TELEMETRY STUDIES OF THE INTERNAL BODY TEMPERATURES OF ADÉLIE AND EMPEROR PENGUINS AT CAPE CROZIER, ROSS ISLAND, ANTARCTICA

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HOMEOTHERMS of both tropical and polar regions are able to regulate internal temperatures only within certain environmental limits. Extension of these limits is possible only by physiological and/or behavioral adaptations that are often more conspicuous in species of very cold environments. Cape Crozier (Ross Island, Antarctica) is the extreme southern locality where comparative field studies of the Adélie (*Pygoscelis adeliae*) and Emperor (*Aptenodytes forsteri*) Penguins are possible. With emphasis on investigation of behavioral adaptations in temperature regulation, the internal body temperature was monitored and its variation studied during two austral summers of field studies, 1965–66 (Sladen et al., 1966) and 1966–67 (Boyd et al., 1967).

Previous investigators (Eklund, 1942; Goldsmith and Sladen, 1961; Prévost, 1961; Prévost and Sapin-Jaloustre, 1964; Mougin, 1966) had determined internal temperature values for these species, but our data present values of abdominal cavity temperatures monitored continuously during selected states of behavior. The study was aimed at further development of a biotelemetry system to monitor the physiology and behavior of unrestrained birds. In particular, such a technique might be employed to study the winter-nesting Emperor Penguins in 24-hour darkness and severe weather conditions, as they move around while incubating or brooding on the sea ice of the rookery.

Field investigations were carried out at the Adélie Penguin rookery (77° 26′ S, 169° 18′ E), 8 km northwest of Cape Crozier and 7 km west of the Emperor rookery. About 150,000 breeding pairs of Adélie Penguins are present in the main rookery in contrast to the 1,000 to 2,000 pairs of Emperors on the nearby sea ice. The Adélie rookery is part of the large ice-free area at the eastern tip of Ross Island and benefits from a northern exposure and frequent winds, keeping snow cover at a minimum. Nearby Mount Terror (altitude 3,230 m) and the lowered albedo of the dark exposed ground (in contrast to that of nearby ice fields and the Ross Ice Shelf) considerably affect the climate of the rookery. Our 1966–67 weather observations (Figure 1) were taken from the Jamesway hut (134 m elevation). Janetschek (1967: 215) gives a summary of the metereological conditions of Ross Island.

Most field work was done at a coastal site (27 m elevation) from a hut

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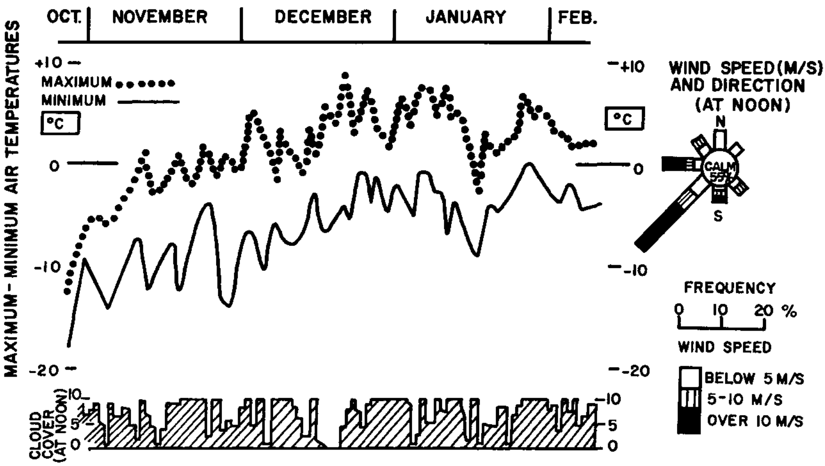

Figure 1. Weather observations at Wilson House (Jamesway), elevation 134 m, Cape Crozier, from 28 October 1966 to 7 February 1967.

surrounded by penguin colonies (Figure 2). Local screening by low hills to the west and by Mount Terror exposed birds to daily periods of shade, varying from 7 hours 20 minutes (9 November) to 34 minutes (23 December). Air temperatures and wind speeds were taken 40 cm above ground and at this site temperatures were 1° to 2°C warmer than at the Jamesway and the prevailing wind was southeasterly. Most experimental birds were kept in aluminum pens of 8 cm mesh—the Adélies on their nest sites and the Emperors on a snow field (after being flown over from their rookery by helicopter). Adults and the larger immature birds were flipper-banded (Sladen et al., 1968: 214). Nestling Adélie penguins were marked with plastic bands or tape.

