

SHORT COMMUNICATIONS

SUN-BATHING AS A THERMO-REGULATORY AID IN BIRDS

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In their study of the Roadrunner (*Geococcyx californianus*), Ohmart and Lasiewski (1971) provided another example of a bird that supplements endothermy with absorption of solar radiation at low air temperatures, but they did not give an entirely convincing proof of a heliothermic function for sun-bathing per se. To do so, they would have to show a difference between sun-bathing and normally postured Roadrunners under the same conditions of ambient temperature and insolation, e.g., a faster rate of warming from hypothermia or a lower rate of metabolism for sunning birds. Other birds utilize solar radiation and thereby reduce their energy expenditure

for thermoregulation in cold air without resorting to a special sun-bathing posture (Hamilton and Heppner 1967; Lustick 1969, 1971; Heppner 1970).

Ohmart and Lasiewski never observed their Roadrunners sun-bathing when the ambient temperature was above the birds' lower critical temperature, but many birds do sun-bathe at high ambient temperatures. I had this fact dramatically brought to my attention during a visit to the Los Angeles Zoo on 18 August 1969. Shortly after 16:00, the slanting rays of the midafternoon sun began to penetrate through the sides of the roofed aviaries. There was a sudden explosion of sun-bathing activity by a wide

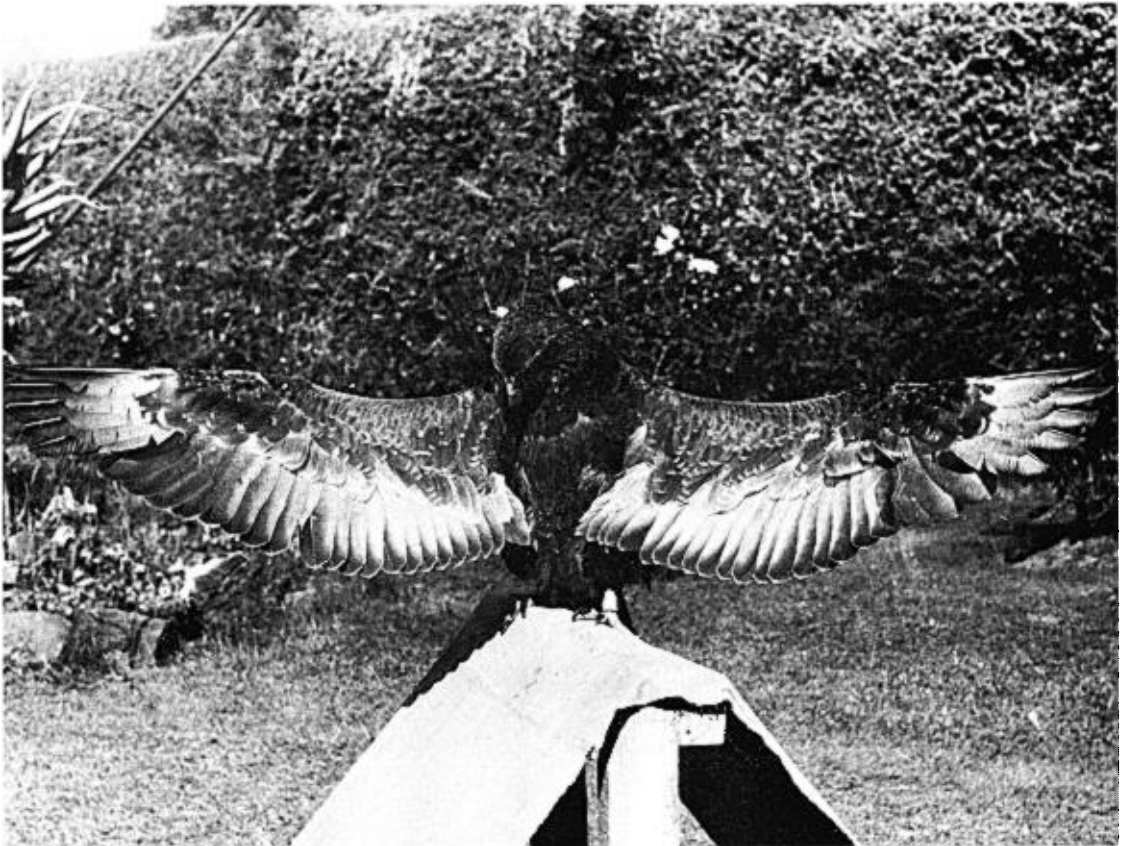


FIGURE 1A. A 2-year old Bateleur (*Terathopius ecaudatus*) sunning in natural light on a hot January afternoon in the austral summer, Pretoria, South Africa, 1966. Note, the Bateleur always suns facing the source of light with its head down, its rump and leg feathers fluffed out, and its wings locked into a position so that the under surface is perpendicular to the plane of the incident radiation.

