Severe acidosis is the rule in primary lactacidemia, but we have observed milder, compensated acidosis in patients with hypotension. Attempts to improve the supply of oxygen by increasing the dissolved oxygen content of blood by use of hyperbaric chambers has been studied experimentally and clinically. In one report (*16*) this form of treatment seems to have had a favorable effect on mortality in experimental hemorrhagic shock in dogs. Methylene blue has had favorable effects in primary lactacidemia (*17*), but no reduction in excess lactate has been shown during shock.

In the work reported here arterial blood was sampled because of the possibility that local influences more directly affecting venous blood might alter the excess lactate as a reflection of oxygen debt. This would be particularly so in patients in shock and in whom peripheral blood flow is selectively impaired. However, the possibility clearly exists that venous blood might be satisfactory. Because of the particular advantage of venous blood for simple clinical tests, the adequacy of the venous sample will be more thoroughly investigated. The applicability of these findings to treatment will be of interest. Oxygen lack is most likely the primary injurious factor in shock, and effective treatment involves prevention of, or prompt repayment of, the oxygen debt. Based on our studies, excess lactate of 1 mmole/lit. or below is a safe level. When excess lactate is increased to 2 to 4 mmole/lit. it is in a twilight zone with regard to survival. If the excess lactate during shock is above 4 mmole/lit., prognosis is grave and circulatory anoxia will probably lead to irreversible change.

GEORGE BRODER
MAX H. WEIL
*University of Southern California,
School of Medicine, Los Angeles 33*

References and Notes

1. J. E. Rhoads, *Federation Proc.* **20**, Suppl. 9, 235 (1961).
2. W. E. Huckabee, *J. Clin. Invest.* **37**, 244 (1958); *ibid.*, pp. 255, 264.
3. P. Harris, M. Bateman, J. Gloster, *Clin. Sci.* **23**, 531 (1962); H. G. Knutkin, *J. Appl. Physiol.* **17**, 639 (1962); R. E. Olson, *Ann. Internal Med.* **59**, 960 (1963).
4. A. C. Guyton and J. W. Crowell, *Federation Proc.* **20**, Suppl. 9, 51 (1961).
5. M. H. Weil, in preparation.
6. V. N. Udhoji, M. H. Weil, M. P. Sambhi, L. Rosoff, *Am. J. Med.* **34**, 461 (1963).
7. S. B. Barker and W. H. Summerson, *J. Biol. Chem.* **138**, 535 (1941).
8. T. E. Friedemann and G. E. Haugen, *ibid.* **147**, 415 (1943).
9. D. B. Hackel and W. T. Goodale, *Circulation* **11**, 628 (1955).
10. A. M. Seligman, H. A. Frank, B. Alexander, J. Fine, *J. Clin. Invest.* **26**, 535 (1947).
11. C. H. Beatty, *Am. J. Physiol.* **143**, 579 (1945).
12. W. F. Ballinger, II, H. Vollenweider, L. Pierucci, Jr., J. Y. Templeton, III, *Surgery* **51**, 738 (1962).
13. ———, *Ann. Surg.* **153**, 499 (1961).
14. M. H. Weil and G. Broder, in preparation.
15. W. E. Huckabee, *Am. J. Med.* **30**, 840 (1961).
16. S. Attar, W. G. Esmond, R. A. Cowley, *J. Thorac. Cardiovasc. Surg.* **44**, 759 (1962).
17. R. E. Tranquada, S. Bernstein, W. J. Grant, *Clin. Res.* **11**, 230 (1963).
18. Supported by U.S. Public Health Service research grant H-5570 from the National Heart Institute and by the John A. Hartford Foundation, Inc., New York. We gratefully acknowledge the statistical collaboration of Frank B. Cramer.

