THERMOREGULATION IN SNAKES

By: P. Schiereck, Physiological Laboratory,
Vondellaan 24, 3521 GG Utrecht, The Netherlands.

Contents: Introduction - Physical factors - Chemical factors - Behaviour and body temperature - Functional thermoregulation - Literature.

INTRODUCTION.

It is a classical misunderstanding to state that the body temperature of snakes is paasively following the temperature of the environment. Ectotherms are dependent upon heat sources from outside the body. However, new insights show that a differentiation has to be made between body temperature and that of the environment. The new view is that the physiological processes and behaviour in snakes are set by the body temperature and that this temperature differs from that of the environment. The question now is how the snake manages it. Especially, If we consider that for this animal the ratio between body mass and body surface is quite abnormal compared to other animals. With that surface the snake has thermal contact with its surrounding and its mass acts as a heat capacitor.
Actually, ectotherms produce heat. Metabolic processes within the cells, liberating energy for all sorts of things, such as movement, but also for keeping the cell alive, always produce a quantity of heat. In endotherms these processes have to produce much more heat to keep the body temperature at a high, constant level. Both types do exchange heat with the environment with regulatory mechanisms enabling snakes to optimally use the heat supplied from outside. In this context the deviating ratio between mass and surface seems to be silly. It seems that due to large surface contact

the snake is able to attain the temperature of the environment quickly. This is partially true. To gain more insight in the processes of thermoregulation it is essential to review some aspects of this regulation.

PHYSICAL FACTORS

Heat is energy that is simply exchangeable. This exchange is controlled by three factors:radiation, flow and conduction. In all these cases the magnitude of the surface at which the exchange takes place is important.
Radiation is transport of heat by space. The colour of the surface is also important differing between a black and a white surface.
Flow is transport of heat by means of transport of material. Its mean function is the velocity of heating up (or cooling down).
Conduction is the possibility of penetration of heat in matter. It sets the velocity of heating or cooling of matter.
In all cases heat is flowing from high to low.

CHEMICAL FACTORS

Heat production is next to what is radiated by the sun to the earth, the result of biochemical reactions in the body - metabolic processes - that ensure that cells are supplied enough energy to stay alive and carried out their jobs properly. In endotherms it is built up so that next to the processes mentioned above, a regulatory system takes care of maintaining the body temperature at the prefered level. This typical system is absent in ectotherms. Using metabolic heat production the snake is able to regulate its body temperature actively, assisted by handy physiological processes. Muscle contraction and digestion produce a tremendous amount of heat. As the metabolic processes do not take care of a high body temperature, the production of biological matter in a year (growing, regeneration etc.) is much cheaper in snakes than in mammals and birds (Pough,1983).

BEHAVIOUR AND BODY TEMPERATURE

The preferred body temperature of the majority of snakes is between 28 and 34°C. If the snake does not have this temperature he will search for the place where this temperature prevails. Above 36°C he will look for shaded places. In spring and in autumn lower thermal preferenda are found, down to 20°C (Hirth & King, 1969). In these seasons the adaptation of the preferred temperature occurs under the influence of hormones. Three physical factors will effect the proces of looking for the right place. Owing to the elongated body part of the body can be in the cold water of a brooklet while the rest is on warm stones on the bank. The need to expose part of the body surface to heat exchange determines the behaviour of the snake in the microhabitats. There is great difference in heat exchange between a coiled or an extended snake. The snake can control its surface - mass ratio, and so attains its body temperature by behavioural changes. When the temperature of the environment deviates too high or too low from the prefered one, then they look for cooling underground or warming up under mounded leafs etc. It is reported that *Boa constrictor* can keep up a 7°C lower temperature compared to the environment by seeking out subterranean places that are cooler (McGinnis & Moore, 1969). Also limited nocturnal cooling can be got by retreating to subterranian shelters and leaf mounds (Johnson, 1972; Ruben, 1976). So a snake is enable to approach its temperature of preference. For normal variation in night- and day temperature in warmer areas (between 10° and 50°C) a snake is able to keep its body temperature between 28° and 30°C througout night and day. A few hours after sunrise the snake is warmed up quickly and subsequently its behaviour regulates the warming up/cooling effects (coiling, retreat in

