Rearing Methods for Obtaining House Crickets, *Acheta domesticus*,[1] of Known Age, Sex, and Instar[2]

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ABSTRACT

The only major requirement in our method is a small room in which all the crickets are housed at a temperature of 30.5°C. The diet is a finely ground, modified chick starter mash. Water is provided via inverted plastic vials in gravel-filled petri dishes. Collected eggs hatch in 13 days and hatchlings are reared in glass aquaria for the 1st 3 or 4 instars. The remaining instars are kept in modified rat cages. Last instar females are picked each day from the appropriate age-group of crickets and kept separately in reusable one-gal cylindrical cartons. These methods are easily adapted to obtain crickets of known age of either sex in the last 2 instars or the adult stage. Cumulative aging is also possible by simply noting the days from hatch for a group of crickets. Freely available standing water is superior to cloggable wicks. Moderate water deprivation, overcrowding, or slight temperature changes may drastically affect the life cycle duration and physiological parameters of the house cricket. Our procedure for cricket rearing emphasizes ease of maintenance and consistency of results.

Many workers (Stone 1953, Jordan and Baker 1956, Patton 1963, Randell and Kevan 1963, and Patton 1967) emphasize the widespread use and adaptability of house crickets, *Acheta domesticus* (L.). House crickets are extensively utilized in insect embryology, physiology, endocrinology, etc., as indicated by perusal of Acridological Abstracts. House crickets have a short life cycle (6–8 wk), are comparatively large in size, and lack the distastefulness associated with cockroaches. Other appealing characteristics include gradual metamorphosis, no diapause, hardiness, ease of handling, and the availability of inexpensive, easily fed diets.

Methods for rearing experimental animals depend on the facilities and equipment available. Stone (1953), Busvine (1955), Ghouri and McFarlane (1958), Stone (1958), Patton (1963) and Burkhardt et al. (1970) outline various methods for the laboratory rearing of the house cricket, but specifics and rearing variables are, for the most part, not given. Jobin and Huot (1966) recognized the undesirable variables introduced by unregulated rearing methods, and they stressed the necessity of describing precisely all details of the rearing methods. We provide a practical guide for the establishment of a colony capable of producing accurately aged nymphs or adults of either sex, and we discuss the effects of varied rearing procedures. A major requirement is a small room in which the temperature can be held to ±0.5°C in the range 28–35°C.

The approach presented here is superior to methods presented in the literature which devote little or no attention to the aging within specific instars. Age can be considered as cumulative, which is the total elapsed time from egg hatch. This produces a mixture of instars and a mixture of ages within those instars. More specifically, age can be determined from the start of a specific instar by daily isolation of newly emerged individuals of a particular instar or newly ecdysed adults. Exact synchrony of growth and molting, as achieved in tobacco hornworms, *Manduca sexta* (L.) (Bell and Joachim 1976), is not possible with our group rearing of crickets. Aged nymphs or adults are necessary in studying various blood constituents (chloride, total lipid, total carbohydrate and others) which vary significantly from day to day within a particular instar, or for toxicological studies as noted by Harris and Svec (1964). If unaged or cumulatively aged animals are used, these variations are obscured by an averaging effect.

MATERIALS AND METHODS

All crickets are kept in a 3×4 m room at 30±0.5°C on a fluorescent lighting schedule of 12L:12D (lights on at 0900 h and off at 2100 h CDT). Humidity ranges from 25–50% depending on outside weather conditions.

Diet.—Commercially formulated chick starter mash is not used because of unstated and unpredictable constituent substitutions by the feed dealers. We store an adequate supply of the necessary ingredients and prepare our own oligidic diet. A 5 kg batch contains 227 g dehydrated alfalfa meal (15% protein), 680 g yellow corn meal, 114 g menhaden fish meal, 680 g ground milo, 340 g meat scraps, 818 g soybean meal, 1600 g mill screenings, 22.8 g poultry premix (Albers Milling Co., Division of Carnation Co., Los Angeles, CA 90035), and 1.14 g NaCl. The analysis of the food is: 19% protein, 5% lipid, 47% carbohydrate, 14% water, and 5.6% ash. Ingredients are thoroughly mixed in a roller mill and then ground in a Wiley mill (1 mm mesh screen). The salt fraction is premixed with the proper amounts of poultry premix and meat scraps, which is thoroughly mixed in a roller mill and then added to the other ingredients. To maintain freshness of the food, ingredients as well as the finished food are stored at 0°C.