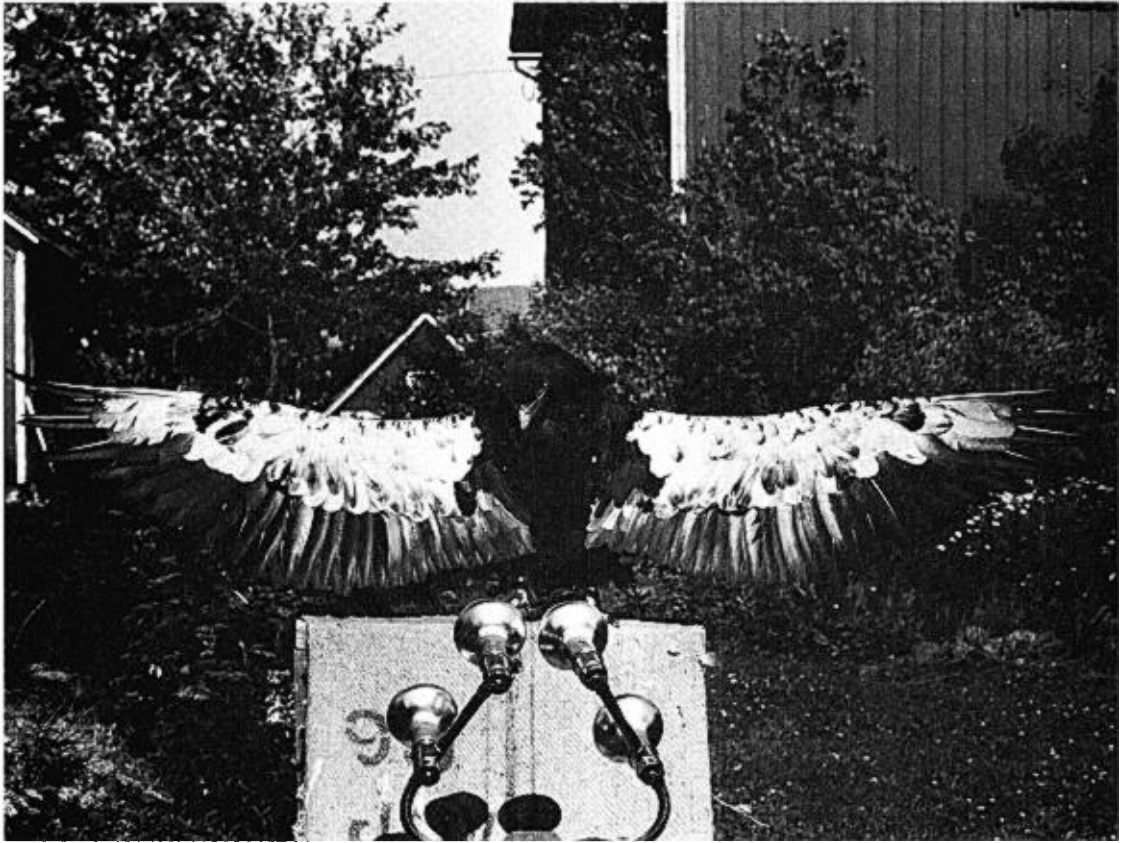


FIGURE 1B. The same bird in 1970 sunning before photo-flood lamps on a hot July afternoon near Ithaca, New York. Compare with the Openbill Stork (*Anastomus oscitans*) in figure 2, p. 717 of Kahl's (1971) account.

variety of birds, including large falconiforms, a King Vulture (*Sarcoramphus papa*), a White-backed Vulture (*Gyps africanus*), and a Bald Eagle (*Haliaeetus leucocephalus*) each weighing several kilograms, by several species of parrots (Psittaciformes), toucans (Piciformes), hornbills (Coraciiformes), doves and pigeons (Columbiformes), herons (Ciconiiformes), tropical American jays and a magpie (Corvidae), and other passerines. Six weather stations around Griffith Park reported maximum air temperatures of 30°–35°C for this day (Climatological Data 1969), indicating that at the time of my observations most of these birds must have been well within their zones of thermoneutrality and were perhaps approaching their upper critical temperatures in some cases.

The stimulus situation in these zoo cages was similar to the natural occurrence of a sudden change from shade to bright sunlight, as when an obscuring cloud moves out of the sun's path or when the sun first appears above the horizon in the morning. Both are situations associated with spates of sunning by birds in nature (Kennedy 1969; Kahl 1971; Cade, unpubl. field notes).

My captive Bateleur Eagles (*Terathopus ecaudatus*) from South Africa continue to sun-bathe in a species-typical, spread-wing posture long after they become hyperthermic and must pant heavily to cool (fig. 1). Many of the birds at the Los Angeles Zoo also panted while sunning. Such behavior is inconsistent with a heat-absorbing function for sun-bathing. Nor can it have a cooling function when birds face the sun.

