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RECENT CONCEPTS IN ENVIRONMENTAL PHYSIOLOGY

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SUMMARY

Heterothermy- that is lability of body temperature (thermal norm)-enables the animal to tolerate changes in environmental temperature,adverse heat or cold stress with the least disturbance of water and/or energy and chemical balances in the animal body. This is more relevant in the non-sweating or weak-sweating animals. Strict Homeothermy (stability of thermal norm)involves disturbances in one or more of the bio-physical norms (Osmotic pressure, Hydrostatic pressure and Acid-base balance) which may be more fatal than change in body temperature.

Successful adjustment of lability in each norm to achieve the proper setup of the norms in response to fluctuations in environmental conditions imposed on the animal leads to the best adaptive performance designated as complementary adaptation. An index of this complex of norms is apt to give better measure of adaptability than thermal index only.

INTRODUCTION

This article exposes concepts in the field of adaptatation of farm animals to environmental conditions in two related objectives (1) Heterothermy versus homeothrmy and (2) Complenemtary adaptation. The article exposes the general outlines avoiding going in detaled physiological processes or discussion of the environmental interrelated conditions. The physiological mechanism in this concern has been previosly discussed (Shafie, 1990). The major climatic conditions in the subtropics are summarized by Shafie (1989). Anyhow the climatic conditions-either natural or artificial microclimate-, nutritional and watering conditions are to be considered concomitant factors in a composite environmental effect.

Heterothermy versus homeothermy

Conventionally, the animals are divided, corresponding to their thermal pattern in relation with environment, into two major divisions, Poikilotherms and Homeotherms. The body core temperature in the former division conforms with the ambient temperature, that is its temperature is in quite positive relation with the environmental temperature. The latter division is deemed to have stable core temperature whatever the change in environmental temperature, this division includes mammals and birds. Either response is achived, through bio-physical activities, within particular range of fluctuation in ambient temperature for each species. Some species have limitted maximum and minimum ambient temperatures beyond which they resort to behavioral responses to scape endangering by harch conditions. Some species (several bird sp.) practice seasonal migration to proper residence with tolerable temperature. Some species practice hibernation in face of critical cold, that is depression of the bio-thermal activities leading to dormancy state (bats and ground squirrel are mammals expressive of this performance). Some species show state of estivation that is a case of torpor at particular high ambient temperature within daily or seasonal periods (Folk, 1974). Prosser and Brown (1961) proposed the definition "heterotherm" for hibernating mammals. Folk (1974) stated that this term is applicable to hibernating or non-hybernating animals.

The term Heterothermy is used by some authors to denote active lability of body temperature in counteraction to daily fluctuations and seasonal changes in environmental temperature. They claimed that this lability enforces the adaptability of the animal to the surrounding environment. Bligh (1972) suggested that the tolerance may not be a capacity to maintain thermostability in an adverse environment, but a capacity to telerate passive variations in body temperature. He stated that, the lower the body temperature is allowed, physiologically, to fall during the cold desert night, the better will be the heat tolerance of the animal to the succeeding hot day. This lability involves shifts in thresholds of body temperature within biological cybernitic mechanisms leading to establishment of ever changing set points.

This thermolability is evoced by composite environmental conditions, not only by thermal changes in the environment. Chquiloff (1964) reported that the less thermostable native Brazilian catlle was more successful in natural hot cases than the more thermostable imported European breeds. Thermolability was not evidenced under controlled hot conditions, under near-natural conditions (Berman, 1971) and under short-term exposure to heat or cold (Johnson, 1971). Availability of water in hot condition is a major factor in this thermolability.

The camel is a superior organism in application of this thermolability as shown in Figure (1) after Schmidt-Nielsen et al. (1957). This mechanism is well suited to desert hot-day, cold-night fluctuation cycles. Toleration of high body temperature in midday enables the camel to store heat in the body which serves in keeping the animal warm within the next cold night. This phenomena is more evident in case of drought condition, thus minimizing the need of water vaporisation for cooling the body with subsequent conservation of body water against lack of water intake. Bligh and Robinson (1965) presented daily lability trend of the deep body temperature in buffaloes (Figure 2). Figure (3) shows the lability of body temperature of buffaloes compared to Egyptian native cattle, imported Dairy Shorthorn and their crosses in renponse to changes in ambient temperature (Shafie, 1958). Contrary to this thermolability of heterotherms Bligh (1972) assumed that sheep is an obligatory homeotherm under hot conditions. He considered that camel and sheep, as farm animals, occupy the extremes of thermal adjustment. The tremendous varieties of sheep may show some breeds with thermolability trend,this needs extensive study of desert breeds which is expected to show this thermal lability in several breeds.Bligh indicated two points of interest in this context; species difference in means of dissipating heat by water evaporizaion and possible nervous arrangment concerning thermostability and lability for broad concept of heat torelance. He concluded that search for heat tolerance in farm animals