Breeding Colony.—A colony of 500–1000 crickets is maintained in a large, screen-topped glass enclosure (116×60×36 cm, Fig. 1). Water is supplied to the breeding colony using a standard chicken

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watering device consisting of a pint jar with a screw-on plastic pan base. The pan is filled with pea gravel. A piece of aluminum screening melted in place over the water outlet prevents the crickets from crawling into the opening (and drowning). Food is provided in a pile at one end of the enclosure.

Egg Incubation.—Eggs are obtained by placing in the breeding colony a plastic petri dish bottom (100×15 mm) filled with wet sand, which is replaced daily. Egg pans (Fig. 1) from 3 consecutive days are kept together in an airtight plastic incubation container (24×24×9 cm), which is labelled with the 3 dates of egg collection. These dates serve as identification for this group of crickets throughout the rearing procedure, and is moved with the crickets from one container type to the next as the crickets grow. The eggs begin hatching 13 days after oviposition at 30.5°C.

Hatchlings. — When approximately 100 crickets have hatched, the 3 egg pans are placed in a 7.5 gal glass aquarium (Fig. 1). Food is provided in the shallow top of a plastic petri dish (100×15 mm) with the sides partially removed to allow easy access for the hatchlings. Water is provided in the petri dish bottom with masking tape applied to the outer wall, assuring easy access for the hatchlings, and filled with clean pea gravel. The aquarium is covered with a glass lid to maintain the high humidity essential for maximal survival of the desiccation-labile 1–1V nymphal instars. After 9 days, the young crickets are dumped into a modified stainless steel rat cage. At this point some or no crickets can be discarded, thus controlling the overall numbers of crickets produced.

Rearing Cages.—The containers we used for the completion of the life cycle are modified stainless steel rat cages (43×36×18 cm), 15 cages in a galvanized roll-around rack (Fig. 1). The original wire mesh front and bottom is covered internally with a tight fitting piece of ¼ in. plywood stapled to the wire mesh making the cage cricket-tight. Crickets cannot climb the stainless steel walls, and a 2–3 cm wide strip of heavy duty aluminum foil glued across the top inner edge of the plywood front is sufficient to prevent escape via the plywood. A rectangular hole is cut from another piece of ¼ in.