The terrestrial ecology of the Adélie and Emperor Penguins is reviewed by Prévost and Sapin-Jaloustre (1965) and Stonehouse (1967) has summarized what little is known of their marine ecology. The ecology, behavior, and physiology of the Adélie Penguin are treated by Sladen (1953, 1958), Sapin-Jaloustre (1960), Taylor (1962), and in five articles in the recent monograph on Antarctic avian studies (Austin, 1968). Physiology and breeding behavior of the emperor are covered by Prévost (1961) and breeding behavior by Stonehouse (1953).

Methods

Conventional means of measuring internal body temperatures may reduce the usefulness of the measurements because of the animal's reactions to repeated human disturbance. Recent electronic developments have made the use of implanted telemeters practical for field experiments. Telemetry was first used for field studies of animals in the Antarctic in 1957 to determine egg temperatures of incubating Adélie

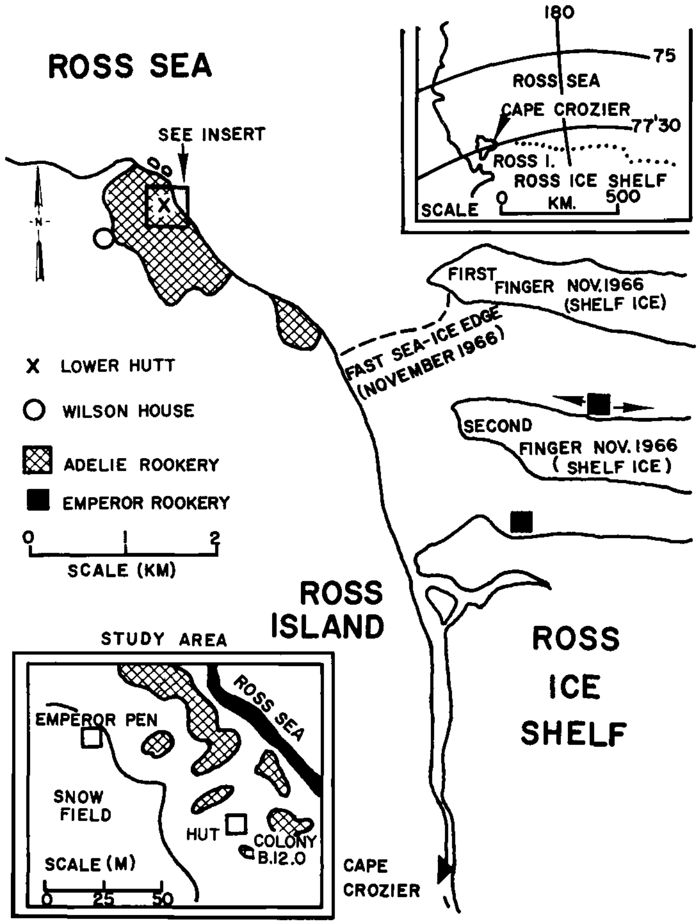

Figure 2. Cape Crozier, Ross Island, and the study area.

Penguins and South Polar Skuas (Eklund and Charlton, 1959). In 1965 preliminary work was done at Cape Crozier (Sladen et al., 1966) with telemeters implanted in both adult and chick Adélie Penguins, part of a system developed by Kenneth Bindle (University of Saskatchewan, Saskatoon, Canada).

The present telemetry system, designed and constructed under the supervision of Howard A. Baldwin (Sensory Systems Laboratory, Tucson, Arizona), was based upon implantable units measuring 3.7 × 1.5 × 1.8 cm and weighing 20 g. The transmitter had a pulsed signal (27 millicycles/sec), the rate of which was the inverse function of body temperature. Each telemeter was powered by two 1.5-v batteries in series (both silver oxide and mercury cells were used), with a practical life of 2–3 weeks, and the unit was encased in epoxy and urethane, with additional protection given the batteries by Silastic coating. Use of a crude receiving antenna was necessary after damage in high winds, and the range of the signal from an implanted telemeter in the abdominal cavity of a free-living bird was 9–12 m. A 14-channel receiver was connected to a digital counter that registered the signal pulse interval in milliseconds on a chart recorder. The receiver and the counter-recorder were housed in two field cases, each 37 × 15 × 15 cm and weighing 7.2 kg, and powered by nickel-cadmium rechargeable batteries.

