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THE EFFECT OF FOOD ON GROWTH AND COLORATION OF THE TOPSHELL (*TURBO CORNUTUS* SOLANDER)[1]

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The topshell (*Turbo cornutus* Solander) is a common herbivorous marine gastropod, distributed in areas of the warm coastal current of Japan. It is a valuable food item and therefore of commercial importance. Under natural conditions the shell is highly spinous and the color greenish brown.

In a previous paper (Ino, 1943) it was reported that the spines did not develop when the mollusk was transported from its normal environment into a calm, dark habitat, and that under these conditions the shell color changed to whitish. The food in this dark habitat consisted of only brown algae, *Eisenia bicyclis*. In order to determine whether absence of light or a changed diet was responsible for the physical change in the color of the shell, studies were performed with a carefully regulated diet and with certain individuals blinded.

MATERIAL AND METHOD

The topshells selected for the experiment were divided into two groups: Group 1 animals were fed a normal diet consisting of *Eisenia bicyclis* (Plate IA) plus calcareous algae (*Cheilosporum maximum*

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(Plate IB) and *Corallina pilulifera*), while Group 2 animals received *Eisenia bicyclis* only. The mollusks used were placed in bamboo baskets and fed abundantly on their respective diets, the baskets being kept in an artificial pool filled with sea water (Fig. 1). These experimental conditions established a habitat that was both calmer and darker than that of the normal environment, with the temperature and salinity slightly lower than that encountered by the animals under natural conditions.

The experiment was begun on April 15, 1943 and concluded on October 3, 1943, when an exceptionally severe storm wrecked the pond. In the beginning each basket contained twelve individuals, six of

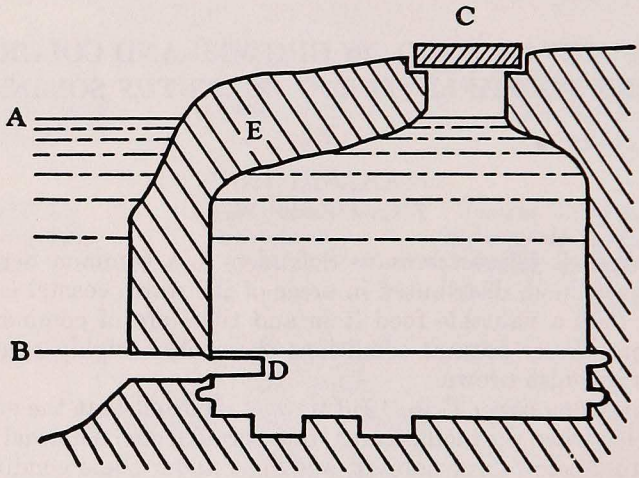

Figure 1. Longitudinal section of the experimental pond. A—High water mark. B—Low water mark. C—Lid. D—Gateway of sea water. E—Rock.

which had been blinded by an operation that consisted of amputating the eye stalk. To perform this operation it was necessary to break the outer lip of the shell aperture sufficiently so that the animal could not conceal its head within the shell. The operation proved to be too severe and six of the operated animals died within twenty days. Three individuals, two operated and one with normal vision, were washed away by the storm that terminated the experiment. In the final analysis, the number of animals was reduced to seven individuals in Group 1 and eight individuals in Group 2. This number, however, proved sufficient to yield definite results.

RESULTS

The following results were noted on the 15 surviving individuals:

Growth and Change of Spines on the Shell. The shell length of individuals growing under normal food conditions (Group 1) showed an average increase in length of 19% during the course of the experiment, whereas individuals fed *Eisenia* alone (Group 2) showed an average increase in length of 14% (Table I). It was noted that normal spines

TABLE I.—Increase in Size of Shell and Weight of *Turbo cornutus* under Controlled Feeding Conditions from April 15 to October 3, 1943