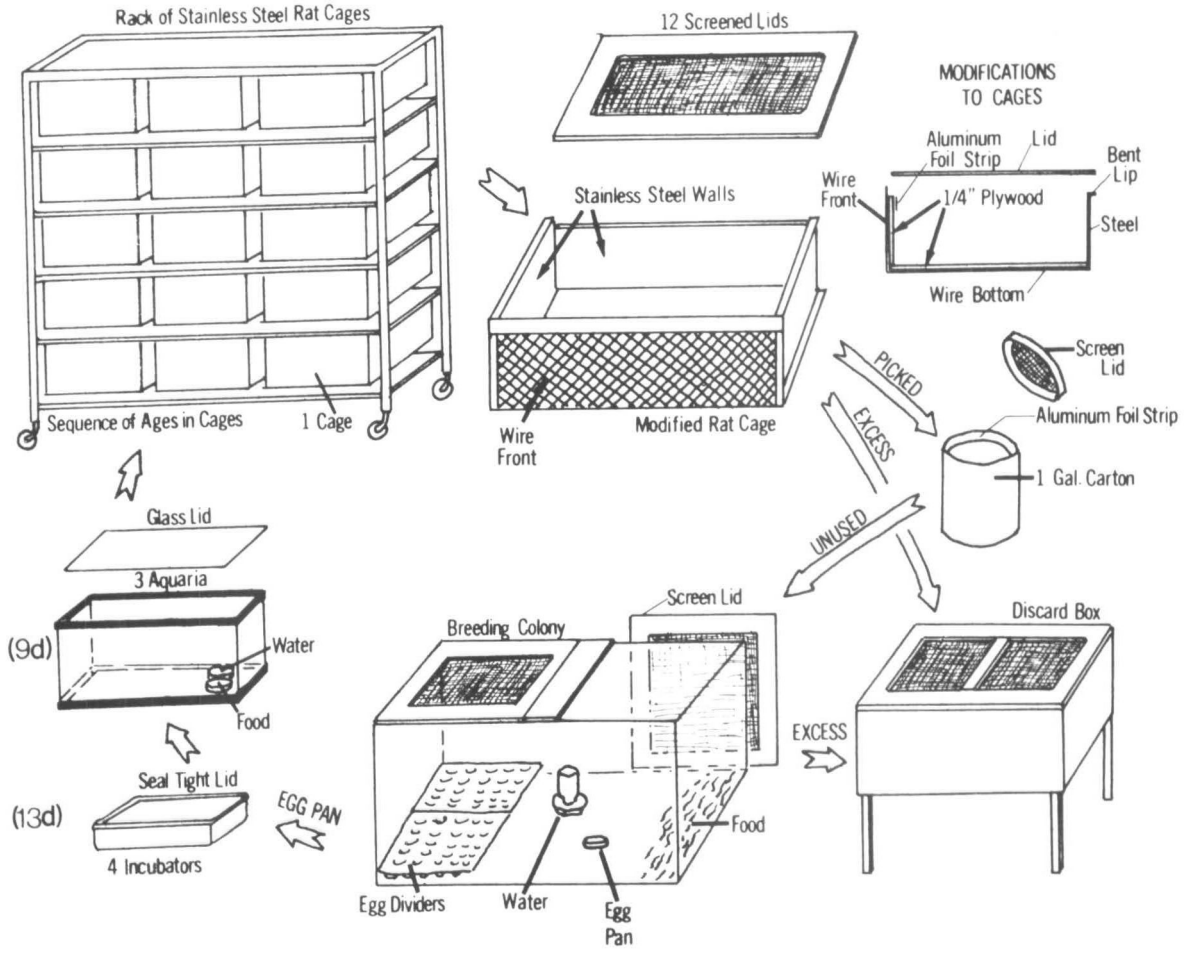

FIG. 1.—Schematic outline of cricket rearing operation. The units are not all drawn to the same scale. The broad arrows indicate the general flow of the operation. A section through a cage illustrates the necessary modifications. Details and measurements of each unit are given in the text.

plywood and aluminum screening is stapled over the opening. This forms a lid which is supported by the plywood front and by a bent lip on the back wall of the cage (Fig. 1). Crickets older than the 4th instar are no longer so susceptible to desiccation and, in fact, do better if the humidity is not too high. Three of the 15 lids have aluminum foil taped over the screen, which are used for the cages containing the crickets newly transferred from the aquarium. This provides a relative humidity intermediate between that of the aquaria and the open screen-topped cages. The cages are slid half-way into the rack to insure adequate exposure to the light regime. Food for all crickets in these cages is provided in the lids of one pint cardboard cartons (8.5 cm diam) in order to reduce the scattering of food by the crickets. Water is provided using plastic vials (55–75 ml capacity) with a 5×10 mm slot cut in the top edge. These are filled with water and inverted in plastic petri dish bottoms (100×15 mm), which are then filled with pea gravel. Such watering containers supply sufficient water for one cage for 6 days, then they are cleaned and reused. The bottom of the cage is scraped clean of feces and scattered food once a week.

Instar Selection.—The methods that follow are designed to obtain known aged last instar females but can be adapted to obtain crickets of known age of either sex in the last two instars or the adult stage. Usually the next to last instar is the 7th and the last instar the 8th.

About 27 days after the crickets are placed in the rat cages, some begin ecdysing to the last instar and the cage is then marked (with a removable magnet) and "cleared"; that is, all last instar females present are discarded. Every day thereafter (at 1530 h) all last instar females are picked by using a clear plastic vial to scoop them up. The picked crickets are placed in groups of 10–12 in 1-gal cartons, which are marked with the picking date, and these are designated as 1-day last instar females. The cartons of known age, last instar females are placed on shelves in the cricket room. We arbitrarily pick at 1530 h and consider 0330 h as the time when the picked crickets become one day older. In our cricket colony, ecdysis is slightly more frequent at night than during the day. Therefore, 12 h after picking, the majority of the picked crickets must be closer to being one day older. If cumulatively aged crickets are desired, picking is not necessary because one simply counts the days since hatch and takes the appropriate cage. Food and watering containers in all aquaria and cages are also checked, and cleaning and general maintenance is performed at picking time (1530 h).

