydrate levels in the large intestine of *H. atra* apparently are exceeded in echinoderms only by the upper range of values for the carbohydrate level in the gut of the asteroid *Oreaster hedemanni* (Rahaman, 1968), and in the gut of the sand dollar *Mellita quinquiesperforata* (Moss, 1970).

TABLE 2

TOTAL LIPID AND CARBOHYDRATE LEVELS IN *Holothuria atra*

	DATE SAMPLED	
REGION	31 JULY	23 AUGUST
Small Intestine		
Total Lipid	9.0	7.6
Carbohydrate	2.6	2.2
Neutral Lipid	49	39
Large Intestine		
Total Lipid	5.5	5.7
Carbohydrate	4.9	4.2
Neutral Lipid	39	37
Rete Mirabile		
Total Lipid	13.2	11.5
Carbohydrate	4.3	3.6
Neutral Lipid	59	53

NOTE: Total lipid and carbohydrate levels given in percent of dry weight; neutral lipid levels given in percent of total lipid. The values are from pooled samples of 10 animals.

The values reported for the rete mirabile are important as they apparently represent the first analyses on structures associated with the hemal system of echinoderms. The organ is quite nutrient rich as indicated by the high level of neutral lipid. Trefz (1958) reported the presence of numerous lipid granules in the rete of *Holothuria atra.* She also found that there was a decrease in their abundance after 6 to 7 weeks' starvation and postulated that the "fatty substances" were either storage substances or intermediate metabolites.

The presence of neutral lipid in the intestine of *H. atra* is consistent with Fish's (1967) and Krishnan's (1968) observations of lipid droplets in the lining of the intestines of two other species of sea cucumbers. Changes in the lipid in the gut of female *H. scabra,* observed histochemically, led Krishnan to suggest that intestinal lipids may be utilized during gonadal development. They may be, but the quantitative contribution of intestinal lipids to gonadal development is undoubtedly small.

The use of these nutrients in the intestines of *H. atra* could provide only a small portion of the energy requirements of the animal. *Holothuria atra* has a respiratory rate of 13 μl of oxygen/g wet body weight/hour (Lawrence, unpublished data). Giese (1966 *b*) used combustion values of 1 g carbohydrate as equivalent to 812 ml of oxygen and 1 g lipid as equivalent to 2,030 ml of oxygen to calculate the significance of nutrient reserves in echinoids. Given these values, all of the lipid and carbohydrate in the intestines of *H. atra* would be utilized in about 2 days. Obviously a source of nutrient reserves other than the intestines would be required during need. The decrease of lipid level of the whole body which Fish (1967) found during the "hibernation" of *Cucumaria elongata* no doubt has a nonintestinal source. Most likely, this additional source of nutrient reserves is the body wall. Excluding the body fluid, the body wall is by far the largest body component and contains both lipid and glycogen (Giese, 1966*b*; Krishnan, 1968). Krishnan suggested that the glycogen in the body wall of *Holothuria scabra* was a potential storage supply.

These results indicate that the gut of holothurians does not play an exceedingly prominent role as a nutrient storage organ, even though the reserves present may respond to the energy demands of gametogenesis and starvation. Giese (1966 *b*), on similar grounds, has relegated the gut of echinoids to a minor role as a nutrient storage organ.

SUMMARY

1. The intestines of *Holothuria atra* Jäger are similar to those of other holothurians in their low levels of total and neutral lipid. These levels are lower than those found in intestinal tissue of asteroids and echinoids.

2. The carbohydrate levels in the intestines of *H. atra* are comparable to those in intestinal tissue of asteroids and echinoids. These levels in *H. atra* are greater than those reported for the intestine of the holothurian *Parastichopus californicus*.

3. Calculations based on the respiratory rate of *H. atra* indicate that utilization of the lipid and carbohydrate during starvation could meet the energy requirements of the animal for only a very short period of time.

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