Sun-bathing has been described for more than 170 species of birds distributed in 48 families or subfamilies and in most avian orders (Kennedy 1969). While a heating function can be inferred for the Roadrunner and some other species, the White-crowned Sparrow (*Zonotrichia leucophrys*) (Morton 1967), mousebirds (Coliiformes), and the Pygmy Falcon (*Polihierax semitorquatus*) in the Kalahari Desert (Cade, unpubl. field notes), it would be a mistake to conclude that sun-bathing is mainly or only a thermoregulatory mechanism. Several unexplained aspects of sun-bathing do not fit this assumption: (a) the compulsive or reflexive character of the response under strongly stimulating conditions even when the bird is overheated; (b) the apparent trance-like condition of sunning birds; and (c) the puzzling differences in posture and orientation to the sun among taxonomic groups of birds.

Mueller (1972) has recently expressed similar reservations about the thermoregulatory value of sun-bathing, based on the responses of captive Broad-winged Hawks (*Buteo platypterus*) to white and red light sources with different intensities of brightness but approximately equal intensities of total radiant energy.

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CYTOLOGICAL AND CHEMICAL ADAPTATIONS OF FAT DEPOSITION IN MIGRATORY BIRDS

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INTRODUCTION

Over the past three decades, numerous anatomical and physiological adaptations have been investigated as they might relate to energetics of protracted avian flights. Most migratory species experience conspicuous biennial weight increases as the result of fat deposition prior to their flights, with the major fat depots being in subcutaneous and abdominal regions. Control mechanisms for these seasonal cycles of fat deposition have been reviewed recently by Farner et al. (1968) and clearly implicate an adaptive hyperphagia which permits some small birds to complete vernal fat deposition in 6-10 days (King and Farner 1965; Odum and Perkinson 1951). All of these activities certainly maximize energy-rich fat depots at times of greatest energetic demands (protracted flights). Less well understood, however, are events transpiring at the cytological and biochemical levels as birds deposit fat, and the present paper is a contribution toward this understanding.

MATERIALS AND METHODS

Many of the birds utilized for the data introduced here were nocturnal casualties at the WCTV television tower near Tallahassee, Florida. Birds were also obtained from various localities in Florida, chiefly in the environs of Gainesville. For consistency, in most cases of fat analyses only the interfurcular fat pad (claviculo-coracoid of McGreal and Farner 1956) was used. Fat-pad volume was measured by liquid displacement in a graduated insulin syringe. Histological manipulations were initiated with either fresh or frozen adipose tissue; sectioning at 8 μ was followed by routine staining with hematoxylin and eosin. Chemical extractions of the fat began with dehydration in a vacuum oven at 55°C until weight loss was negligible. The dried fat was thoroughly pulverized in a tube-and-pestle homogenizer using chloroform-methanol (2:1) as a solvent. The nonfat, dry components were then separated from the dissolved lipids by double-filtration through Whatman No. 42 filter paper. Subsequent complete solvent evaporation permitted quantification of the purified fat or lipid extract. Triglyceride composition of the extract was determined by the method of Van Handel and Zilversmith (1957).

CYTOLOGICAL CHANGES IN ADIPOSE TISSUE

In 1964, Odum et al. proposed that ". . . fat is added to and used from preexisting tissue spaces [adipocyte vacuoles] without appreciable change in the water content or the nonfat dry weight of the body as a whole." Essentially, this proposition meant that fat bodies of birds can increase in size without an increase in adipocyte number. Subsequent analyses of several species have generally confirmed this "tank theory" (see Hicks 1967; King and Farner 1965; Helms et al. 1967), but among these investigations only Hicks made direct histological studies. His photomicrographs suggested that fat deposition in thrushes is accompanied by only a small increase in nonfat material but a significant increase in cell size.

Subsequent to Hicks' findings, Clark (1970) made extensive histological examinations of fat from a large number of Indigo Buntings (*Passerina cyanea*) in our Florida laboratories. The results, summarized in part in figures 1 and 2, show that (1) the interfurcular fat pad increased in weight at a constant rate with an increase in volume; (2) no significant variation in adipocyte numbers was detected in fat pads of a very wide range of volumes; (3) adipocyte numbers in a given high power field diminished in a curvilinear fashion as the fat pad volume increased; and (4) the mean adipocyte volume increased in a curvilinear fashion with an increase in fat pad volume.

These data are consistent with the concept of constancy in adipocyte numbers, and suggest a further, important energetic adaptation for a migratory bird. If a bird can "simply" add or remove lipid materials to and from pre-existing cells, it would essentially avoid the high energetic cost of a biennial production of new cells prior to migratory flights. At first, this cytological adaptation appeared to be unique to migratory birds, but the report by Ewing et al. (1970) on bats (genus *Myotis*) also indicates the probable capacity to fill pre-existing adipocytes without the construction of new cells. Migratory salmon, furthermore, very likely also have a reasonably constant adipocyte number (A. A. Benson, pers. comm.), despite seasonal increases in fat.

CHEMICAL COMPOSITION OF ADIPOSE TISSUE

Qualitative or quantitative composition of adipose tissue for feral birds has been treated by Walker (1964), Rosen (1966), Hicks (1967), King (1967), Hartman and Shorland (1968), Moss and Lough (1968), West and Meng (1968a,b), and Tanhuupaa and Pulliainen (1969). The Domestic Chicken (*Gal-*