Calibration curves were made between 35° and 41°C and observed temperature values were calculated from the fitted regression line of the individual telemeter. A change in resistance characteristics with time ("drifting") was noted in each telemeter, but this error could be controlled by choice of data soon after calibration. Maximum error in temperature determination occurred during field calibration, and total calculated error ranged between ± 0.13° and ± 0.24°C, depending upon the individual unit. Estimates of the 95 percentile confidence interval were made for (1) the whole calibration line of the individual unit for a given time period (the intervals ranging between ± 0.6° and ± 1.1°C depending upon the unit), and for (2) the mean "resting" abdominal temperature value of each bird (the intervals ranging between ± 0.1° and ± 0.2°C). The telemeter time constant, or response time, was 90 seconds—the time required by the telemeters to complete approximately two-thirds of a total change of 10°C (20° to 39°C) when shifted between two water baths. In the abdominal cavity it was assumed that the implanted telemeter and the encapsulating cyst formed around it were affected by changes in temperatures of the surrounding tissue much as a corresponding tissue mass in a similar situation (Mackay, 1968: 253). The similarity of such a mass to water cannot be assumed and the response time obtained in the water bath is reported only as a demonstrable characteristic of the system.

Thermistor probes (Yellow Springs Instrument Co.).—(1) Abdominal insertion (Model 421): internal body temperatures of nestling Adélie chicks were monitored by a probe inserted 3 cm abdominally, just posterior to the proventriculus, and sutured externally to the skin. (2) Proventricular insertion (Model 401): internal body temperatures of several birds were monitored by an insertion of 30 cm (Adélie adults) and 35–40 cm (Emperor adults). Average values were within 0.4°C of mean "resting" values obtained from telemeters. Control measurements were made with this probe during telemeter calibration. (3) Surface temperatures (Model 421): probes were attached by tape (5 mm wide) to the palmar surface of the flipper and to the acrotarsal surface of the foot.

Rectal thermometers.—Internal body temperatures of several birds were monitored by an insertion of 7–8 cm through the cloaca into the rectum. Rectal temperatures were recorded within a minute from experimental birds captured for periodic weighing—values were taken after at least 30 seconds of insertion, but within 1 minute of capture. In eight instances when simultaneous readings were taken, all rectal temperatures were within ± 0.3°C of the telemeter record. Observations were read from telethermometers (Yellow Springs Instrument Co., Models 41TD, 43TF and 43TK) and recorded continuously on a battery-powered potentiometer recorder (Instrument Corp. of America, Model 400).

Thermal stability and ease of telemeter implantation were major reasons for the choice of the abdominal cavity. Complex variation in thermal characteristics over the whole body force any representative internal body temperature to be a statistical abstraction. It was assumed that temperature measurement in a deep central area will approximate a meaningful estimate of internal body temperature most closely because these areas require a minimum of temperature variation in order to function correctly. The abdominal area probably approaches more closely a steady state condition of temperature. During the 1965–66 season both plastic dummy "telemeters" and actual telemeters were implanted at various sites. Fifteen autopsies indicated least complication and irritation from abdominal cavity implantation; subcutaneous sites, although better suited for data transmission (less signal attenuation), were more labile thermally than deeper locations.

Surgical procedure was uncomplicated and anesthesia was administered with halothane in an open system (plastic bag and cotton wad). Telemeters were implanted in the abdominal cavity through a 6-cm midline incision between the xiphisternum and the cloaca, and 15 postoperative autopsies or examinations under anesthesia showed formation of a simple fibrocollagenous capsule around the implant. Two adult Adélies autopsied had carried the implant for 1 year and had reestablished territories in the area where captured before implantation. One was incubating a single egg—significant evidence of recovery.

RESULTS

Data are presented from telemeters implanted in the abdominal cavities of three adult and two 5- to 7-week-old Adélie Penguins, and of two adult and one chick Emperor Penguins. Abdominal cavity temperatures, recorded by inserted thermistor probes, are reported from two 2- and 11-day-old Adélie chicks while they were under brooding adults. Specifics of these birds are listed in Table 1. Data were drawn from simultaneous sources: from a continuous chart recording of telemetered data and from notebooks of bird behavior, ambient conditions, and recorded pulse intervals of the telemeters.

