THE EFFECTS OF TEMPERATURE ON THE SUCROSE THRESHOLDS OF THE TARSAL CHEMORECEPTORS OF THE FLESH FLY, SARCOPHAGA BULLATA

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It has long been known that insects possess contact chemical receptors which enable them to select desirable and reject undesirable foods. Earlier studies on the locations of these receptors are reviewed by Frings and Frings (1949) and on the functions by Dethier and Chadwick (1948). One of the many problems evolved from these studies is whether stimulation of gustatory receptors is due to absorption, in which the stimulating substance penetrates the exoskeleton, or to adsorption, in which the substance adheres to the surface of the taste receptor. Dethier (1951) suggests that penetration is most important by stating that the limiting mechanism in tarsal chemoreception probably involves a two-phase system, in which highly water-soluble compounds gain access to the receptor through an aqueous phase and the larger lipid-soluble molecules chiefly through a lipid phase.

A likely hypothesis, if penetration is involved, would be that the higher the temperature, within limits of death, the faster the penetration and the lower the threshold. Conversely, the lower the temperature, the slower the penetration and the higher the threshold. If, on the other hand, adsorption is involved, the negative temperature coefficient, other factors being equal, would cause the threshold to be lower at lower temperatures and higher at higher temperatures. The present study was an attempt to answer this absorption-adsorption question by testing the effects of temperature on the sucrose threshold of the tarsal chemoreceptors of the flesh fly, Sarcophaga bullata.

MATERIALS AND METHODS

The flies were reared in the laboratory as described by Frings and Frings (1952) and Knipe and Frings (1952). Adults were kept in wire cages (30 x 30 x 30 cm.), where they were given a constant supply of water and sugar cubes. Protein was supplied to the flies in the form of skinned dead mice. A mouse was supplied every 24 hours to each cage of flies until larviposition occurred, which was within 5–7 days after the protein was first furnished. After approximately 200 larvae were obtained, the mice were withheld until a new supply of larvae was needed. This insured a constant supply of larvae and flies at regular intervals. The larvae were reared on moistened dog biscuit.

Techniques described by Frings (1947) were used in mounting the flies for

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testing. After they had recovered from mounting, each was allowed to consume
to satiety water and 1.0 M sucrose solution.

The constant temperature chamber used in this study consisted of two plywood
boxes, one within the other. The inside box (56 × 56 × 56 cm.) was separated
from the outer one (64 × 64 × 64 cm.) by 4 cm. of insulating material. Both
chambers had removable tops with glass apertures (30 × 30 cm.) situated in the
center to provide necessary illumination for the inner chamber, which was easily
viewed through glass doors (30 × 30 cm.) at the front of the boxes. To aid in
the maintenance of desired temperatures, a suction fan was installed near the top
of the inner chamber to circulate the air after it was heated by an infra-red bulb
or cooled by ice. Ventilation of the chamber was controlled by a sliding glass
panel made to cover an opening (6 cm. diam.) situated directly in front of the fan.
A light socket was installed near the bottom of the inner chamber for the infra-red
bulb and the electrical apparatus of the light and fan were operated from the
outside. A slit (5 × 30 cm.) was cut along one side of the boxes for the purpose
of inserting the experimental animals. This opening was covered on the outside
with compressed sponge rubber with corresponding slits through which the mounted
flies could be inserted. A table (56 cm. long × 15 cm. wide × 15 cm. high) was
placed in the chamber to hold Syracuse watch-glasses containing the test solutions.

Much preliminary experimental testing with sucrose molarities was done before
settling on the following molarities used throughout the experiment: 0.02 M,
0.04 M, 0.06 M, 0.08 M, 0.1 M, 0.2 M, 0.4 M, 0.6 M, 0.8 M, and 1 M. A fresh
stock solution (1.0 M) was made up every four or five days and refrigerated be-
tween tests to avoid fermentation. Other molarities were made up from the stock
solution every two days.

The flies were tested in the constant temperature chamber at three ranges of
temperature: 19–21 °C., 27–29 °C., and 37–39 °C. The experimental temperature
for each day was picked at random in order to avoid the flies’ possibly learning a
particular pattern of testing. The temperatures, 27–29 °C., were those of the
box without the addition of heat or ice. A pan of water in the chamber assured
a saturated atmosphere in the box. For temperatures of 19–21 °C., two containers,
one a gallon jar and the other a half-gallon jar, were filled with ice a few hours
before testing and, if needed, were refilled immediately before the admission of the
flies to the chamber. For temperatures of 37–39 °C., a flat pan (30 × 15 × 5 cm.)
of hot water, about 50 °C., was placed in the chamber to increase the humidity
sufficiently to keep the flies from cooling themselves, thus keeping their internal
temperature the same as that of the surrounding environment. An infra-red bulb
was used as the source of heat and in a matter of minutes the temperature was
at 38 °C. The ventilator and fan aided in maintaining an even temperature.