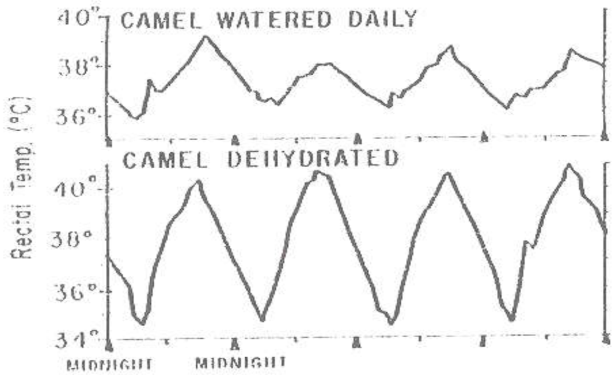


Fig. 1. Daily body temperature fluctuation of Camels. The day-night rhythm of body temperature in camels shows an increased amplitude when the animal is dehydrated. This fluctation of as much as 6°C is useful in temperature regulation; when staying in the hot sun during the day, the body temperature is permitted to rise. The heat that goes into warming the body is stored. Instead of dissipating this by evaporation, it is dissipated during the cool night by conduction and radiation. (From Folk, 1974 after Schmidt- Nielsen <u>et</u> <u>al</u>., 1957)

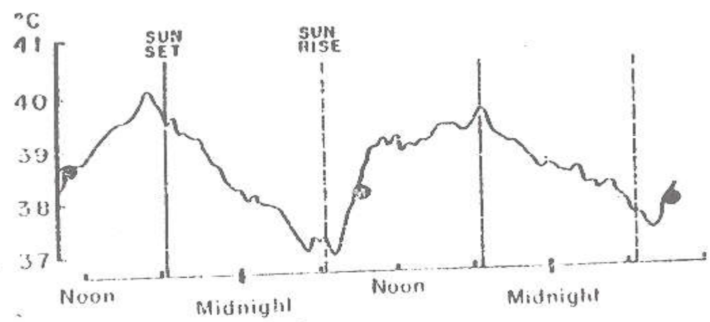


Fig. 2. The labile body temperature of a large mammal. A record of the deep body temperature from the lower neck region of a water buffalo recorded by radio-telemetry. The solid circles indicate spot measurements of rectal temperature. (From Folk, 1974 after Bligh and Robinson, 1965).