Mean internal temperatures of "resting" birds.—For calculation the data were taken at intervals of not less than 15 minutes. An attempt was made to follow the guidelines of King and Farner (1961: 269); data were obtained from birds incubating, apparently asleep, or not noticeably disturbed within the preceding 30 minutes. Thermoneutral conditions were assumed to exist 40 cm above ground at air temperatures between −10° and +5°C and winds below 9 m/sec. Penned birds were not fed and data from the free-living individual were included when certain that the bird had not returned within the hour from the sea. Data from eight birds are summarized in Table 2.

Internal temperature variation associated with behavior and human disturbance—(1) Preening: an Adélie adult (AA1) maintained 37.8°C for 50 minutes after standing up and remaining quiet, ending a period of at least an hour in a prone resting position (ambient conditions: sunny, −06°C, calm). After starting to preen its temperature rose 0.5°C (37.8°C to 38.3°C) in 40 minutes; the bird then returned to a prone position, temperature dropping 0.3°C (38.3° to 38.0°C) in 15 minutes, and remaining at 38.0°C for 40 minutes.

(2) Breeding behavior: (a) Mating: no variation of abdominal temperatures was noted during or after mounting and copulation in five instances monitored from the Adélie adult AA1. (b) Nest relief: mon-

TABLE 1
EXPERIMENTAL BIRDS

No.	Species	Sex	Age	Plumage	Date of implantation	Conditions
AA1	Adélie	Male	Over 1 year	Adult	4 November	Incubating with mate at nest site in pen
AA2	Adélie	Female	Over 1 year	Adult	29 November	Incubating with mate at nest site in pen
AA3	Adélie	Male	Over 1 year	Adult	17 December	Incubating and brooding, free-living
AC1	Adélie	—	5 weeks	2nd down	23 January	Free-living except in pen for telemetry
AC2	Adélie	—	7 weeks	Juvenal	29 January	Free-living except in pen for telemetry
AC3	Adélie	—	2 days	1st down	6 January	(Thermistor probe), on nest, free-living
AC4	Adélie	—	11 days	1st down	8 January	(Thermistor probe), on nest, free-living
EA1	Emperor	—	Over 1 year	Adult	25 December	In pen on snowfield at Adélie rookery
EA2	Emperor	—	Over 1 year	Adult	30 December	In pen on snowfield at Adélie rookery
EC1	Emperor	—	3–4 months	Molt 2nd down	7 December	In pen on snowfield at Adélie rookery

TABLE 2
MEAN "RESTING" ABDOMINAL TEMPERATURES

No.	Mean (°C) and SE[1]	Range (°C)	No.	Kg	Date recorded	Ambient conditions[2]
Adélie Penguins						
AA1	38.4 ± 0.09	37.8–38.8	21	5.2	5 and 9 November	Cld cvr 10, –10 to –05°C, calm to 9 m/sec
AA2	38.5 ± 0.07	37.8–39.2	48	3.5	30 November–13 December	Cld cvr 5, –06 to +01°C, calm to 4.5 m/sec
AA3	39.4 ± 0.09	38.4–39.9	26	4.3	18–21 December	Cld cvr 5, –05 to +04°C, 2–7 m/sec
AC1	38.7 ± 0.03	38.6–39.2	10	2.3	26 January	Cld cvr 10, +03.5°C, calm
AC2	39.2 ± 0.07	39.1–39.2	12	3.3	31 January	Cld cvr 5, –04 to 0°C, 4–7 m/sec
Emperor Penguins						
EA1	38.4 ± 0.03	38.2–38.5	15	29.0	26–28 December	Cld cvr 10, –02 to +03°C, calm to 7 m/sec
EA2	38.7 ± 0.06	38.1–38.9	16	23.0	31 December–1 January	Cld cvr 10, –02 to 0°C, calm to light winds
EC1	38.7 ± 0.03	38.2–39.0	20	16.7	8 December	Light to heavy snow, –06 to –04°C, calm to light winds

[1] For calculation, data were taken at intervals of not less than 15 minutes.
[2] Ambient conditions were taken at the time of telemetry recording, and average conditions noted when several dates are given. "Cld cvr" is cloud covering (in tenths of visible sky). Air temperature and wind speed taken at the coastal study area (elevation 27 m) at 40 cm above ground surface, approximately 10 m from the birds.

