Comp. Biochem. Physiol. Vol. 67A, pp. 269 to 271

0300-9629/80/1001-0269$02.00/0

THE EFFECT OF TEMPERATURE ON HEART RATE OF THE FRESHWATER MUSSEL, *LIGUMIA SUBROSTRATA*

THOMAS H. DIETZ and RAY U. TOMKINS
Department of Zoology and Physiology, Louisiana State University, Baton Rouge, LA 70803, U.S.A.

(*Received* 12 *November* 1979)

Abstract—1. Heart rate was recorded for *Ligumia subrostrata* using a photocell technique.
2. The heart rate was highest when the animals were active and siphoning water and were lowest when the valves were closed.
3. The heart rate was an exponential function of temperature when the bathing medium temperature was abruptly changed from the 20–22°C acclimation temperature. The heart rate reached a maximum at 32°C.

INTRODUCTION

Ligumia subrostrata displays a variety of diurnal activity patterns and changes in oxygen consumption (McCorkle *et al.*, 1979). In other molluscs, it has been observed that the heart rate depends on the activity of the animal (Helm & Trueman, 1967; Trueman & Lowe, 1971; Coleman, 1976; Harrison, 1977a,b). However, the technique frequently used for measuring the heart rate employs an impedance pneumograph. This instrument is sensitive to changes in volume coincident with the cardiac cycle but it also responds to changes associated with valve or foot movements and mechanical disturbance of the animal (Trueman, 1967). Alternative techniques are direct visual observation of the heart if the shell is sufficiently transparent (Harrison, 1977a,b) or cannulation of the ventricle (Florey & Cahill, 1977).

The technique we have used is to record variations in voltage from a photocell positioned on the external shell surface with the heart located between the photocell and the light source. The photocells are sufficiently sensitive to detect the shadow cast by atrial and ventricular movements. The technique allows continuous recording of the heart beat with minimal influence from the movement of the animal.

MATERIALS AND METHODS

Ligumia subrostrata (Say) (Pelecypoda; Unionidae) were obtained from local ponds and acclimated to an artificial pondwater (0.5 mM NaCl, 0.4 mM $CaCl_2$, 0.2 mM $NaHCO_3$, 0.05 mM KCl). The animals were maintained in aerated aquaria in the laboratory (20–22°C) for a week before use.

One or two days before the heart rate was to be measured, the animals were removed from the pondwater and the valves were wiped dry. The periostracum over the cardiac region was removed by scraping. On one valve, a rubber grommet was glued in place over the heart to hold a miniature 12 V lamp. With the lamp on, a silicon/selenium photocell (2 × 5 mm) was positioned on the opposite valve with the heart located between the lamp and the photocell. The photocell was secured in place to give the maximum voltage change as the beating heart cast a shadow over the photocell. The lamps and the photocells were coated with clear epoxy to insulate the electrical connections. The animals were returned to pondwater for heart rate recordings.

Groups of four mussels were placed in an aerated aquarium in pondwater. The temperature was held constant by circulating water from a Gilson Omnibath through glass tubing immersed in the aquarium. This arrangement allowed us to maintain temperature (±0.2°C) in the aquarium, by passive heat transfer, without contaminating the water or disturbing the clams. The lamps from the four animals were connected in parallel to a variable power supply and the voltage was adjusted to the lamps for optimal voltage output from the photocell. The photocells were attached to a rotary switch connected to a recording potentiometer. This arrangement allowed us to switch from one animal to another without disturbing the animals. Except where noted, the heart rates were recorded for 12–15 min intervals from animals actively siphoning pondwater.