Food	Eyes	No.	Shell length (cm.) IV/15	Shell length (cm.) VI/3	Shell length (cm.) VII/3	Shell length (cm.) X/3	Weight (g.) IV/5	Weight (g.) VI/3	Weight (g.) VII/3	Weight (g.) X/3
Group 1 *Eisenia* plus calcareous algae	Blind	986	4.06	4.33	4.49	5.18	17.2	19.4	21.3	?
		998	3.71	3.71	3.82	4.54	13.1	13.7	16.0	?
	Normal	989	4.75	4.92	5.02	5.50	24.5	28.4	33.0	?
		979	4.45	4.62	4.78	5.19	23.2	25.4	27.3	?
		968	4.20	4.32	4.45	5.10	17.7	21.7	23.6	?
		999	4.07	4.15	4.22	4.86	16.5	18.4	19.5	?
		977	3.58	3.58	3.58	3.85	12.7	13.5	13.7	?
Mean			4.11	4.23	4.33	4.89	17.8	20.1	22.1	?
Group 2 *Eisenia*	Blind	983	3.63	3.65	3.80	4.45	13.3	13.5	14.5	?
		992	3.51	3.55	3.80	4.35	12.4	13.2	14.4	?
	Normal	971	5.24	5.24	5.29	5.38	34.2	36.4	37.9	?
		991	4.85	4.98	5.10	5.45	29.9	32.2	35.6	?
		975	4.60	4.70	4.80	5.22	21.9	24.9	26.9	?
		980	4.52	4.63	4.82	5.20	23.4	26.2	29.2	?
		987	4.35	4.42	4.58	4.92	19.7	21.8	23.5	?
		988	3.95	4.10	4.25	4.64	15.4	17.3	19.5	?
Mean			4.33	4.41	4.56	4.95	21.3	23.2	25.2	?

did not develop on the portion of the shell generated during the period of the experiment, although a few weak spines were present on certain individuals in both groups of shells (Table II). This suppression of

TABLE II.—Increase in Number of Spines of *Turbo cornutus* under Controlled Feeding Conditions

Spines		Group 1 (*Food: Eisenia plus calcareous algae*) Blind 986	998	Normal 989	979	968	999	977	Group 2 (*Food: Eisenia*) Blind 983	992	Normal 971	991	975	980	987	988
A*	Upper row	0	0	6	6	7	2	8	0	0	10	7	9	5	3	5
	Lower row	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B†	Upper row	0	0	1	0	1	0	2	0	0	0	0	0	3	0	1
	Lower row	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0

* Number of spines before controlled feeding.

† Newly developed number after controlled feeding.

spine growth was discussed in a previous paper (Ino, 1943) and was probably due to changed factors caused by removal from the natural environment to a closed tank where temperature and salinity were lower.

Color Changes in the Shell. *Turbo cornutus* fed with *Eisenia* plus calcareous algae did not show any marked color change in the newly formed parts of the shell (Plate II, Table III). A color change was

TABLE III.—Color Changes in Shell of *Turbo cornutus* under Controlled Feeding

	Group 1 — *Food: Eisenia plus calcareous algae*							*Group 2* — *Food: Eisenia*							
	986	*998*	*989*	*979*	*968*	*999*	*977*	*983*	*992*	*971*	*991*	*975*	*980*	*987*	*988*
Color* of shell	B	B	B	B	B	B	B	B	G	G	B	B	G	B	B
before experiment	P	P	P	P	P	G	P	P	P	B	P	P	B	P	P
	W	G	G	G	G	P	G	G	W	P	G	G	P	G	G
	G	W	W	W	W	W	W	W	B		W	W	W	W	W
Color* of newly	P	W	P	B	B	B	W								
formed area	W	B	B	W	W	W	B	W	W	W	W	W	W	W	W
after experiment	B	P	W	P	P	P	P								
	G	G	G	G	G	G	G								

* Colors on each shell are listed in order of intensity as determined by visual inspection. B—Brown; P—Purple; W—White; and G—Green.

apparent when the food consisted of *Eisenia* alone. The appearance of the newly grown part of the shell was white, with almost no trace of color (Plate III, Table III). Blinded top shells in this group also showed this color change. It is concluded, therefore, that the color change resulted from the change in diet.

DISCUSSION

This study yielded the same results as shown previously (Ino, 1943) relative to spine development and change of shell color in the topshell. Now, however, it can be stated definitely that the type of algal food influences shell color. Many students have pointed out the presence of calcareous algae in the alimentary tract of these mollusks, but it was generally assumed that these plants were picked up incidentally while the topshells were searching for food. It is now concluded that calcareous algae are important foods for this species under natural conditions.