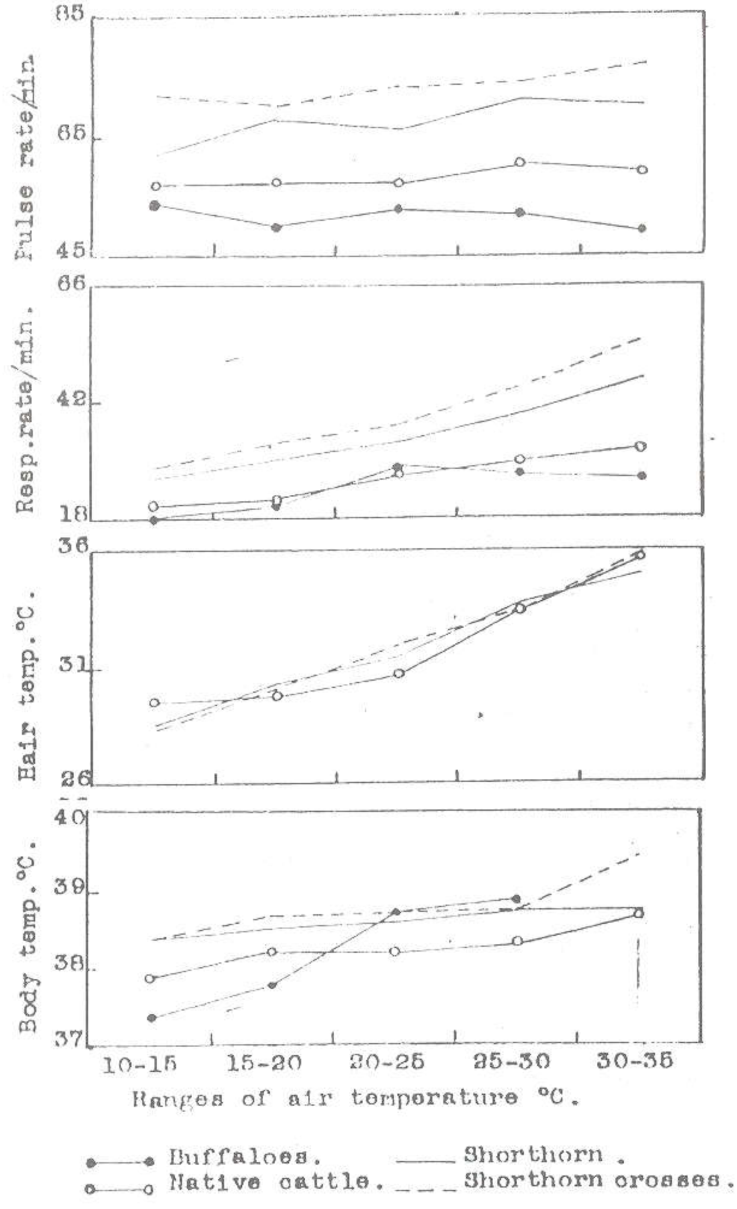


Fig. 3. Lability of buffaloes'body temperature compared to cattle breeds (From Shafie, 1958).

was directed towards selection of animals with capacity of thermostability, anyhow thermolability may be of practical significance. An animal which could graze under sun rays and avoid excess water vaporization with labile body temperature is better adapted to hot condition than that seeking shade and excersizing more vaporization to stay thermostable.

On compilation of data by several authors Bligh (1985) stated that finely controlled homeothermy is not a strict mammalian characteristic, rigidity or lability of body temperature seem to differ between species as adaptive responce to environment.It seems of vital value that the basal thermo,respiratory and cardiac levels are lower in buffaloes than in both subtropical (Egyptian)cattle and temperate cattle as found by Shafie (1985) (Table 1). Mullick (1960) reported similar case for Indian buffaloes and cattle (Table 2). Sethi and Nagarcenkar (1981) stated that negative correlation between initial and increase in body temperature (by 6 hrs. exposure to direct solar radiation), also for pulse rate indicated that buffaloes with lower basal metabolism exhibited better resistance to heat stress. Bligh (1985) stated that there may be variation in thermolability within a genetic pool. He proposed, what he considered as pragrmatic approach, selecting cattle on basis of thermolability (Heterothermy) for adaptation in arid environment.

Thermolability may be practiced in one direction not the other, sheep considered of rigid hometherm against heat strees show passive thermolability in face of cold stress. This needs further elucidation as suggested by Bligh (1985). The reduction in body temperature in cold environment is a serviceable biological function better than thriving to maintain rigid temperature by further metabolic work , particularly with scarsity food resources.

Complementary adaptation

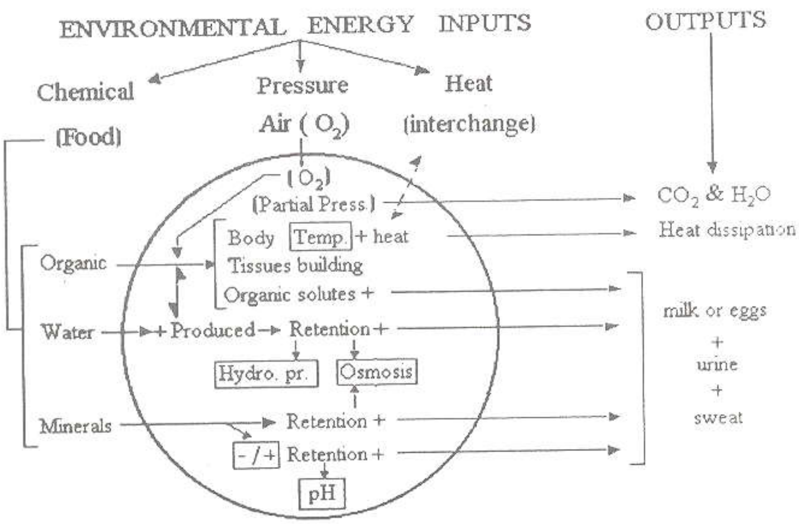
The animal, a living organism,is surrouded by environment which is always imposing status (lack or excess) of its physical energy forms on the animal.The animal,in order to maintain his life, has to adjust his internal energy norms against the ever imposed changes in environmental energy. Figure (4) shows the forms of inputs to the animal body as related to the internal forms of energy in the animal body.Life is achieved by maintenance of the vital norm for each of these internal physical energy forms; thermal, pressure (osmotic, hydrostatic & gases) and pH.