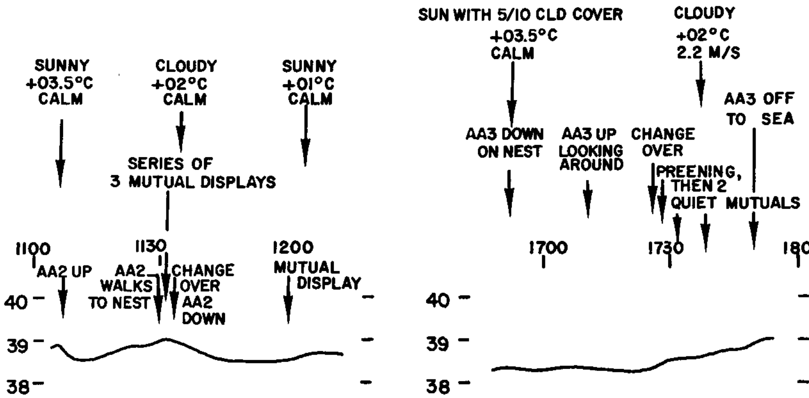

Figure 3. Left, abdominal body temperature of Adélie (AA2) during nest relief of an incubating mate. Right, abdominal body temperature of Adélie (AA3) when relieved from brooding by mate.

itored twice with a penned pair (Figure 3, left) and twice with a free-living pair. Maximum variation occurred with relief of the free-living male (AA3) brooding a 3-day chick, a rise of 0.6°C (38.3° to 38.9°C) in the 25 minutes following changeover (Figure 3, right) with AA3 preening and performing two mutual displays before going off toward the sea.

(3) Human disturbance: (a) Disturbance of a nearby investigator: a free-living bird (AA3) was suddenly awakened with no response noted. A penned Adélie (AA2) showed a rise of 0.4°C (38.3° to 38.7°C) in 20 minutes when visibly disturbed by the capture of an adult 2 m from the pen, the temperature response first detectable only 9 minutes after the incident. (b) Tail lift of nesting adult to observe eggs or chicks: no detectable response was noted in three cases after the incubating or brooding bird (AA3) had been lifted by the tail and then freed as it scrambled off the nest. (c) Brief handling to obtain rectal temperature and weight: an Adélie chick (AC1), after being held for 2 minutes, showed a rise of 0.4°C (38.7° to 39.1°C) in 20 minutes, the first response noted 8 minutes after capture. Abdominal temperature returned to 38.7°C 55 minutes after release. Another chick (AC2) exhibited no variation after being held 2 minutes. An adult Adélie (AA1) was twice handled for weighing during a 30-minute period, with much struggling (Figure 4). The apparent cumulative effect, after an initial 5 minutes of no detectable response, was a rise of 1.2°C (38.0° to 39.2°C) in 40 minutes. The bird remained up and the temperature averaged 39.0°C for the next 4 hours. (d) Prolonged handling: an Emperor chick (EC1) was dressed with a harness (while inside the hut with air temperature 15°C) and fixed with

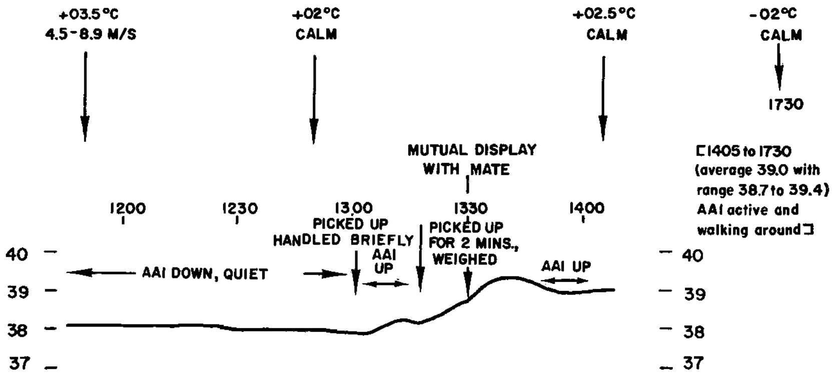

Figure 4. Abdominal body temperature of Adélie (AA1) when picked up twice and weighed.

thermistor probes subcutaneously in the palmar aspect of the right flipper. After 30 minutes it was released into a pen (air temperature –02°C). The abdominal temperature had risen 0.5°C (38.7° to 39.2°C) 55 minutes after capture and returned to 38.7°C only 2 hours after release.