After the temperature of the box was set, the flies were allowed to take all the
water they wanted in order to prevent a response to the water in the sucrose
solution rather than to the sucrose itself. This was administered outside the
chamber. Five mounted flies were tested at a time. The flies were allowed to
remain in the chamber for 5–10 minutes before testing to reach the temperature
of the chamber and were then tested, one at a time, first with water to make certain
they had all they wanted, and then from the lowest molarity of sucrose to the
highest. A rest period of one or two minutes was allowed after each few tests,
so that the fly would not become fatigued to the sucrose.
Each test was made by touching the fly’s tarsi to the solution in the Syracuse watch-glass. If the fly dropped its proboscis, it was considered a positive response. If the fly did not drop the proboscis at a low molarity, the fly was tested at successively higher molarities until a positive response was obtained. The flies were always tested from the low molarities to the higher molarities, and the tarsi were rinsed after each few trials to avoid any collection of sucrose on the feet. After the five flies were tested in this manner, they were removed for feeding and watering, and a new batch of five water-sated flies was admitted to the chamber.

**Results**

The flesh fly, *Sarcophaga bullata*, is easy to handle, because of its convenient size and relative docility. Flies mounted at 24–48 hours of age did not live as long on the mounting rods as those mounted at 96–120 hours. If the animals did not have an opportunity to get all the water they wanted before being anesthetized with ether, they died before or shortly after coming out of the anesthesia, as noted by Frings (1941). Flies that were water-sated before etherization were seemingly unaffected.

Temperatures a few degrees above 40° C. or below 15° C. affected the activity of the flies. The movements of the legs and the proboscis responses were slower than at temperatures of 37–39° C. and 19–21° C. The flies were most active at room temperature.

Approximately 2000 flies were used in this experiment, but over half of these were used to develop experimental techniques. Tests were made on 748 flies, 313 males and 435 females. These flies were subjected to 8241 tests at the three temperature levels.

The median thresholds, as determined by probit analysis (Dethier and Chadwick, 1950; Finney, 1952), were: at 19–21° C., 0.14 M; at 27–29° C., 0.06 M; at 37–39° C., 0.17 M. Significant differences between the per cent response of the flies at the various molarities were determined at the upper probability limits of 0.005 from the tables in Mainland (1948). The lower temperature compared with room temperature (27–29° C.) showed significant differences at 0.6 M, 0.4 M, 0.2 M, 0.1 M, 0.08 M, 0.06 M, 0.04 M, and 0.02 M. The higher temperature compared with the room temperature showed significant differences at 0.8 M, 0.6 M, 0.4 M, 0.2 M, 0.1 M, 0.08 M, 0.06 M, 0.04 M, and 0.02 M levels. No significant differences between the thresholds of the sexes were noted.

**Interpretations and Conclusions**

The median tarsal threshold for sucrose (0.06 M) for *Sarcophaga bullata* at 27–29° C. is relatively high when compared with that of some other Diptera. For instance, Hassett, Dethier and Fans (1950) reported a median threshold of 0.0098 M for the blow fly, *Phormia regina*, and Deonier and Richardson (1935) reported a median threshold of 0.025 M for the house fly, *Musca domestica*. Frings and O’Neal (1946), however, found the median sucrose threshold for *Tabanus* to be 0.06 M which is the same as that of the flesh fly. A possible explanation for the difference between the median thresholds of *Sarcophaga* and *Tabanus* and those of other Diptera might be that the food habits and habitats of these flies are different from those of the other species.

As to the question of absorption or adsorption in tarsal stimulation, no definite
From the results, it would seem that penetration was the factor involved at temperatures below room temperature, while at the higher temperatures adsorption was the factor. It is highly improbable, however, that different factors are involved at different temperatures. Perhaps the action, if any, of temperature on the peripheral threshold is masked by the action of temperature on central nervous functions, and thus on general behavior. Possibly neither adsorption per se nor penetration is involved, but instead discharge of surface potentials on the sensory hairs. This reaction would be basically independent of temperature. Such a phenomenon would show Hofmeister seriation of inorganic ions and seriations of organic compounds. In such a case, the effects of temperature would be entirely on other systems and thus would give no information of significance on the point in question.

**Summary**

1. The effects of temperature on the sucrose thresholds of the tarsal chemoreceptors of the flesh fly were studied. Flies were mounted on rods and the thresholds determined in a constant temperature chamber at 19–21°C, 27–29°C, and 37–39°C.

2. A total of 748 flies (313 males and 435 females) were subjected to 8241 tests.

3. The median threshold at 19–21°C was 0.14 M, at 27–29°C was 0.06 M, and at 37–39°C was 0.17 M.

4. On the basis of these data, no definite stand can be taken on the limiting mechanism of tarsal chemoreception.

**Literature Cited**


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