RESULTS AND DISCUSSION

The heart rate of *L. subrostrata* is variable depending on the activity of the animal (Fig. 1). When the valves are open and the animal has its siphons

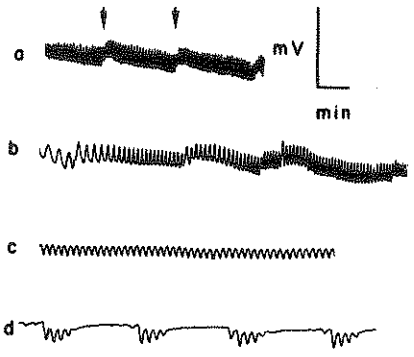

Fig. 1. Recording of heart movements of *L. subrostrata* in pondwater at 23°C. (a) actively siphoning pondwater (16–19 beats/min), the arrows indicate valve closure. (b) as the valves open and siphoning is initiated. (c) after 1 hr with the valves closed. (d) intermittent heart rate of the mussel in pondwater with the valves partially open but not siphoning water.

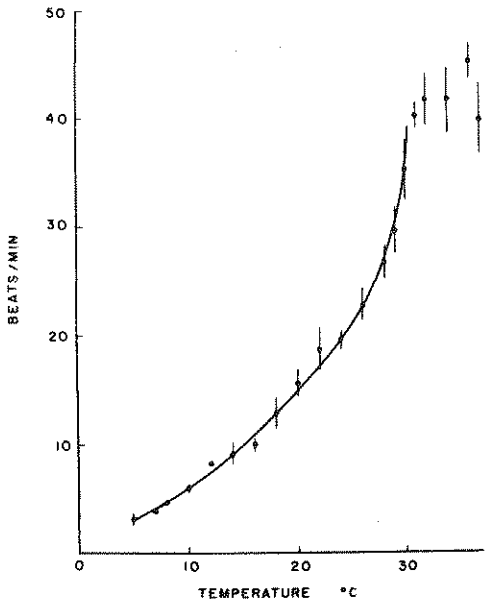

Fig. 2. The effects of acute temperature change on the heart rate of pondwater acclimated *L. subrostrata* acclimated to 20–22°C. The exponential equation for the curve between 5–30°C is: HR = 2.34 exp (0.0904 (temperature)). The points represent the average of between three and eight different animals and the vertical line is ±1 SEM.

extended, the heart rate is maximal for that temperature (Fig. 1a). The rhythmic changes in baseline are due to the valve opening and abrupt valve closures. When the animal is in the process of opening the valves, there is a gradual increase in heart rate from a low of 2–4 beats/min to the normal rate of 16–19 beats/min at 23°C (Fig. 1b). There was no consistent indication of a transiently higher heart rate in *L. subrostrata* when reopening the valves as observed in other animals (Trueman, 1967; Helm & Trueman, 1967; Trueman & Lowe, 1971; Coleman, 1976). The changes in baseline of the tracing are associated with abrupt valve closures discharging mucous, pseudofeces and debris from the animal. When the valves are closed, the animal displays a pronounced bradycardia with the heart rate decreasing to 4–8 beats/min (Fig. 1c). More interesting is the complete suppression of heart movement for periods of 2 min followed by 1 min of beating (Fig. 1d). This particular animal had stopped siphoning and closed its valves 85 min previous to the cessation of heart beat. Associated with the period when the heart beat was intermittent, the valves were partially gaped and the mantle margins were visible but the animal was not siphoning water. The intermittent heart rate in *L. subrostrata* has been noted to occur when these animals are out of water. Similar intermittent cardiac rhythms have been noted in marine mussels exposed to air during the tidal cycle (Helm & Trueman, 1967; Trueman & Lowe, 1971). We have recently noted that *L. subrostrata* displays diurnal activity patterns with the animals tending to be least active during the photoperiod (McCorkle *et al.*, 1979). All of our continuous recordings were confined to the late morning and afternoon and the reduced or intermittent heart rate may be concomitant with the periods of inactivity.