Screen Top Cartons. — The picked crickets in groups of 10–12 are maintained in 16-cm diam, 1-gal cylindrical containers obtained from Sealright Co., Inc., Kansas City, KA 66115 (Fig. 1). These compressed cardboard cartons are quite sturdy and can withstand frequent washings. A 2–3 cm wide strip of heavy duty aluminum foil is glued to the top inner edge of the carton to prevent escape. The cardboard center of the carton lid is replaced by aluminum window screening to allow air circulation. The inner wall of the carton provides resting area for the crickets. We find no need for sand bottoms or any need for excelsior, crumpled paper or other materials in our cages or cartons. Food is placed in a plastic petri dish bottom (60×15 mm) with masking tape on the outside wall. Tap water is provided in a small plastic vial (26 ml capacity) with two 5×10 mm slots cut in the rim, filled and inverted into a plastic petri dish bottom (35×10 mm) with no garvel or wick. By this means, more than sufficient food and water for the 8 days duration of the instar is provided for 10–12 last instar females, and they are not disturbed until needed.

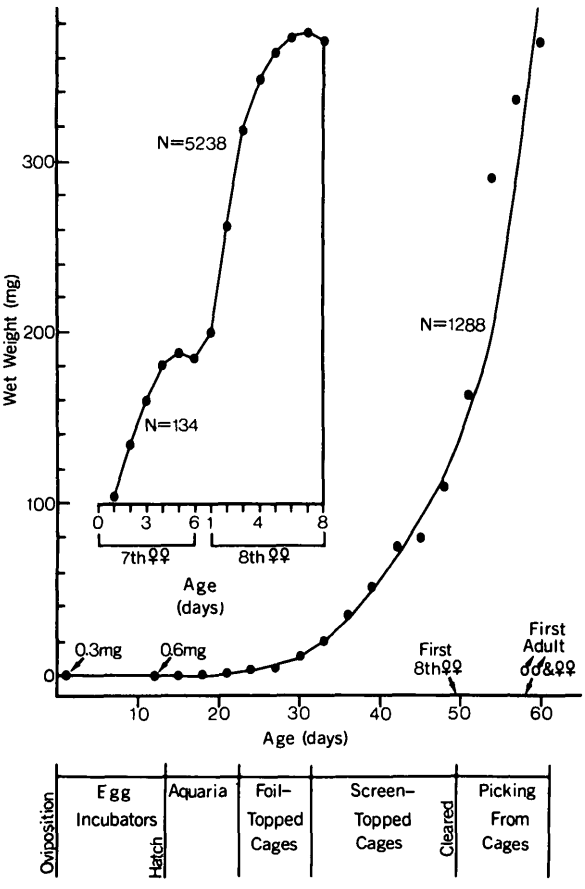

FIG. 2.—Cumulative growth curve (right) and growth curve of the next to last (7th ♀ ♀) and last (8th ♀ ♀) instar females (left). N = number of crickets used to generate the curve. The bottom scale indicates the particular unit of the rearing operation (Fig. 1) in which the given ages are maintained. Cages are cleared when the first (8th ♀ ♀) appear (see text for details).

Colony Management.—The egg incubators, aquaria, rat cages, and cartons are in continuous rotation (Fig. 1). As one set of eggs begins to hatch, (after 13 days in the incubator, Fig. 2), they are transferred to one of three aquaria. This forces the emptying of the young crickets already in the aquarium, having been there for 9 days, into one of the 3 rat cages with foil tops. After 9 days, the foil-

covered lid is replaced with a screen lid, so that the crickets remain in the same cage until picked or discarded. The first of the last instar females appear after 26 days and adult males or females after 34 days (Fig. 2). Males have exactly the same nymphal duration. From this series of containers (3 aquaria and 15 rat cages) nymphs and young adults of almost any size or cumulative age are readily available. Usually as a young group of crickets is ready to be transferred from an aquarium to a cage, the oldest cage of crickets is completely picked of the desired instar and is ready to be dumped into a large discard box (Fig. 1). These are used as food for other laboratory animals, such as frogs, lizards, etc. Unused cartons of picked crickets are likewise discarded, thus all equipment is cycled. Food remaining in the emptied cages or cartons is placed in the breeding colony, thus very little food is wasted. Periodically, young males and females must be added to the breeding colony.

