JOURNAL OF THE AMERICAN GERIATRICS SOCIETY Vol. 19, No. 5
 Printed in U.S.A.

A CRITICAL RATIO OF AGING: WATER LOSS—HEAT PRODUCTION*

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ABSTRACT: **The ratio of water content to heat production in the rat, guinea pig, chicken, and human increases with age. The slope of the line increases at a different rate for each species. There is an interesting relationship between the onset of rapid senile death and the water-heat ratio in each species when the ratio of water content to heat production exceeds 2.0.**

Attempts to explain aging by finding mechanisms of specific changes that occur universally in all cells have not been successful. As previously pointed out (1), the change in water content of the cells is continuous throughout life. Similarly, the basal metabolic rate, or heat production, declines with age. Again this is continuous from birth until death in all species studied (2), including rats, guinea pigs, chickens and man.

This paper attempts to extend these concepts and show that they apply to many species; also, that the ratio between the rate of water loss and the rate of decline in heat-producing ability changes constantly throughout life. The alteration in this ratio of water loss to heat production is continuous; thus the ratio of these functions changes continuously throughout life. For example, when the percentage of water in the body is divided by the heat production at the same age, a ratio is obtained. This ratio continues to increase with advancing age. When the ratio is individually plotted for each species studied, it forms a continuous line, indicating that these changes are somehow related to each other; extrapolated values indicate that these changes begin before birth.

The observation that heat production declines throughout life, and that water loss proceeds smoothly and continuously throughout life indicates that these are two prime changes (3) which represent an overall summation of alterations caused by failures within the cell. Although these changes do not indicate the mechanism by which processes fail, they do indicate that any mechanism proposed to explain the failure of a cell must follow the basic laws of senescence (4). These laws demonstrate that there is a smooth and predictable decrease in the rate of aging as the individual increases in age.

* Presented in part at the 27th Annual Meeting of the American Geriatrics Society, New York, N. Y., April 3–4, 1970.

This work was financed by the Calloway Research Fund.

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MATERIALS AND METHODS

The materials used in this study came from the literature. The empiric data were taken from tables of various investigators which include some of our own (5,6). The species in the present study on heat changes, ranged from reptiles to birds to mammals, including the snake, guinea pig, horse, chicken, rat, cow, and human. This range shows that the observed changes are not confined to one species or even to one order of animals. The graphs were constructed so as to illustrate the changes with time. This material was used to derive the ratios for the various species when the information was complete enough to allow interpretation.

RESULTS

Figure 1 shows that heat production in animals of various species declines in the same general fashion (data from the literature). Some animals have surprisingly high metabolic rates when young. For example, the rat has an extremely high metabolic rate that rapidly declines with age. Rates vary in the other species illustrated—guinea pig, chicken, cow, and horse. The horse has a remarkably low metabolic rate, especially when young. In Figure 1 the human decline is also shown for comparison. For most species