14 January 1964

■

Defense of Mate and Mating Chamber in a Wood Roach

Abstract. *Studies of the eastern wood roach,* Cryptocercus punctulatus, *reveal that, under laboratory conditions, the mating chambers in rotten wood are inhabited by mated pairs, the male of which will usually defend the chamber successfully against intruding males by a form of fighting. In every staged contest in which the intruder won the fight, it also won the resident female. Females, as well as unmated males singly inhabiting a chamber, could not be induced to defend against an intruder of either sex.*

Living individuals of the eastern wood roach (*Cryptocercus punctulatus*), which are maintained for study of the well-known mutualistic protozoa that inhabit their hind-gut, have incidentally shown an interesting pattern of combative "territorial" behavior. This behavior, as seen under laboratory conditions simulating the natural rotten-log habitat, takes place in narrow "mating chambers" and the adjacent connecting galleries constructed by the roaches in the rotten wood. Each of the chambers normally contains a single mated pair of roaches, and unmated males placed in their vicinity may or may not attempt to enter a chamber. An invading male is usually engaged in combat by the resident male, which attempts to eject its rival from the chamber and its approaches.

Initial contests were watched rather casually, without checking sexes by definitive examination, but a comparison with later experiments in which marked individuals of determined sex were used makes it reasonably clear that the males do all the fighting. A common type of encounter is exemplified by the following account of an early observation, the sexes being assumed from the context: An unpaired male entered one of the occupied mating chambers. Almost immediately this individual and the resident pair evacuated the chamber by the opposite gallery opening. The female then quickly returned to the mating chamber, but the resident and intruding males began a contest lasting about 10 minutes. Head-on butting by pronotum contact became vigorous as each individual blocked advance of the other attempting to gain side access. Butting continued within the limited space just outside the mating chamber as both individuals turned first one way and then the other. Later, one of the two roaches gained advantage by quick approach to the side of the other which was then deftly pushed over onto its back. The overturned roach righted itself after considerable struggle, during which it received numerous leg bites from the other roach. These events were repeated twice with the balance of force favoring the same individual in each attack. The scramble continued until the "weaker" roach was forced into a position of retreat, which happened to be one end of the mating chamber. There it held forth facing its opponent for approximately 5 minutes. The opponent was blocked from entrance in spite of persistent butting and pushing. The blocker finally gave way in further retreat, forcing the female out of the opposite end of the mating chamber. The blocker exited in reverse, and the opponent followed. Pushing continued until both roaches ended the struggle behind a piece of wood adjacent to the mating chamber. There the roach which had fared badly all along remained. It was seen several hours later grooming its appendages. The "victor" returned to the mating chamber to join the unchallenged occupant which had moved back in as before when the opening was clear of the battling pair.

To obtain more systematic results, I used freshly collected mating pairs from Mountain Lake, Virginia. Insects were transported to the laboratory, each in its original mating chamber cut whole out of the rotten log during collection, and placed in a special plastic chamber filled with rotten bits of wood. An alternate mating chamber constructed by another pair not to be involved in the experiment was included. Each pair was allowed 1 week to adapt to the plastic chamber. At the end of this time, an unpaired male was removed from stock and directed into the plastic chamber through a side port. Twelve tests were made. In cases of conflict, the male that was successful in battle, and which afterward maintained close contact with the female roach (sharing the interior or immediate area of the mating chamber), was judged successful. Observed results are summarized.

1) No evidence indicates that a mating pair prefers or even recognizes its own mating chamber. In some cases occupancy was first established in the chamber originally constructed by the pair being tested, but, in each test, moves between original and alternate chambers occurred at least once during the week of adjustment.

2) In 10 of the 12 tests the resident male of each pair fought the intruder male. The resident male in each of seven mating pairs fought its intruder successfully. In three tests the resident was defeated by the intruder. The resident female was never observed in combat.

3) In 2 of the 12 tests conflict failed to occur, and resident and intruder roaches remained indifferent to one another for the period of confinement.

4) Defeated males remained indifferent to the resident pairs, and no repeat encounters of force were observed during the week after the conflict.

