Reports

Painless Killing of Crabs and Other Large Crustaceans

Abstract. Large crustaceans used for food are customarily scalded to death. This is unnecessary torture, for it can be avoided easily. It is possible to kill the animals quickly, without pain, by placing them in cool fresh water and raising the temperature steadily to about 40°C.

The ability to feel pain and avoid it is probably an absolute necessity for motile organisms, but where pain cannot be avoided it is useless, and to inflict it only results in the torture of helpless creatures, whatever the circumstance. Predatory animals quite generally inflict pain in the process of getting food, and C. S. Sherrington pointed out some years ago that life existed for eons on the earth without the manifestation of pity or compassion, until the relatively recent advent of the human mind. Attitudes of kindness are not uniformly present in the human race, but probably the more civilized components of this group agree with the zoologist W. K. Brooks (1), who said, "As for myself, I try to treat all living things, plants as well as animals, as if they may have some small part of a sensitive life like my own. . . ." Thus, there is some tendency for civilized man to avoid inflicting unnecessary pain upon lower animals. Recent laws concerned with the painless killing of cattle in slaughterhouses are a case in point. However, these laws, and public sympathy, largely apply to mammals, and the invertebrate animals are given very little consideration, as yet.

The more hardy crustaceans, such as several kinds of crabs, lobsters, spiny lobsters, and the like, are generally taken alive and sold alive, because the consumer has come to believe that a dead crab or lobster is a spoiled one. The assumption is not always justified, but it is a good rule of thumb, and its widespread application has prevented a great deal of food poisoning. Because of the fact that a live crustacean is the only accepted guarantee of an unspoiled one, these animals are killed at the time of cooking. In the home the prevalent custom is to scald the crabs to death in boiling water. Commercial packers and canners make use of live steam for the same purpose. Some people think nothing of this because the victims are lower animals, and others excuse themselves on the grounds that the process only lasts a few seconds. However, anyone who watches the violent reactions of crabs being scalded to death can see that they suffer extreme pain, and fishery marketing agents have pointed out that thousands of American housewives will not cook fresh lobsters or crabs because of that fact.

The purpose of this report is to describe an easy and painless way to kill large crustaceans, which depends upon the simple fact that most aquatic organisms can withstand very little heat. Marine organisms, especially those in tropical and warm temperate regions, live in their natural environment much closer to the lethal limit of heat than to the lethal limit of cold. Most tropical marine invertebrates cannot survive when water temperatures rise above 37°C, and nearly all of them are killed by the equivalent of mammalian blood heat. (These remarks do not apply to intertidal animals.) Crustaceans from colder climes may even be killed by temperatures of 30°C. Further details are given in the "Treatise on Marine Ecology and Paleoecology" (*2*).

Some people try to kill crabs by placing them in fresh water. This is not effective with euryhaline organisms, such as the blue crab, which sometimes invade fresh water (*3*). However, fresh water has some anesthetizing effect because it leaches salt from the body fluids. Only one more thing is needed for painless killing of crabs and that is a low flame under the pot, which slowly raises the water temperature to about 40°C. Crustaceans subjected to this treatment die quickly and easily without showing distress. The water feels only lukewarm to the hand, and the dead crabs or lobsters are perfectly limp because death from heat occurs long before coagulation of the protein, which takes place at about 70°C (*4*). Occasionally, a crab in the bottom of the pot, where his legs are in direct contact with the metal, will stir about because he feels the heat. This can be prevented by using a small wire or metal lattice to keep the animals on the bottom from direct contact with the vessel.

I have demonstrated this little experiment several times, but the facts deserve wider publicity because they may lead to some lessening of the practice of inflicting unnecessary pain. There is a false idea in some quarters that crabs are not good unless they are scalded to death suddenly. With the procedure described above, as soon as the crustaceans are dead, the heat can be turned up and the water boiled quickly; the meat of crabs treated in this manner is just as good as that of animals killed by scalding.

GORDON GUNTER
Field Laboratory, Texas Game and Fish Commission, Seabrook

References

1. W. K. Brooks, *The Foundations of Zoology* (Columbia Univ. Press, New York, 1907), p. 17.
2. G. Gunter, *Geol. Soc. Am. Mem. No. 67* (1951), vol. 1, chap. 8.
3. ———, *Science* **87**, 87 (1938).
4. L. V. Heilbrunn, *Am. J. Physiol.* **69**, 190 (1924).