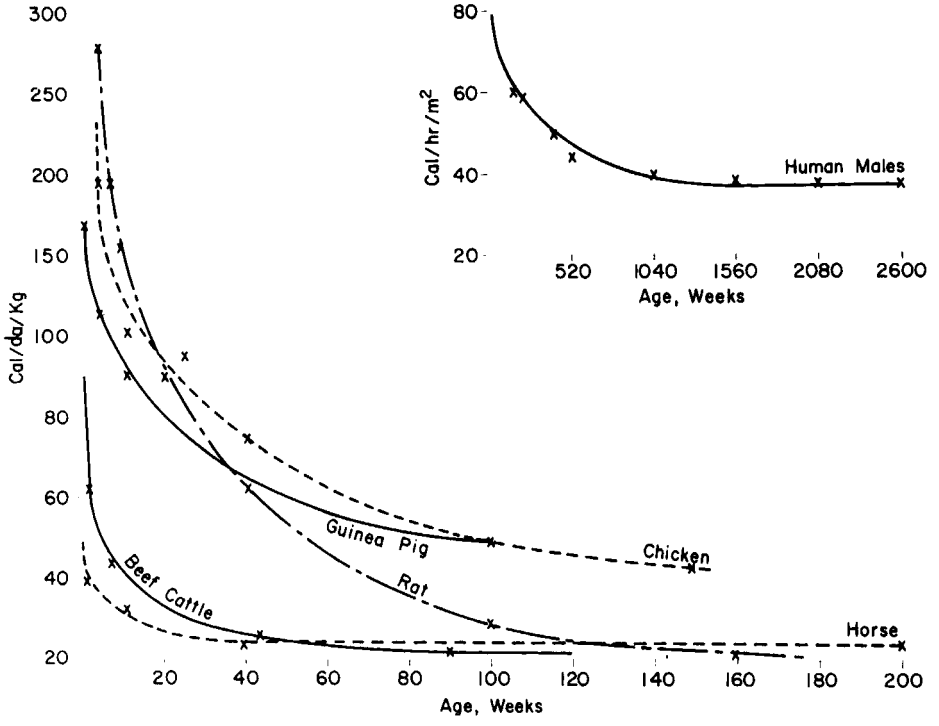

FIG. 1. Heat production against age for various species. Human values are expressed in calories per hour per square meter. Other values are expressed in calories per day per kilogram.

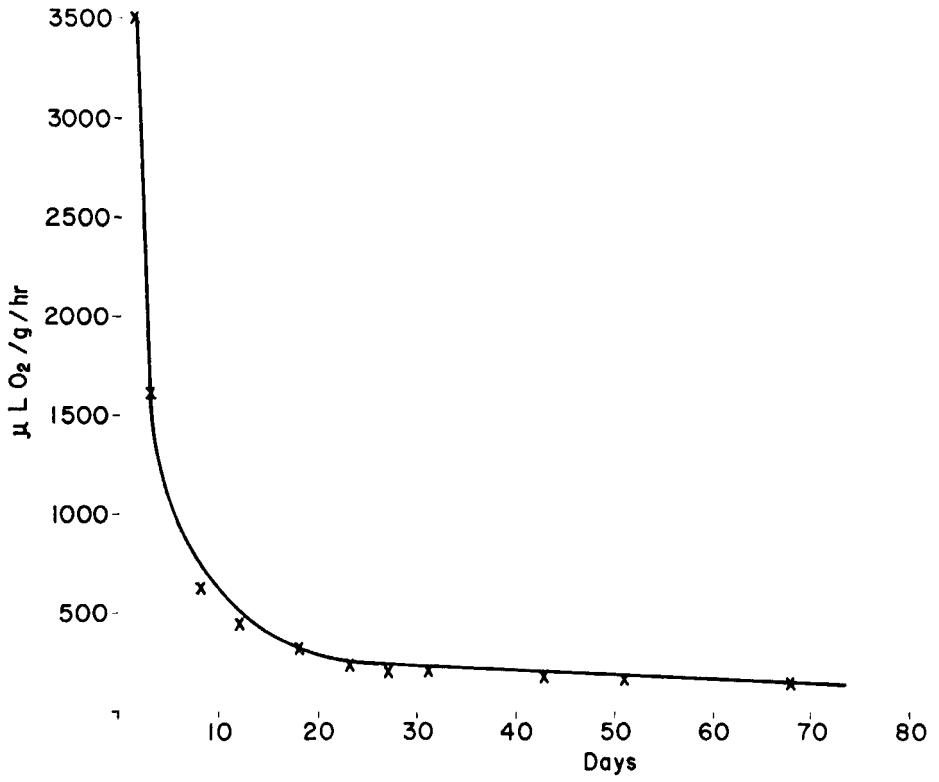

FIG. 2. Oxygen utilization of the hatching egg of a Coluber constrictor (racer snake).

the findings are expressed as calories per day per kilogram, and this represents the nearest approach to the basal metabolic rate that could be obtained for these animals. A better term would be resting metabolic rate. The data on humans are in a separate section since they are expressed in calories per hour per square meter and represent a true basal metabolic rate.

For some time the question has been raised as to whether or not eggs (representing a pre-birth state) show a similar trend. It also has been questioned whether cold-blooded animals would show a similar trend when placed under constant temperatures.