Colton (1916) noted that the shell color of *Purpura lapillus* was influenced by the environment. In the same species, Moore (1936) reported the close correlation of color (brown or mauve) with the abundance of *Mytilus* in the diet. Various other authors have described color variation in relation to environment, but Moore's work

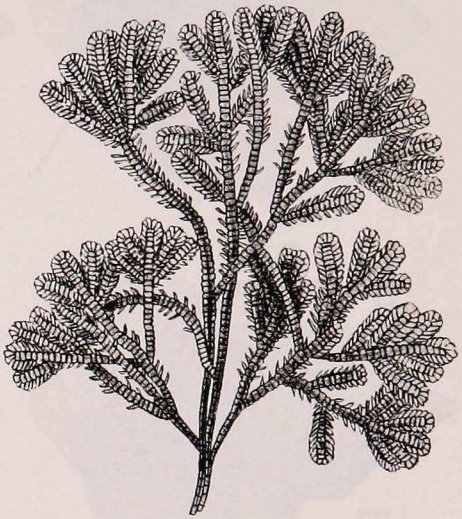

Plate I. A. *Eisenia bicyclis*. B. *Cheilosporum maximum*.

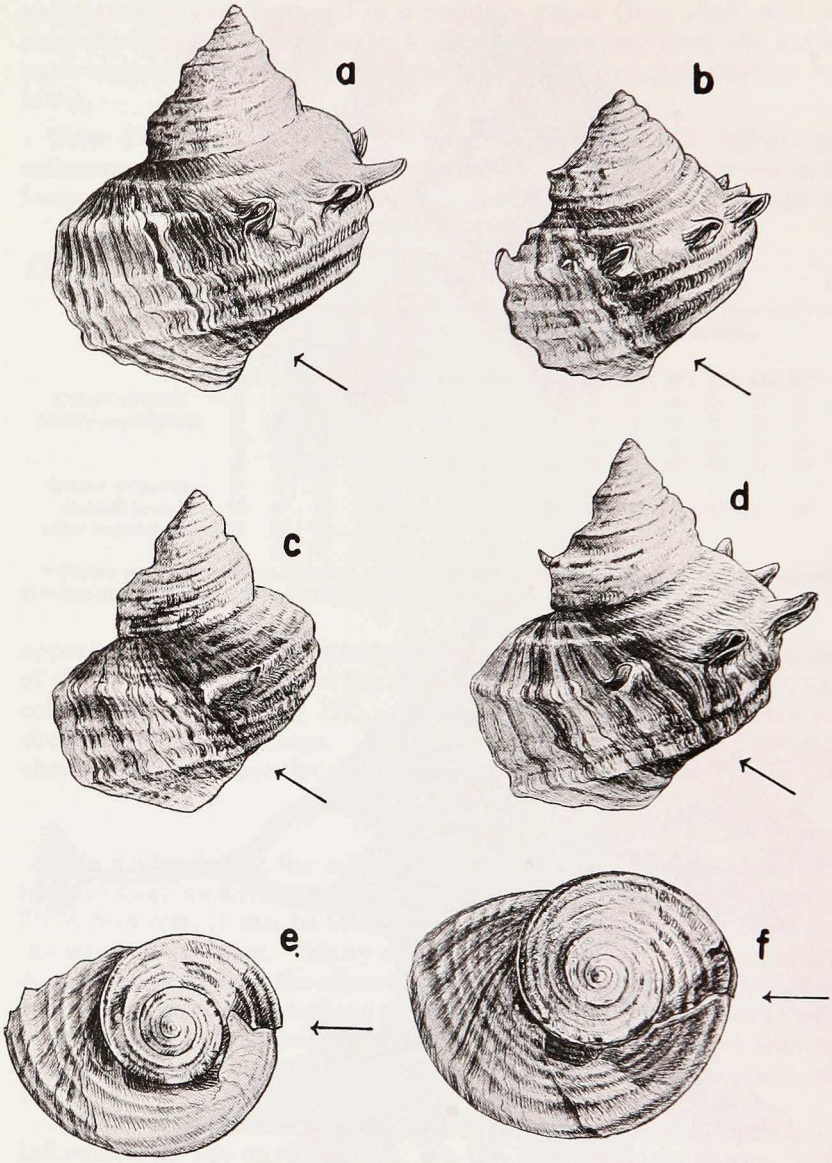

Plate II. *Turbo cornutus* (Group 1). Normal individuals: a – 979; b – 977; c – 999; d – 989. Blind individuals: e – 998; f – 986.