Internal temperature variation in Adélie nestlings associated with exposure to the ambient.—Altricial Adélie chicks are heterothermic during their first 2 weeks (Sapin-Jaloustre, 1955: 67; Goldsmith and Sladen, 1961: 260; LeResche and Boyd, 1969: 88).

(1) Exposure of 2-day-old chick: AC3 (weight 115 g), alone under a brooding parent, was removed from the nest and placed on the ground. The abdominal temperature fell 10.7°C (37.2° to 26.5°C) in 20 minutes, then remained at 26.5°C for 10 minutes before dropping again. Shivering started 20 minutes after first exposure (abdominal temperature 29.0°C; surface temperature, flipper 11°C and foot 13.8°C) and the abdominal temperature continued to drop but both surface sites rose to 18°C after 10 more minutes of exposure (Figure 5).

(2) Competition for warmth between 2 brooded chicks: a 300-g chick was placed with AC3 (115 g) under the same adult and competition for space resulted in increased exposure for AC3. Its abdominal temperature fluctuated between 27.5 and 36.5°C (ambient conditions: shaded area, 0°C, calm). Surface temperatures from the flippers and feet maintained high levels (31° to 37°C) while still under cover of the adult.

(3) Exposure during nest relief: the abdominal temperature of a 625-g chick (AC4) dropped 6.7°C (36.2° to 29.5°C) in 9 minutes during nest relief. It remained near this level (27° to 30°C) for 35 minutes (while the adult was arranging the chick and itself on the nest) until premature probe removal. Ambient conditions were overcast, –03°C, calm. Under

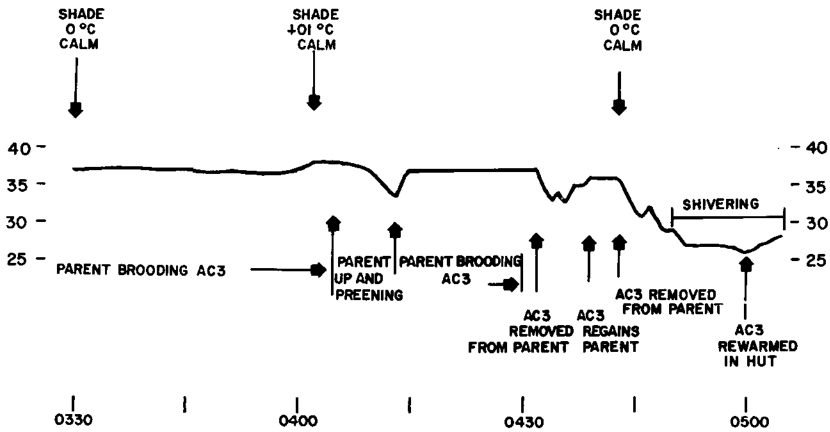

Figure 5. Abdominal body temperature of 2-day-old Adélie (AC3) when brooded and when removed from parent.

the parent surface temperatures of the extremities were sometimes within 2°C of abdominal levels, but dropped precipitously when the chick became exposed during nest relief. In 20 minutes the proximal flipper and foot temperatures fell from 36° and 37°C to 18.5° and 14.5°C, respectively. After 30 minutes of low brooding posture by the adult, surface temperatures at these sites had returned to 34°C (flipper) and 38°C (foot).

Discussion

An internal body temperature is necessarily dynamic—changing in space as well as time—and the first task of the investigator is to define which "body temperature" is to be monitored. Sophistication of instrumentation and more accurate realization of this temperature must be further defined by specification of method used and of site being sensed, season of the year, as well as activities of the animal and other factors.