The effects of acute changes in temperature of the pondwater bathing *L. subrostrata*, acclimated to 20–22°C, are shown in Fig. 2. Changes in temperature above or below 21°C cause an exponential change in heart rate. The correlation coefficient (r) between temperature and heart rate is highly significant ($r = 0.99$; $P < 0.01$) for temperatures up to 30°C. The temperature coefficient (Q_{10}) varies from 3.0, at low temperatures, to 2.4 near 30°C.

The heart rates of animals acclimated to 20–22°C abruptly plateau at temperatures above 31°C. The highest heart rate we observed was 52 beats/min in one animal at 35°C. A few animals were exposed to temperatures up to 40°C but the heart rates were 41 beats/min or less. An abrupt plateau of heart rate above the acclimation temperature has been noted in other molluscs (Lowe & Trueman, 1972; Harrison, 1977a,b).

When *L. subrostrata* were exposed to temperatures greater than 35°C, their behavior changed. The valves gaped to a maximum extent, >1 cm, the foot was extended and the amplitude of the heart movement decreased. If the animals were kept at 38°C for 10 min or more, the extended foot became rigid and unresponsive to mechanical stimulation.

The use of photocells to detect heart beat offers several advantages over the use of an impedance pneumograph. The signal is minimally affected by the animal activity or mechanical movements. The voltage output can be recorded in the field using a battery powered chart recorder. In addition, the photocell voltage output is sufficiently high to use ambient light. Our use of an external light source was primarily to reduce the effects of shadows falling on the animal while working near by.

The observation that the photocells pick up the variation in ambient light passing through both valves and the soft tissue, demonstrates the relative transparency of the valves to visible light. We have observed that these animals will display reflexive valve closures when a transient shadow is cast over them. The freshwater mussels do not have recognized peripheral photoreceptors but they are apparently responding through an internal sensing system (Imlay, 1968).

Acknowledgements—This work was supported in part by National Science Foundation Grant BMS75-05483 A01. We thank Deborah M. McMullan for typing the manuscript.

REFERENCES

COLEMAN N. (1976) The aerial respiration of *Modiolus modiolus*. *Comp. Biochem. Physiol.* **54A**, 401–406.

FLOREY E. & CAHILL M. A. (1977) Hemodynamics in lamellibranch molluscs: Confirmation of constant-volume mechanism of auricular and ventricular filling. Remarks on the heart as site of ultrafiltration. *Comp. Biochem. Physiol.* **57A**, 47–52.

HARRISON P. T. C. (1977a) Seasonal changes in the heart rate of the freshwater pulmonate *Lymnaea stagnalis* (L.). *Comp. Biochem. Physiol.* **58A**, 37–41.

HARRISON P. T. C. (1977b) Laboratory induced changes in the heart rate of *Lymnaea stagnalis* (L.). *Comp. Biochem. Physiol.* **58A**, 43–46.

HELM M. M. & TRUEMAN E. R. (1967) The effect of exposure on the heart rate of the mussel, *Mytilus edulis* L. *Comp. Biochem. Physiol.* **21**, 171–177.

IMLAY M. J. (1968) Environmental factors in activity rhythms of the freshwater clam *Elliptio complanatus catawbensis* (Lea). *Am. Mid. Nat.* **80**, 508–528.

LOWE G. A. & TRUEMAN E. R. (1972) The heart and water flow rates of *Mya arenaria* (Bivalvia: Mollusca) at different metabolic levels. *Comp. Biochem. Physiol.* **41A**, 487–494.

MCCORKLE S., SHIRLEY T. C. & DIETZ T. H. (1979) Rhythms of activity and oxygen consumption in the common pond clam, *Ligumia subrostrata* (Say). *Can. J. Zool.* in press.

TRUEMAN E. R. (1967) Activity and heart rate of bivalve molluscs in their natural habitat. *Nature, Lond.* **214**, 832–833.

TRUEMAN E. R. & LOWE G. A. (1971) The effects of temperature and littoral exposure on the heart rate of bivalve mollusc *Isognomum alatus* in tropical conditions. *Comp. Biochem. Physiol.* **38A**, 555–568.