Figure 2 shows the changes in oxygen utilization and therefore heat production, of a hatching Coluber constrictor, the common racer snake. This and much other information (6) may be found in descriptive handbooks. The material in Figure 2 represents the microliters of oxygen per gram per hour utilized by the eggs of the snake. The eggs were maintained at 23.9 degrees Centigrade. There was a rapid decline in the utilization of oxygen with age. After the first few days, the eggs rapidly decreased their oxygen demand to a fairly constant lower level, which declined very slowly after

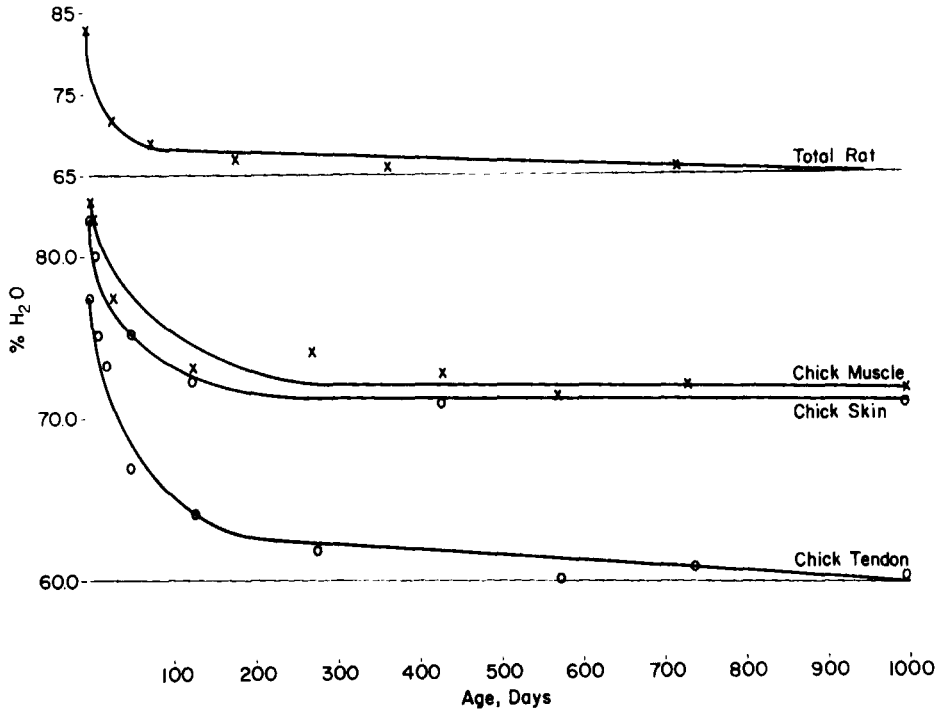

FIG. 3. Changes in percentage of water with age—total body water of the rat, and tissue water of the chicken.

the twenty-third day. This is in keeping with all known heat production and oxygen utilization curves for other species (see Fig. 1).

Water loss follows the same type of declining curve. In all cases there was rapid loss of water from the individual with age. Figure 3 taken from previously published data (7), shows both the decline in total body water

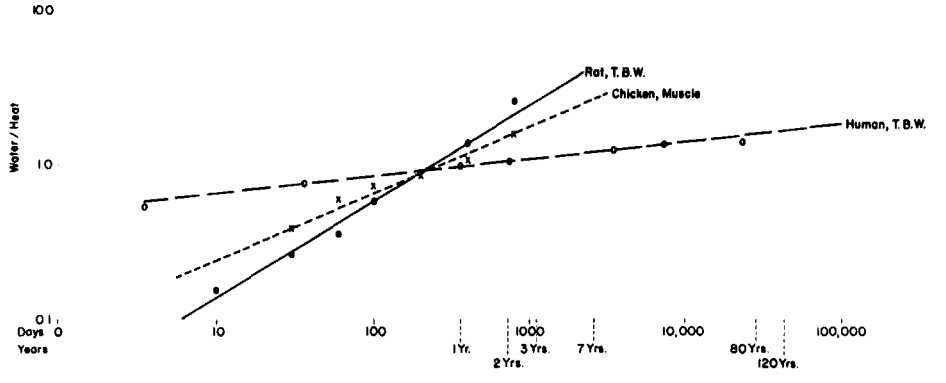

FIG. 4. Water-heat ratio plotted logarithmically against age (days and years).

of the rat and the decline in the various tissues of the chicken. This is exactly the same type of decline found in the human (8).

In order to obtain the ratio which is critical in considering senescence, the value for water content (expressed as percentages) was divided by the value for heat production (expressed as calories per unit time per unit weight) in the rat, guinea pig, chicken—or calories per unit time per unit surface area in the human. When graphed, it was found that there was a steady increase in the size of this ratio. This material was plotted logarithmically as shown in Figure 4. The logarithmic graphs of these increases form straight lines. It is noteworthy that by the time the ratio exceeds 2.0, the period of rapid senile death is approaching for all three species.

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