Table 1. Physiological Norms of Buffaloes and Cattle at different air temperaturs

Air temp. range	Physiological norms	Buffaloes	Cattle breeds		
			Egyptian	Diry Short-horn	Short x Egypt.
10-15°C	Body temp.(°C)	37.4	37.9	38.4	38.4
	Resp. rate/min.	18.0	21.0	27.0	29.0
	Pulse rate/min.	54.0	21.0	62.0	72.0
15-20°C	Body temp.(°C)	37.8	38.2	38.5	38.7
	Resp. rate/min.	23.0	23.2	38.5	38.7
	Pulse rate/min.	50.0	58.0	68.0	70.0
20-25°C	Body temp.(°C)	37.9	28.2	38.6	38.7
	Resp. rate/min.	30.0	28.0	34.0	38.0
	Pulse rate/min.	53.0	57.0	66.0	73.0

Table 2. Body temperature (°C), respiration rate and pulse rate (/min.) of lactating Indian buffaloes (Murrah) and cattle at 33°C environmental temperature in arid and humid conditions (From Mullick, 1960)

Relative humidity	Biological norms	Buffaloes	Cattle
	Body temp.	38.2-38.3	38.7-32.9
Arid	Resp. rate	27.0-23.0	30.0-35.0
30-33%	Pulse rate	38.0-43.0	48.0-56.0
	Body temp.	38.0-38.3	38.4-38.7
Humid	Resp. rate	21.0-29.0	26.0-34.0
82-85%	Pulse rate	37.0-44.0	56.0-66.0



Specific Norms of Biophysical Conditions of Life : Temp., Osmosis, pH. **and Hydrostatic pressure.**

Fig. 4. Intricate response of animal to the complex of environmental conditions to maintain the vital biophysical norms.

Fluctuations in the inputs of environmental energy result in shifts in values of the biological norms unless physiological efforts are carried out to stop fatal changes in any of these norms. The physiological efforts are triggered by sensors; thermal, external in skin and internal in the hypothalamus, Osmoreceptors (in the hypothalams), pressoreceptors-hydrostatic pressure of blood-in the carotid sinus and aortic arch and Sensors of O_2,CO_2 and acidity in the carotid body. pH? The sensory inpulses evoke relevant comprehensions,in the CNS with subsequent neural and neuroendocrine actions to adjust balance between rise or drop in any of that forms towards achievement of the best complement of norms.

Figure (5) illustrates the physiological and behavioral performance of the animal(mammals and birds) under hot enviromental conditions. It is clear in the figure that thermal energy input on the animal evokes several physiological events which involve shifts in the internal physical norms; thermal, osmosis, hydrostatic pressure and pH. Under such condition the thermal norm (body temp.)is affected by the quantity of stored heat in accordance with the equation of heat flow:-

$$A + M = D + S$$

A: absorbed heat from the environment surroudings (heat input), M: metabolic heat production, D: dissipated heat from the animal body, S: stored heat(excess non-dissipated heat causing rise of body temperature).

The high ambient temperature impairs heat dissipation through physical acualities of heat flow(radiation,and convection) consequently heat dissipation through water vaporization is called on, meanwhile metabolic heat production is hampered. There are wide difference between animals, species and breeds in the dilemma of coincidences and harmony of these intermingled pathways of reactions. Anyhow the animal has to be well equipped to direct the pace of each reaction to attain the most proper combination of the vital norms,that is the complementary adaptation to enviroment.