One half man-hour per day is sufficient for routine maintenance and to obtain cumulative aged crickets. Slightly more than 1 man-hour per day is required to obtain crickets of known age, for example, with 15 rat cages up to 80 last instar females can be obtained per day. More containers can be interposed at any point to accommodate lengthened development with lower temperatures or to increase production at any temperature.

Cleanliness.—Cleanliness is important for esthetic reasons and to assure normal growth through uniformity of eating and drinking. All watering pans are thoroughly rinsed between use. The dry feces and spilled food is troweled weekly from the cages and from the breeding colony. Used gravel, sand, and egg cartons are never reused. All cartons, aquaria, plastic incubators, and cages are thoroughly scrubbed and dried between use. Sterilization of sand, food containers, or cages is not necessary, thus saving considerable time and effort. In the 3 yr of operation, we have had no disease and only one incident of large scale mortality. This was due to infestation of the egg pans by wild fruit fly larvae. The larvae produced high concentrations of ammonia which apparently killed the remaining eggs. Use of sand with some clay content, placing of waste containers outside the rearing room, and frequent changing of watering containers alleviated the problem and has prevented subsequent infestations of fruit flies. The Pharaoh ant, common in many buildings, can also be devastating to a cricket colony. We solved this problem by banding the legs of tables, cage racks, and shelves with tanglefoot.

Transfer Box.—It is necessary for photoperiod studies to obtain crickets at specific times throughout the dark period. A 2-compartment box, which is mounted in the wall of the cricket room, projects into an adjacent room. Each compartment of the transfer box has a light-tight inner (cricket room) and outer (adjacent room) sliding door. This allows containers of crickets to be placed in the transfer box during the photophase and removed during the scotophase without disturbing the rest of the colony and with the least deviation from control conditions.

Growth and Survival.—A cumulative growth curve was obtained by randomly removing at least 50 crickets from each aquarium and cage. Thus an average weight was determined for each 3 days group of crickets (Fig. 2). Also an average daily weight of next to last and last instar females was determined (Fig. 2, inset). The %-survival was determined by placing 10–15 first instar nymphs in cartons and counting survivors when all had molted to the adult.

DISCUSSION

Certain factors, such as watering, environmental temperature, composition of the food, crowding, and type of rearing container have pronounced effects on various physiological parameters. Careful consideration of these basic factors is essential for certain kinds of experimentation.

Water Availability.—A supply of clean water for unrestricted ad lib. drinking is important. We tried various kinds of wicks and other methods given in the literature, but most resulted in incomplete water satiation. One day old last instar females with inadequate water (for example, with use of cloggable wicks) will successfully reach maturity without any readily apparent morphological effects on the animal. Such water restrictions, however, are revealed by elevation of blood % lipid, protein, carbohydrate, and trehalose, ion concentrations, and osmolality as well as changes in growth rate. To reduce the chance of even mild desiccation, adequate fresh, free-standing water is made available to the crickets at all times.

Temperature.—Below 27°C growth is very slow and cricket mortality increases for unknown reasons. Egg incubation time is unacceptably long at room temperature. Stone (1953) hatched eggs in 30 days at 27°C, Kemper (1937) gives an incubation time of 56–84 days at room temperature (unspecified), and Busvine (1955) found that incubation duration was 46–51 days at 23°C. We find a consistent incubation period of 13 days at 30±0.5°C.

The time from hatching to final molt for the house cricket is reported to be 28–42 days at 35°C (Patton 1963) and 42–56 days at 26.5°C (Patton 1967). In our operation, at 30±0.5°C, males and females took 45 days from hatch to the final molt usually in 7–9 instars. We noted that significant changes in developmental time result from very slight temperature changes. A maintained 0.5°C increase from 30.5 to 31.0±0.5°C over a period of many weeks results in a 10-day shortening of the life cycle. Egg incubation is 14 days at 29.5±0.5°C and 13 days at 30.5±0.5°C. The duration of the last nymphal instar is 9 days at 29.5±0.5°C and 8 days at 30.5±0.5°C. Adult females lived on the average of 70 days at 30±0.5°C, and some males survived for 90 days.

Attempts to hold the temperature to less than ±0.5°C are excessively expensive, and therefore, we

maintain the temperature within as narrow a range as possible and accept the sensitivity of the animal system involved.