Prévost (1961: 54) demonstrated that the internal temperature level is registered on the inserted rectal thermometer after an average of 1 minute of insertion under antarctic field conditions. Farner (1958) in a study of the Yellow-eyed Penguin (*Megadyptes antipodes*) gives evidence that internal temperature measured by rectal insertion, if completed approximately 1 minute after capture, was probably very close to the rectal temperature at the time of capture. Farner found that rectal temperature change was statistically significant after the bird had been held for 5 minutes; our data show a detectable change in the continuous record after 7 minutes at least. Our data from the proventricula of Adélie and Emperor Penguins approached closely the means from the abdominal telemeters, but birds with proventricular insertion, with probes strapped to the gape, appeared irritated by the wires. In addition, neither the exact position of the thermistor nor the nature of its surroundings (gas, liquids, or food particles) may be known. The swallowing of snow by an Adélie resulted in a drop 1.4°C (from 39.3° to 37.9°C) in 3 minutes in recorded proventricular temperature. The telemetry technique utilized provided a means of monitoring temperature variations at a thermally stable site, while noting simultaneous, apparently normal, behavior.

With data segregated by behavior an approach is made towards field determination of a "standard deep body temperature" (King and Farner, 1961: 269). Our telemetry data from fasting and incubating Adélie adults and data from the large sample of Prévost and Sapin-Jaloustre (1964: 76) differ by 0.1°C and the values from the older chicks and those reported by Prévost and Sapin-Jaloustre (1964: 76) and Mougin (1968) are within 0.7°C. Nestling Adélie Penguins showed considerable variation depending upon the age of the bird, the attentiveness of the parent (during early stages), and the ambient conditions, and ranged between 25° and 39°C in chicks monitored on the nest with adults. When the chick's weight has attained 0.5 kg or more, at least half the chick is exposed to the ambient. This situation arrives earlier when two chicks are brooded.

The tempered microenvironment encountered by experienced breeders in the center of a colony might be an important factor in the survival of very young chicks subjected to exposure either because of competition for space with a sibling or during nest relief of the parents. Guarding by the very young chicks of the radiative surfaces appeared in chicks only a day or two old, and when these chicks first sit erect, protected by the parent, at 7 to 10 days of age, they are able to cover the acrotarsal surface of the foot by assuming a posture commonly seen in adults: sitting upon the tarsometatarsal joint with feet raised up under the abdomen.

Prévost and Sapin-Jaloustre (1965: 611) reported that Emperor Penguins in enclosures at the Terre Adélie station registered mean rectal temperatures consistently above 38°C when studies were first started in 1952. They found later that rectal temperatures, when taken immediately from birds captured in the rookery, gave lower mean levels. As our studies were limited to birds in enclosures and with the added factors of a warmer climate than at their rookery and human disturbance, it is not surprising that our mean levels were 1.2° and 1.5°C higher than those from Prévost's rookery birds. The mean values for temperatures of older Emperor chicks agree with those given in Prévost (1961: 131).

Much of the data on internal temperature variation presented here was from two penned pairs of Adélies each incubating on a territory and, in contrast to the Emperor Penguins penned in an abnormal environment, there is no reason to believe that the penned situation affected their abdominal temperature readings. Abdominal temperature variation appears to be related to muscular activity: preening and nest relief with mutual display are followed by some response, whereas the act of mounting and copulating gave none (where the male's activity is mainly a rapid flipper movement of short duration). The studies of human disturbance show at least a 5-minute period after a bird is captured before any temperature response is evident, in agreement with Farner's suggestion (1958). After a struggling bird is handled continuously for several minutes or longer, its abdominal temperature may remain 1°C or more above precapture levels for as long as several hours after release.

The mean values proposed by different investigators using the three techniques seem to be in good agreement. As during both rectal and proventricular insertions the bird must always be restrained to some degree, these techniques are not suited for repeated use on the same individual. Implantation is rapid under anesthesia and human contact is kept to a minimum, but it involves surgical incision trauma and possible postoperative effects. The investigator must choose carefully depending upon the desired goal: implant telemetry is advisable for long-term studies of individuals, whereas the continuous record from proventricular insertion should be viewed primarily as a short-term method for controlled experiments. Technical and financial aspects of telemetry limits the number of individuals that can be monitored, and the results are less convincing statistically as a measure of the population. Rectal insertion with behavior noted just before capture enables the investigator to sample a larger number of individuals and gather data for seasonal comparisons of mean temperature levels.

