Changes in Dermal Reflectance and Vascularity and Their Effects on Thermoregulation in Amphibolurus nuchalis (Reptilia: Agamidae)

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Summary. 1. The contributions made by changes in dermal reflectance and dermal vascularity to temperature regulation have been studied in the agamid lizard Amphibolurus nuchalis with the use of $^{85}$Kr and $^{133}$Xe.

2. Skin reflectivity varied directly with the body temperature, increasing at elevated body temperatures which decreased the rate of absorption of radiant energy. Decreases in body temperature below the preferred are accompanied by decreases in reflectance which increase the rate of absorption of radiant energy.

3. Subcutaneous blood flow varied directly with the body temperature when measured under conditions of thermal stability. This temperature-dependent increase in dermal blood flow is interpreted as a mechanism facilitating the transfer of heat between the core and the periphery of the animal.

4. Peripheral blood vessels demonstrate the capacity to autoregulate and may dilate during basking as a result of local heating, facilitating the increase in dermal blood flow.

5. Dead α-MSH-injected animals heated at a faster rate than dead hypophysectomised animals, suggesting that local heating of the skin due to low reflectance is a major factor responsible for increased subcutaneous blood flow during heating.

Introduction

The observation that dark-coloured bodies heat at a faster rate than light-coloured bodies is a truism derived from simple physical principles. The rate of absorption of radiant energy is slower in the lighter-coloured body where the reflectance is greater.

This concept has been readily applied to the question of the biological significance of reptilian colour change. Atsatt in 1939 observed different lizards over a range of temperatures and noted their colour. Invariably light colours were associated with high body temperatures. It was assumed that these colour changes facilitated temperature regulation in reptiles by modifying the radiant energy absorption rate. Similar suggestions were forwarded by Cole (1943) and Bogert (1959) and have been elaborated by Norris (1967), Porter (1967) and Pearson (1977). Cowles (1958) was one of the first to appreciate that changes in subcutaneous blood flow may also play an adaptive rôle in reptilian thermoregulation, although the techniques at his disposal did not enable him to marshal unassailable experimental evidence to support his contention.

Studies on rates of heating and cooling of lizards in which marked hysteresis has been found (Bartholomew and Tucker, 1963, 1964; Weathers, 1970) point to the existence of temperature-dependent changes in blood flow through the periphery. Morgareidge and White (1969b) used the $^{133}$Xe clearance technique to measure dermal blood flow and presented evidence for changes emanating from local heating of the skin; furthermore, they showed that these responses bear no direct relationship to either heart rate, core temperature or temperature of the portion of skin other than that undergoing heat flux.

Weathers (1971) further confirmed and extended these findings in his study of Dipsosaurus dorsalis, suggesting that local changes in subcutaneous blood flow are a direct result of heat on the vascular smooth muscle. Baker et al. (1972) presented evidence to suggest that the peripheral circulatory response to local heating is dependent on the thermal load. They also demonstrated that although heart rate did not increase during local heating, cutaneous vasodilatation is associated with an increase in dorsal aorta blood flow.

Abbreviations: α-MSH, melanophore stimulating hormone; SBF, subcutaneous blood flow
They propose two ways by which this increased dorsal aorta blood flow could occur in the absence of an increased heart rate: (i) increased right-left intracardiac shunt, and (ii) a decreased resistance of the area undergoing heat flux which could divert blood away from areas of higher resistance. Baker et al. (1972) summarise their study in the statement “control over heat transfer in lizards would appear to depend upon selective distribution of blood flow between shell and core”.

The majority of studies concerned with rates of heating and cooling have employed constant temperature chambers for heating, where the primary modes of heat transfer are by convection and long wave length radiation, e.g. Bartholomew and Tucker (1963, 1964) and Weathers (1970); and by conduction in the case of the water baths used by Bartholomew and Lasiewski (1965). Changes in the colour of the skin should have little effect on the rate of heating under these conditions (Bartholomew and Tucker, 1963). However, in those studies where incandescent heat lamps have been used (Weathers, 1971; Baker et al., 1972), changes in dermal reflectance could alter the rate of heating.

