Experimental Panel 6.1 Investigating water loss by the beetle *Protaetia cretica* during continuous and discontinuous ventilation.

Background and hypotheses

In this panel, we examine a study of beetles (*Protaetia cretica*) collected from flowers of dragon lilies in an olive orchard in Crete to determine whether their use of discontinuous ventilation significantly reduces evaporative water losses. Ideally, investigations of the potential benefits of discontinuous ventilation for water balance need to take account of metabolic rate, since metabolic rates of insects can affect gas exchange patterns. In the study of the beetles, the rates of water loss were investigated at a range of metabolic rates resulting from changes in temperature in beetles using both continuous and discontinuous gas exchange. It was hypothesised that at the same rate of metabolism, the beetles would show lower respiratory water loss during discontinuous gas exchange than when using continuous gas exchange.

Experimental procedures

- The rates of water loss and CO_2 exchange from individual beetles were measured in a flow-through system. Dried air was delivered to a chamber containing a beetle, and held at a constant temperature of between 10°C to 30°C. Respirometer traces of CO_2 and water vapour were collected. For individuals using discontinuous gas exchange cycles these traces allow identification of the three phases of the ventilation cycle (closed, flutter, open).
- Measurements of CO_2 exchange and loss of water vapour were computed for each phase of discontinuous ventilation and when beetles were ventilating their tracheal system continuously.
- During the closed phase of discontinuous ventilation, water loss occurs only via the cuticle, so measurement of water loss in each phase of the discontinuous cycle allows separation of cuticular water loss (in the closed phase) and respiratory water loss (from total water loss minus cuticular water loss).

Results and interpretation

Protaetia cretica typically show discontinuous ventilation, as illustrated in Figure A, but sometimes ventilate continuously.

An increase in metabolism as temperature increases resulted in an increase in the rate of CO_2 release, as shown in Figure B. However, the rate of release of CO_2 was higher at all temperatures during continuous gas exchange than during discontinuous gas exchange. The rate of total water loss also increased with temperature and was again higher when the beetles ventilated continuously rather than discontinuously. Thus discontinuous ventilation achieves significant water saving in these beetles.

The rate of total water loss has two components: loss via the cuticle and respiratory water loss. Separation of these components is possible in insects using discontinuous ventilation, as explained on Figure C using data for the Cretan beetles.

Respiratory water loss over time was higher during continuous gas exchange than during discontinuous ventilation. When averaged for all temperatures, respiratory water loss accounted for 29 per cent of total water loss during continuous gas exchange but reduced to 16 per cent during discontinuous ventilation. Figure D shows that respiratory water loss relative to CO_2 exchange (a measure of the rate of metabolism) is less than half during discontinuous gas exchange than during continuous gas exchange.

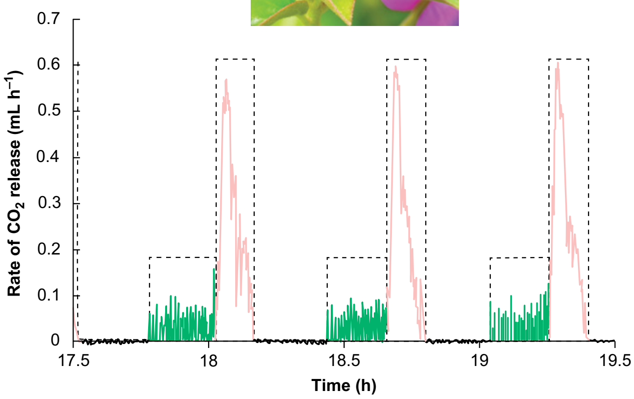

Figure A Discontinuous gas exchange by the beetle *Protaetia cretica*

The dashed line indicates the three phases of the cycle. The solid line shows the rate of CO_2 release: as a black line in the closed phase, a green line in the flutter phase, and a pink line in the open phase. There is no CO_2 release in the closed phase, a small rate of release in the flutter phase and greater release of CO_2 in the open phase.

Source: adapted from Matthews PGD and White CR (2012). Physiological and Biochemical Zoology 85: 174–182. Image: https://www.biolib.cz/en/image/id33678/.