Behavior of the male intruder and mating pair individuals in the early stages of each test generally follows a pattern. The intruder runs two or three circuits of the plastic chamber after it is introduced by way of the chamber port farthest from the pair. Both male and female roaches of the mating pair instantly sense the intruder. Antennae become hyperactive, the usual almost motionless stance is broken by change in position, and rapid, jerky antero-caudad movements, which Cleveland (*1*) likened to those of termites, always occur in the resident male. First contact between the intruder and either individual of the pair is usually made in accidental collision. The intruder male continues running the circuit if this contact is made before hyperexcitability from handling has abated. Eventual behavior depends upon the sex of the member of the pair contacted by the intruder male. If female, the intruder male begins careful anterior and caudal end inspection. Rapid side-to-side female abdominal movements interrupt the inspection ritual whenever body contact is made by the male. On occasion, the female displays great curiosity, even to the point of following the intruder as it wanders away after inspection. Meanwhile the resident male actively seeks the intruder, and inspection is brief when contact is made. Fighting begins with the resident male taking the offensive. The duration of contest is sometimes brief, and, as reported for two cases, battle failed to occur in tests in which the resident male remained apathetic.

Further tests with the same pairs were designed to determine whether a female roach selected from stock and offered as the intruder would battle either member of a chamber-adapted mating pair. Negative results were obtained in each of five tests.

In additional experiments it was found that isolated but chamber-adapted females do not battle male intruders, and that isolated and chamber-adapted females do not battle female intruders. All stock roaches used as intruders in these tests were found paired in logs at collection time.

The behavior described takes on unusual significance when one considers the primitive status of *Cryptocercus*, a genus of a group possibly more primitive than termites (*1, 2*). Further investigations into other aspects of behavior and the phenomenon of possible pheromone release are warranted (*3*).

HOPE RITTER, JR.
Department of Biology, State
University of New York, Buffalo

References and Notes

1. L. R. Cleveland, S. R. Hall, E. P. Sanders, J. Collier, *Mem. Am. Acad. Arts Sci.* **17**, 185 (1934).
2. L. R. Cleveland, *J. Morphol.* **85**, 197 (1949).
3. Supported by NIH grant E-4708 and NSF grant GB-988. I thank Dr. William L. Brown, Jr., Dr. Thomas Eisner, and Dr. Carl Gans for advice during experiment and manuscript preparation.

3 February 1964

Lower Limit of Water Availability to Plants

Abstract. *Measurements of transpiration, cell division, and cell enlargement show that no single lower limit of available water can be defined for these three plant processes. The soil-water content at which permanent wilting is exhibited does not represent a true lower limit for any of these.*

The soil-water content at which plants appear permanently wilted has been found to correlate well with the soil-water content at 15 bars' suction. This water content has often been considered as the lower limit of available water in the soil. The exact interpretation of the permanent-wilting percentage and the relative availability of water above this water content have been subjects of interest to, and of some controversy among, soil scientists and plant physiologists (*1*). Some of the confusion has arisen from the frequent failure to distinguish between at least two different aspects of a plant's requirement for water, transpiration and growth. This report summarizes results of several studies showing that water availability affects these two processes differently.

The water in the plant is seldom in equilibrium with the water in the soil. In order for the plant to extract water from the soil, the potential energy of the water in the plant must be lower than that of the water in the soil. The difference in energy between plant water and soil water depends upon the rate of uptake of water from the soil and the water-conducting properties of the soil and plant. Results of an experiment designed to measure this energy difference are shown in Fig. 1. The energy of the water is plotted as soil matric suction (soil-moisture tension) and leaf suction (diffusion pressure deficit), both measured as energy per unit volume of water expressed in bars. The suction in a leaf of a pepper plant and the average matric suction of the soil in which the plant was growing are plotted as a function of time. The experiment was conducted in a growth chamber with 12-hour alternate light and dark periods at a temperature of 25°C. The dark periods are indicated by the solid bars at the bottom of the figure. The plant was grown in a 3-gallon crock filled with a clay loam soil. The leaf suction was obtained by continuous monitoring of the β-ray transmission by a single leaf. The procedure was the same as that used by Mederski (*2*), except that Tc^{99} was used instead of C^{14} for the β-ray source. The transmitted radiation was detected with a thin-window Geiger counter, and the result