Prévost (1961: 55) demonstrated several levels of mean rectal temperature from Emperor Penguins and Prévost and Sapin-Jaloustre (1964: 76) measured rectal temperatures of two Adélies sleeping in the rookery at 36.3° and 36.4°C. We found a mean abdominal temperature of a resting, fasting male to be 38.4°C in early November, in contrast to the 39.4°C level of a resting, brooding bird in late December. The marked overlap of mean "resting" values in both species, obtained by the same technique (Figure 6) but under varying conditions, emphasizes the problem of attempting comparative data. Both species apparently exhibit internal temperature variability of several degrees, which is not exceptional in birds (Stonehouse, 1967: 187), and the behavior of both species, their level of activity, varies seasonally. Prévost and Sapin-Jaloustre (1964: 68) emphasize that the lowest levels of the Emperor Penguin are

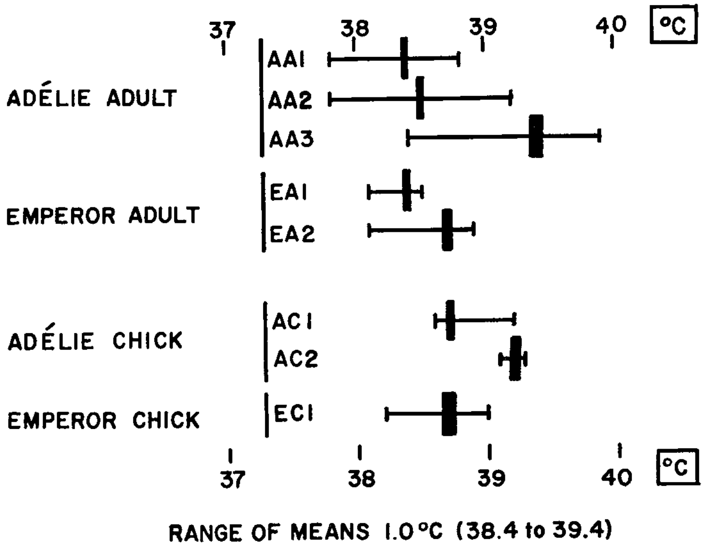

Figure 6. Mean values and ranges of abdominal body temperatures of "resting" Adélie and Emperor Penguins obtained by telemetry.

during the period of fasting. Our data from individual Adélie Penguins suggest a seasonal variation in body temperature levels for this species, apparently governed by marked activity levels at different periods during the terrestrial breeding cycle, though limitations must be placed on inferences from a few individuals to allow for variation between individuals. A recent study (Müller-Schwarze, 1968) shows a daily activity cycle in an Adélie rookery; our observations did not determine daily internal temperature cycles. Müller-Schwarze does describe differing circadian patterns at differing times during the breeding season, but makes no mention of differing activity levels. Our data may describe with the fasting Adélie a normal feature of lowered temperature in fasting homeotherms (King and Farner, 1961: 235). The variability is more pronounced in the winter-breeding Emperor Penguin, but the length of fasting and associated behavior appears more important than any climate-induced bioenergetic level. These variations are perhaps in concert with variation in metabolic rates and probably take the form of rising temperature values from the long fasting and incubation period to the active period of chick-raising.

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Summary

Field studies at Cape Crozier, Ross Island, Antarctica, concerned the internal temperature values of Adélie and Emperor Penguins. The most thermally stable area was considered the abdominal cavity and telemeters were implanted for remote monitoring of temperature levels from relatively unrestrained birds and, in one case, from a free-living individual.

Adélie adult means ranged from 38.4° to 39.4°C, depending upon the part of the season when monitored, and two chicks 5 and 7 weeks old averaged 38.7° and 39.2°C, respectively. Nestling chicks being brooded were monitored with thermistor probes; their abdominal temperatures varied between 25° and 39°C. Two Emperor adults had means of 38.4° and 38.7°C and an Emperor chick a mean of 38.7°C.

Short-term variations of abdominal temperature of over 1°C were monitored after human handling, but only after an initial period of at least 5 minutes after capture with no detectable response in monitored temperature. Telemetry is recommended for long-term studies of individual birds, whereas rectal thermometer measurements seem best for larger samples of the population. Evidence is presented of seasonal fluctuations in the mean internal body temperature of the Adélie Penguin.

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