Pearson (1977) quantified the change of reflectance that occurs on heating in the lizard Liolaemus multiflorum and found a linear increase in reflectance with body temperature. In an attempt to estimate the contribution that reflectance changes made to thermoregulation he physically changed the reflectance by spray-painting lizards black or silver. Black lizards were observed to heat faster than silver-painted or normal lizards. This approach, although suggestive, does not unequivocally establish the contribution that reflectance changes made to thermoregulation. To demonstrate unequivocally the effects of reflectance changes on thermoregulation it is necessary to separate the contributions due to changes in both dermal reflectance and dermal vascularity. The present investigation was addressed to this problem.

A lizard particularly suited for this study is the agamid lizard Amphibolurus nuchalis (formerly A. inermis). Its temperature regulatory behaviour has been documented in detail (Bradshaw and Main, 1968; Heatwole, 1970) and it undergoes marked changes in colour with body temperature change. By simultaneously measuring changes in dermal vascularity and dermal reflectance we have attempted to assess the relative importance of these two factors in determining rates of heat gain and heat loss of this lizard. The results presented here suggest that changes in dermal reflectance are of considerable significance in reptilian thermoregulation.

Materials and Methods

Capture and Maintenance of Animals

Amphibolurus nuchalis were caught at Shark Bay (26°04’ S Lat., 114°11’ E Long), approximately 900 km north of Perth, Western Australia, in February 1976. They were maintained in an indoor terrarium (95 x 40 x 44 cm) and fed at least twice weekly on a diet of arthropods (mainly Tenebrio larvae, termites and Drosophila melanogaster). Water was provided ad libitum and the lizards were exposed to a 10L/14D photoperiod. Heat was supplied by a 250 W incandescent heat lamp. Their mean body weight was 23.4 g (range 14.7–52.6 g).

Heating and Cooling Regimes

Body temperature, skin temperature, heart rate and reflectance were measured in control animals, in animals injected with melanophore stimulating hormone (α-MSH) and hypophysectomised lizards during heating from 20 to 40 °C and during cooling from 40 to 20 °C.

Animals were secured to a perspex platform and left for 15–30 min to attain thermal equilibrium. On reaching a body temperature of 23.4 ± 0.36 °C an incandescent heat lamp, positioned 40 cm above the animal, was illuminating for 40–60 min. On attaining thermal equilibrium (about 40 °C) the heat lamp was turned off and temperatures and heart rate (see below) were monitored for a further 40–60 min during cooling.

Body and Skin Temperature Measurements

Body temperatures were measured with a thermistor probe (No. 402, Yellow Springs Instrument Company, Yellow Springs, Ohio, U.S.A.) inserted through the cloaca and 1 to 1.5 cm into the rectum. Subcutaneous temperature was measured with a YSI needle thermistor (21G) inserted beneath the dorsal skin 1 cm from the mid-line, mid-way between the pectoral and pelvic girdles. Both temperatures were monitored by a YSI eleven-channel scanning telethermometer (Model 47) and recorded on a YSI single-channel laboratory recorder (Model 80A).

Shielding experiments followed the protocol outlined by Morgareidge and White (1969b). Rates of change in body temperature during heating and cooling were also measured under conditions of constant temperature, using the procedure outlined by Weathers (1971).

As we are only concerned with one primary mode of heating in the analysis of reflectance change effects under conditions of free radiant heating, and not with generating an “energy budget” statement (Bakken, 1976), we have chosen to express the data in terms of instantaneous rates of temperature change at 30 °C (IRt30). This also allows comparison with previous heating and cooling data.

Measurement of Subcutaneous Blood Flow

A method similar to that of Morgareidge and White (1969a) was used to measure subcutaneous blood flow (SBF). Both radioactive Krypton (51Kr) and Xenon (133Xe) at a concentration of 1 mCi ml⁻¹ in 0.9% NaCl, containing no bacteriocide, were supplied from the Radiochemical Centre, Amersham, England, in 10 ml multidose syringes. The handling technique was as described by Abdel-Dayem (1972).