Food Composition.—The minimum nutritional requirements for rearing the omnivorous house cricket are easily fulfilled by a variety of commercial animal feeds and mixed oligidic diets, but optimum growth and high %-survival requires specific dietary components. Our diet (see Materials and Methods) is basically a nonmedicated chick starter mash, whose composition and analysis is very similar to the four best diets for routine cricket rearing formulated by Patton (1967). Patton linked improved growth with a labile compound, a growth factor, found in commercial meat scraps and menhaden fish meal, both of which are included in our diet. McFarlane et al. (1959) also noted that plant materials do not provide crickets with growth factors as do materials of animal origin such as skim milk or fish meal.

Crowding and Containers.—McFarlane (1962) found that nymphal house crickets in 16-oz jars grew more rapidly when reared in groups of 10 than singly. Jobin and Huot (1966), on the other hand, found no difference in growth between groups of 10 and 25. No specific study has been done on the minimum area needed per cricket to obtain maximal growth. Overcrowding, however, should be avoided. In addition to restricting access to food, water, and resting space, crowded conditions increase cannabalism and may alter the number of instars. Under crowded conditions, losses also occur in the teneral period when the crickets are easily nipped and injured by other crickets. We keep 400–500 crickets in each rat cage, and 10–12 picked individuals per carton.

Randell and Kevan (1963), Stone (1953), Ghouri and McFarlane (1958), and Busvine (1955) kept all ages of crickets in glass containers of various sizes. We find that glass containers present problems because of excess condensation. High humidity, though essential for the survival of the newly hatched crickets, is detrimental to the later instars and adults. Also, crickets cannot climb on glass and are limited to the floor of glass containers. Sand floors are not only inconvenient and unnecessary, but are to some extent detrimental because of uncleanliness. Cardboard or wooden containers do not present humidity problems and provide ample resting area with the floor and wall available to the crickets. Total available surface area in our 1-gal cartons is 766 cm^2, with the floor contributing only 192 cm^2. Cardboard cartons wear well even with frequent washings, but eventually must be discarded after several months of service. A light coat of plastic spray on the inside carton bottom will greatly lengthen the carton's life.

Oviposition Substrate.—Busvine (1955) used pads of cotton wool, noting that the proper moisture level was more easily maintained in cotton wool than in sand. Most workers employ moist sand as a substrate for oviposition (Ghouri and McFarlane 1958, Randell and Kevan 1963, Stone 1953, Bate 1971, and Benke and Wilkinson 1971). Sterilization of the sand is unnecessary because some mold growth does not interfere with hatching. We find that sand with some clay content retains water and inhibits mold growth better than clean masonry sand. Because we expose an egg pan for only 24 h and then place it in an airtight plastic incubator, further moistening of the sand is unnecessary.

Percent Survival.—A possible basis for realistic comparison between our method and those reported in the literature is %-survival from hatchling to adult. The average total %-survival is 82% with our rearing method; however, the loss occurs in the 1st and 2nd instars with 100% survival thereafter. Patton (1967) indicated a low of 50% survival and a high of 80% depending on which of the sixteen experimental diets he used. McFarlane et al. (1959), using several meridic diets and baby rabbit food, obtained a %-survival of 75% and 73%, respectively.

Growth Curves.—A growth curve provides another evaluation of rearing success. Our cumulative growth curve (Fig. 2) is similar in shape to that given by Lipsitz and McFarlane (1971), but our last instar females are larger. Most of the cumulative growth curves given by Patton (1963) on ten different diets have a sigmoidal shape, which differs from our curve. His average last instar and adult cricket weights are 300 mg with individual crickets as large as 480 mg when fed rabbit food. In our culture the next to last instar females grow from 100–200 mg, and the last instar females grow from 200–380 mg (inset graph of Fig. 2) though 400–450 mg is not uncommon. Our average adult male cricket weighs 410 mg, the young nongravid female 370 mg, and the gravid female 500 mg.

Our rearing method is a scientific approach to rearing the house cricket as an experimental animal. We have made extensive physiological studies on the blood as well as the whole cricket reared with this method. Identical physiological results are always obtained for crickets of the same age tested as much as two years apart (provided the average weight is $<\pm 15$ mg of the average weight, Fig. 2, inset). The main advantage of our method is the convenience and ease of obtaining crickets of known age and instar.

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