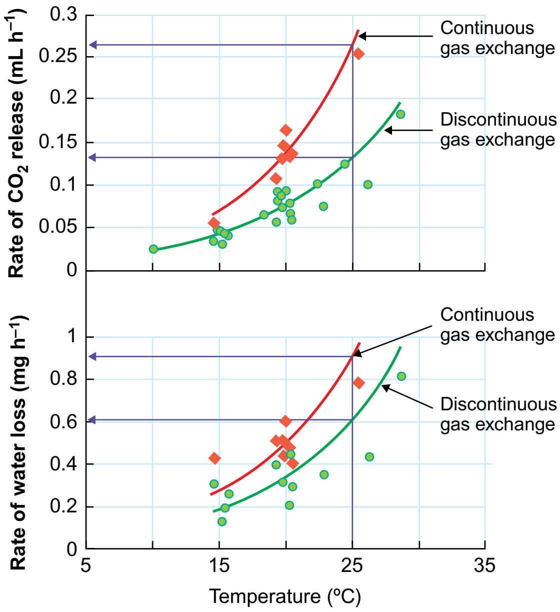

Figure B Effect of temperature on rates of water loss and metabolism (CO_2 release) by *Protaetia cretica*

Measurements were made during continuous and discontinuous gas exchange. Blue lines and arrows compare rates of CO_2 release and water loss at 25°C during continuous and discontinuous gas exchange.

Source: adapted from Matthews PGD and White CR (2012). Physiological and Biochemical Zoology 85: 174–182.

Implications of findings

The findings of this study of beetles are consistent with the predicted reduction in water loss during discontinuous gas exchange compared to the water loss during continuous gas exchange for beetles at the same temperature. Second, the ratio of respiratory water loss to CO_2 exchange is lower during discontinuous gas exchange than during continuous gas exchange.

Find out more:

Matthews PGD and White CR (2012). Discontinuous gas exchange, water loss, and metabolism in *Protaetia cretica* (Cetoniinae, Scarabaeidae). Physiological and Biochemical Zoology 85: 174–182.

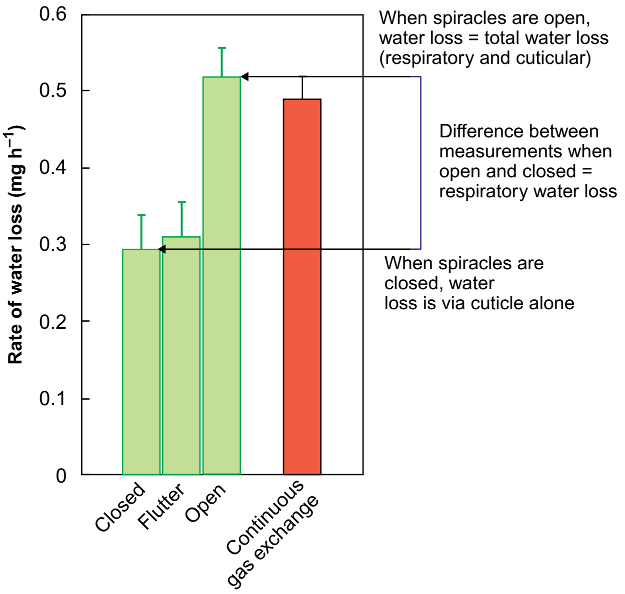

Figure C Water loss during discontinuous and continuous gas exchange of *Protaetia cretica*

The rate of total water loss when spiracles are closed is less than when the spiracles are open or during continuous gas exchange. Data are means + standard errors (*n*=6)

Source: adapted from Matthews PGD and White CR (2012). Physiological and Biochemical Zoology 85: 174–182.

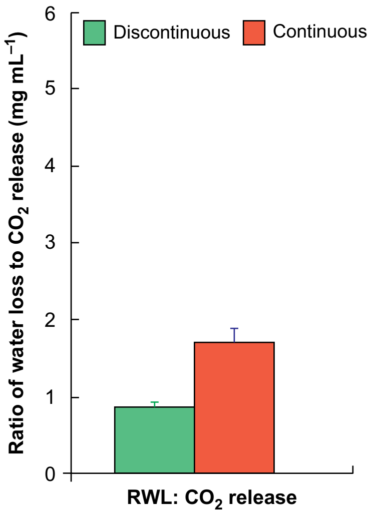

Figure D Respiratory water loss (RWL) relative to carbon dioxide (CO_2) release is reduced during discontinuous gas exchange compared to continuous gas exchange of *Protaetia cretica*

Data are means + standard errors, *n*=7

Source: adapted from Matthews PGD and White CR (2012). Physiological and Biochemical Zoology 85: 174–182.