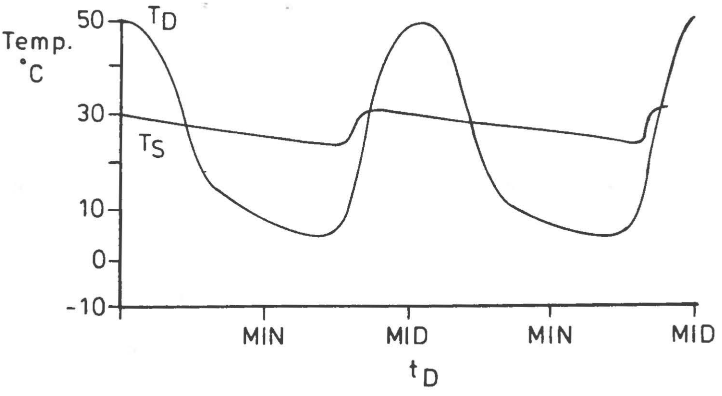

Figure 1: Schematic relation between the temperature of the environment (TD) and the temperature of the snake (TS), plotted versus the day- and night cycle. MIN = 24.00 h, MID = 12.00 h.

shelters, etc.). Figure 1 shows the day- and night variation in temperature in the snake and its environment schematically.

In moderate climates, where night temperatures can reach below 0oC, the differences in night and day temperatures are larger. By day the snake warms for a longer period to reach as much as possible its thermal preference. By night the snake is cooled, but can keep its temperature considerably above the environmental temperature (figure 2).

These measurements show that body temperature can deviate from the environmental one by means of specific behaviour. Thes measurements also show that

the warming up velocity is much larger than the cooling velocity. Conduction in the skin layers of the snake play an essential regulatory role. The results of the regulation of conduction of heat is that the snake can extend the period of prefered temperature. This conductivity regulation system is most effective in larger snakes. For snake less than 20 g in weight this mechanism does not work very well (Fraser & Crigg, 1984; Turner, 1987).
When the day temperature does not reach the prefered 28°C the snake does not get the opportunity to warm up to its thermal preference. Also the urge to sunbath decreases. Hormones are also involved in this process. The impulse to gain a certain temperature seems to be inversely related to the environmental temperature (Scott & Pettus, 1979).
In a hibernating snake a further decrease in temperature of the surrounding will lead to activity to find the place with the highest temperature in

Foto 1: *Python molurus bivittatus*, broedend, breeding, Foto J. v.d. Pols.

the den. These few degrees higher can be the difference between life and death. Survival at low temperatures, below the critical minimum, is possible for a limited period, while above the critical maximum lethality is much higher becaus of the disorder of biochemical and physiological processes, starting above 42°C. This is the same as in endotherms. Lower temperatures are better for survival. Lowe et al (1971) reported the possibility of escaping from the lethal effects of freezing by supercooling the entire body to as low as -7°C. This is several degrees below the freezing point of body tissue, which is about -0.6°C (Llowe et al, 1971). When the snake is leaving the den in spring the difference between the existing and prefered temperature will be large. The impulse to gain a higher body temperature therefore will lead to a fast and better function of activies resulting in propagation.

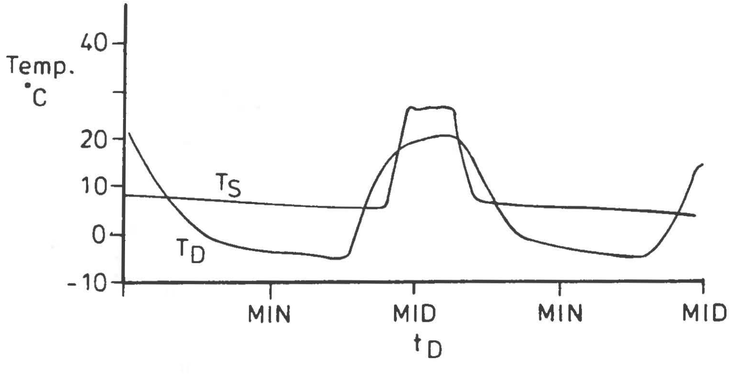

Figure 2: Same as in figure 1, however in a moderate climate zone.

Food intake can also lead to a higher body temperature. Saint Girons (1975) showed that in vipers digestive hyperthermia was proportional to the size of the prey. It suggests receptors that can record the mechanical activity of the gastro - intestinal tract. This knowledge is very new and it is evident that sophisticated telemetrical recording techniques have to be used. Experiments with simple mercury thermometers and occasional readings are inadequate.