3 October 1960

Instructions for preparing reports. Begin the report with an abstract of from 45 to 55 words. The abstract should *not* repeat phrases employed in the title. It should work with the title to give the reader a summary of the results presented in the report proper.

Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

Depression of Taste Sensitivity to Specific Sugars by Their Presence during Development

Abstract. A chemoreceptor neuron of the adult blowfly contains several different sites for activation by sugars. It appears that the number or affinity of the sites for fructose and perhaps those for glucose may be depressed by rearing the larvae in the presence of the sugar in question.

The labellar and tarsal chemosensory hairs of the blowfly (*Phormia regina* Meig.) contain two neurons that respond to chemical stimulation (*1*). The input of one of these, the *S* fiber, is responsible for the behavioral modality "acceptable" and is evoked by a highly specific group of polyols, especially sugars (*1–3*). Behavioral studies of the effectiveness of sugar mixtures sug-

Table 1. Relative sensitivity of adult flies to sugars as affected by sugars in the larval medium (0.1*M*). Individual ascending tarsal thresholds to the sugars were obtained (molar units), and n was calculated from the following formula: glucose threshold = fructose (or sucrose) threshold $\times 2^n$.

Larval medium	$\bar{n} \pm$ S.E.	*t* Test with controls		Tests (No.)	$\bar{n}$ 2	Mean threshold		
		t	*P*			Glucose	Fructose	Sucrose
Control	+ 4.70 ± 0.07			251	26.1	0.76	0.032	
Mannose	+ 4.74 ± 0.11	0.3	>0.7	114	26.7	0.70	0.036	
Glucose	+ 5.21 ± 0.35	4.0	<0.001	273	37.0	0.69	0.026	
Fructose	− 0.52 ± 0.10	43	<0.001	120	0.73	1.34	1.46	
Control	+ 3.50 ± 0.058			251	11.3	0.76		0.078
Glucose	+ 4.77 ± 0.066	14.5	<0.001	273	27.4	0.69		0.034
Fructose	+ 1.67 ± 0.080	12.9	<0.001	138	3.2	1.18		0.65

gested that there must be more than one type of receptor site on this neuron, each with its own structural requirements for effective combination. Glucose and fructose, for example, appear to act at independent sites (*3, 4*). Even more effectively, one can argue on the basis of configurational and conformational analysis that a single site cannot account for the effectiveness of all the polyols that have been tested (*3*). Such a specific system with apparent adaptive significance would be expected to be under genetic control and susceptible to environmental influences during development. An example of the latter, "olfactory conditioning," has long been known in insects (*5*) but remains essentially unanalyzed. The presence of an odorous compound during larval life can make that compound attractive to the subsequent adult even though that chemical normally would be repellent or would lack adaptive significance, and in spite of the intervention of a complete metamorphosis. Homing by the adult salmon also seems to involve orientation to chemicals that were present during development (*6*).

On the basis of these considerations, we have assessed the effect on the taste sensitivity of adult flies of rearing them as larvae on media containing glucose, fructose, or mannose. The usual medium (*7*), composed of dried yeast and milk, agar, and water served as the control. To it in the three experimental groups was added 0.1*M* glucose, fructose, or mannose; in these cases it was necessary to reduce the agar concentration by one-fourth to retain the requisite physical properties. The adults that emerged were tested, behaviorally, on sugar solutions between 3 and 6 days after eclosion, by the method of Evans and L. Barton Browne (*8*). This method measures the minimal concentration of each of two sugars that will elicit proboscis extension when applied to the tarsal taste receptors. The results are then expressed as the relative sensitivity to the two sugars, since the absolute sensitivity varies greatly with feeding and starvation (*9*). Accordingly, the ascending thresholds for glucose and fructose (or sucrose) were determined for each fly; the results (Table 1) were then expressed and analyzed in terms of n in the following formula:

$$\text{Fructose threshold} \times 2^n = \text{glucose threshold}$$

For the controls and mannose-reared flies, fructose was about 26 times more stimulating than glucose [23 is the value obtained by Hassett *et al.* (*10*) under the same conditions as those of our controls]. This value was elevated to 37 in the glucose-reared and depressed to less than unity in the fructose-reared flies; both of these values were highly significant. Also given in the table is the average threshold for each sugar. In the fructose-reared flies the change in relative sensitivity is plainly due to a great decrease in sensitivity to fructose.