There are several options for this biological performance:

1) Reduction of heat production to equal the minimized heat dissipation(torpor and/or estivation), 2) Store of excess of heat production (rise of body temperature) by elevation of the threshold temperature for outbreak of water vaporization (increase of sweating and respiratory. water vaporization) to retain body water (lability of body temperature, a, heterothermy case), 3) Intensificating water vaporization through skin (surplus sweating)to maintain stable body temperature(ideal case of homeothermy,sweating hom.) humans are perfect for this case.

4) Intensificion of water vaporization from the respiratory system(in non-sweating and weak-sweating animals)by excess of ventilation (respir. rate X resp respir. depth) to maintain stable body temperation (resp. homeothermy). This excess of ventilation is apt to increase CO_2 dissipation from the body which disturbs H_2CO_3/HCO_3^- balance leading to kidney interference in repairing this disturbance.

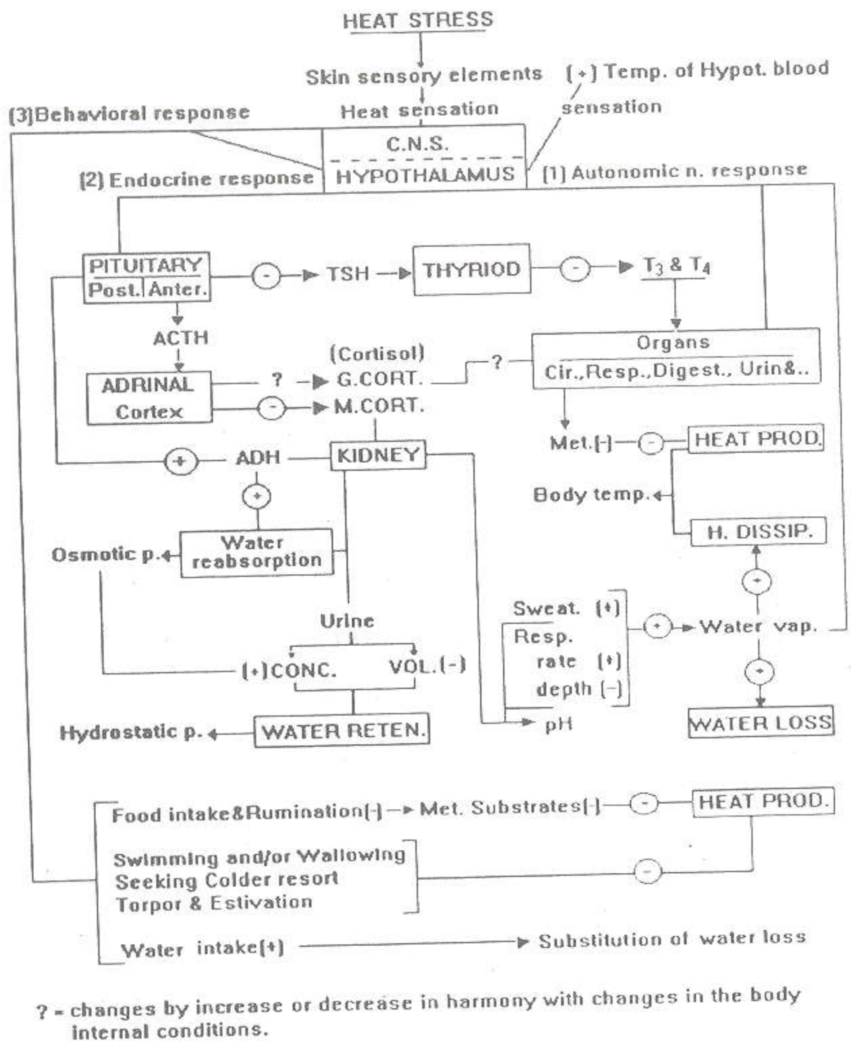


Fig. 5. Autonomic,endocrinological and behavioral responses of animals to environmental heat stress.

Each animal species and breed usually go through these options within limits more or less in each option through its nural and endocrinological systems in accordance with the most stressful environmental condition, i.e. temp., water restriction, lack of feed energy (lack and composition of feed resources).

The best adapted animal to a particular environment is that which succeed in lability of its phyical norms-within vital limits-in accordance with the conditions of that environment.

According to this concept the stability of thermal norm(body temperature,homeothermy)is not a true measure of successful adaptation since it could be achieved with severe interruption of one or more of the other norms. An index of combined levels of the complementary norms will be a more accurate measure of adaptation to diurnal fluctuations and seasonal changes in the environmental conditions.

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