FUNCTIONAL THERMOREGULATION

In the introduction it was indicated that heat exchange with the environment (via radiation, flow and conduction) the ratio between surface and mass is an important factor. Variation of this ratio influences the exchange. The conduction of heat through the skin layers, in which the blood circulation is the transport system (flow) is the next step in this regulation of heat exchange. The effectivity of the warming up period will depend upon the heat conductance from outside to inside and the cooling period from the opposite. We have already learned that the conductance velocity in warming up is larger than that in cooling. The reason for this is that the rheologocal properties of the blood depend upon temperature. In warming up the viscosity of the blood decreases. The blood flows faster and so heat. With a lowering of the temperature viscosity increases and the blood flow slows and the exchange with the environment decreases. Also variation in vascular diameter gives the opportunity to use the blood as effective heat transporter under the very skin.
Webb & Heatwhole (1971) showed that in *Morelia spilotes* exposed to equable warming up, firstly the head was brought to the prefered temperature and after that the rest of the body. In the case of transient warming up both head and body warmed up simultaneously. Also when the head has warmed up the body temperature increased too, even when not exposed to a warmer environment. Generally is seems that the thermoregulation of the head is a more precize affair that that of the body. There are always differences in temperature between head and body,

the circulation controlling this (Webb & Heatwhole, 1971). Johnson (1975) showed that in the taipan (*Oxyuranus scutellatus*) the temperature of the head was more constant than that of the body. The differences between head and body could be 6°C.
When snakes live in groups together and make use of the same den for hibernating or at night the ratio between surface and mass can decrease subtantially. White & Lasiewski (1971) calculated that in a group of 150 rattlesnakes in one den the temperature of the snakes can be up to 15°C above the environment assuming a surface mass reduction of 40% and estimated fat consumption. They used older observations of Benedict (1932). If this is realistic is on doubt but combined effects of metabolic heat and surface reduction offers opportunities. Generally the temperature of the snake is above that of the environment. Much research has been carried out on pythons and boa's. Cogger & Holmes (1960) showed that pythons can keep their body temperature 5 to 12°C above the environment even as a bright night in the open air. It is not concerned with the metabolic heat in endotherms but with variations in surface and decreased conduction. Also the effect of muscle contraction is important: shivering of the snake. In brooding pythons (*Python molurus bivittatus*) V Mierop & Barnard (1976) showed that the snake is attempting to keep the temperature of the eggs at 33°C decrease in temperature of the surrounding increases the frequency of the contractions. This is also found in the oxygen consumption. Through this mechanism the snake can ccpmpensate for a differnce of 8°C (see figure 3). In such a situation the snake uses 20 times more oxygen than a non brooding snake under similar circumstances (Harlow & Crigg, 1984).
In viviparous snakes it has been shown in females of different species (*Crotallus viridis lutosus*: Hirth & King (1969); *Thamnophis sirtalis*: Steward, 1975) body temperature is about 2°C higher

than in males. The question rises if this is because they are viviparous or because they are pregnant and have to produce more biological mass than males.

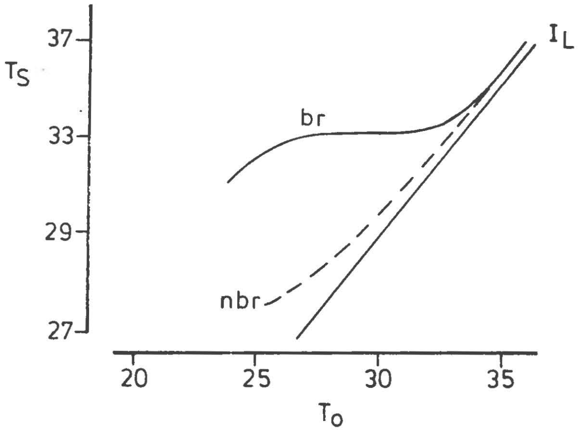

Figure 3: Relation between the temperature of the snake Ts (*Python molurus bivittatus*) and the temperature of the environment To. The line IL is the identity line. The dashed curve (nbr) is the relation in a non brooding snake, the curve (br) is the relation in a brooding python. (adopted from v Mierop & Barnard, 1976).

The activity of muscles is strongly dependent upon temperature. Not only the metabolic processes, but also processes as shortening velocity, stimulation rate are restricted to an optimal temperature (Bennett, 1984). On the other hand more muscle contractions have their impact on body temperature. Because snakes are peculiar animals in terms of thermoregulation: variation in surface - mass ratio, in size and ecology, it is very interesting to study the thermoregulation in these animals. As mentioned above it makes high demands upon research. Large variation in observations of which the origin is unknown, obscure the unambiguous interpretaion of the results. It is evident that snakes react to different temperature in a specific manner. It is advisable to observe the behaviour of the snakes during changes in temperature as they occur when spots are switched on, or the sun is shining into the terrarium. It will give you an insight into the way your snakes enjoy their environment (or not).

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