The behavioral testing method leaves much to be desired, but there is as yet no reliable electrophysiological method suitable for obtaining quantitative data. Nonetheless, the results permit a few unequivocal conclusions. Rearing on fructose markedly altered the relative sensitivity to the two sugars, primarily by greatly decreasing the sensitivity to fructose. Rearing on glucose had less effect, but, significantly, altered the relative sensitivity in the opposite direction; the data do not permit a decision as to whether or not this was due to a decrease in sensitivity to glucose. The influence on sucrose sensitivity of media fed the larvae (Table 1) paralleled the influence on fructose sensitivity; sucrose acts predominantly at the fructose site (*3*). The mannose medium was without effect; this sugar normally is very weakly stimulating [the extrapolated 50-percent acceptance threshold is 7.6*M* (*10*)]. The mannose-reared flies were repeatedly tested on mannose solutions, but no response was obtained even to saturated solutions.

Upon analysis it was found that the normal medium contains approximately 0.1*M* lactose and no appreciable amount of any other mono- or oligosaccharide; lactose is tasteless to flies grown on this medium (*10*). As was later realized and is now being practiced, *Phormia* larvae can readily be grown on a chemically defined, sterile medium that does not contain any carbohydrate; casein is the only constituent present at macronutrient levels (*11*). And we have found that sugars may be added to the medium without detriment at the concentrations used in the experiments reported above. The experiments are being repeated with this improved medium.

We are attracted to the hypothesis that the effective sugars act by depressing sensitivity specifically to themselves and to other sugars that act at the same site, and that this is due to a decrease in the number of affinity of their combining sites on the sugar-sensitive neuron. While this is purely hypothetical, one may realistically expect to be able soon to make a direct test by electrophysiological methods.

As for possible mechanisms for the depressive effect obtained, recent progress in the study of "regulator" genes suggests a possible model. In *Escherichia coli,* tryptophan leads to repression of the formation of the sequence of enzymes responsible for its synthesis (*12*). Recent attempts to apply the concepts of biochemical genetics to immune tolerance and development (*13*) predict the direction of the result obtained in the case reported here under certain assumed conditions. The gene product here would be, in all probability, a specific receptor site associated with the cell surface (like "permease"), the function of which was the transduction of chemical into electrical potential (*14*).

DAVID R. EVANS
Department of Biology, Johns Hopkins University, Baltimore, Maryland

References and Notes

1. V. G. Dethier, *Quart. Rev. Biol.* **30**, 348 (1955).
2. M. L. Wolbarsht and V. G. Dethier, *J. Gen. Physiol.* **42**, 393 (1958).
3. D. R. Evans, in preparation.
4. V. G. Dethier, D. R. Evans, M. L. Rhoades, *Biol. Bull.* **111**, 204 (1956).
5. W. H. Thorpe and F. G. W. Jones, *Proc. Roy. Soc. London* **B124**, 56 (193 → W. H. Thorpe, *ibid.* **126**, 370 (193 → J. E. Cushing, *Proc. Natl. Acad. Sci. U.S.* **27**, 496 (1941).
6. A. D. Hasler, *Science* **132**, 785 (1960).
7. D. Hill, V. A. Bell, L. E. Chadwick, *Ann. Entomol. Soc. Am.* **40**, 213 (1947).
8. D. R. Evans and L. Barton Browne, *Am. Midland Naturalist* **64**, 282 (1960).
9. D. R. Evans and V. G. Dethier, *J. Inst. Physiol.* **1**, 3 (1957).
10. C. C. Hassett, V. G. Dethier, J. Gans, *Biol. Bull.* **99**, 446 (1950).
11. M. Brust and G. Fraenkel, *Physiol. Zool.* **28**, 186 (195 → V. H. Cheldelin and R. W. Newburgh, *Ann. N.Y. Acad. Sci.* **77**, 373 (1959).
12. J. Monod and G. Cohen-Bazire, *Compt. rend.* **236**, 530 (1953); G. N. Cohen and F. Jacob, *ibid.* **248**, 3490 (1959); F. Jacob and J. Monod, *ibid.* **249**, 1282 (1959).
13. L. Szilard, *Proc. Natl. Acad. Sci. U.S.* **46**, 293 (1960); J. D. Ebert and F. Wilt, *Quart. Rev. Biol.*, in press.
14. This work was supported by grants from the National Science Foundation (G 5927) and the National Institutes of Health (E 2358) and was aided by the competent technical assistance of Mr. M. Jahn.

21 September 1960