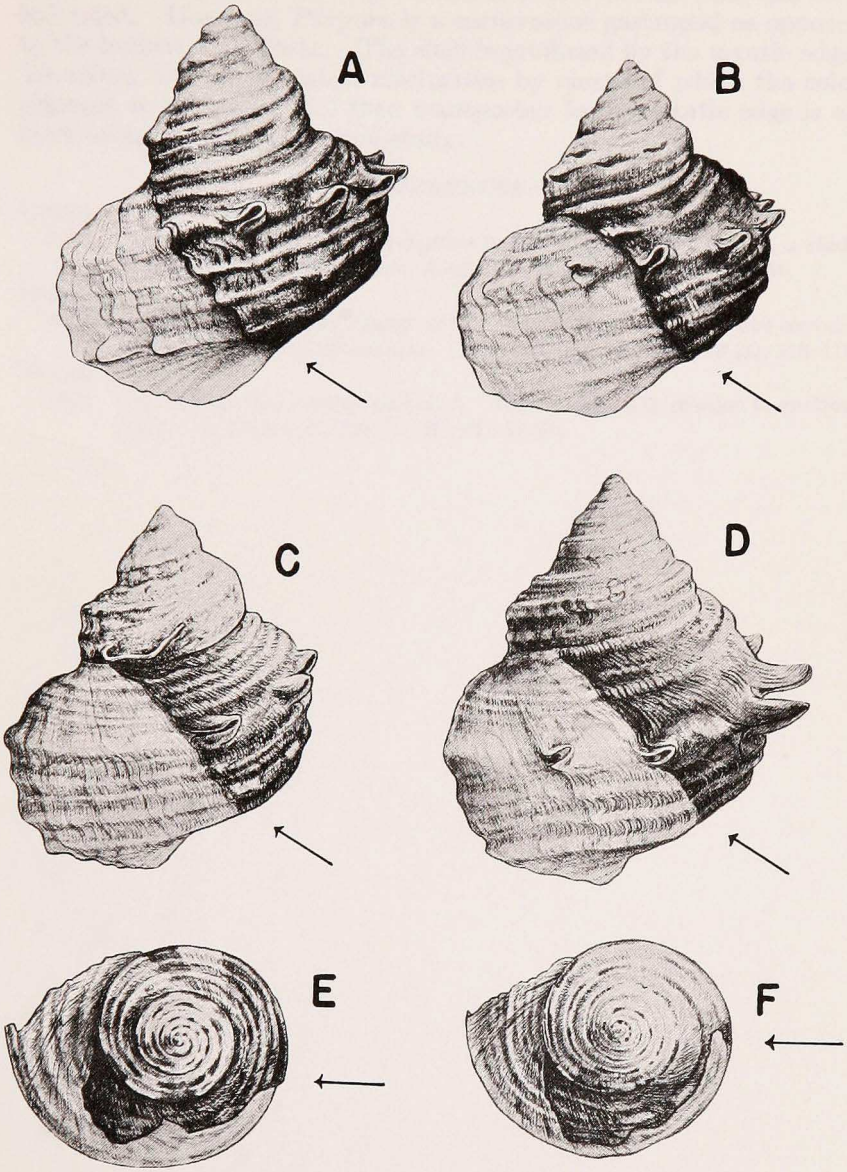

Plate III. *Turbo cornutus* (Group 2). Normal individuals: A – 975; B – 988; C – 987; D – 991. Blind individuals: E – 983; F – 992.

was the first report in which the influence of diet on shell color had been indicated. However, *Purpura* is a carnivorous gastropod as opposed to the herbivorous *Turbo*. The shell is produced by the mantle edge. Therefore, the physiological mechanism by means of which the color pigment is controlled and then transported to the mantle edge is an interesting problem for future study.

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