reported. The resonance line of N at 1200 Å is blended with the far more intense Lyman-α line in our spectra and is not distinguishable therein.

Figure 4C also reveals the spectrum of the dark-side airglow bands, which are evident only in the oxygen resonance lines. In agreement with the OGO-IV spectrometric results of Barth and Schaffner (*3*), the ratio of the intensity at 1356 Å to that at 1304 Å is nearly unity in the equatorial night airglow, whereas it is much less than unity in the day airglow. The mechanism responsible for the equatorial airglow is still highly controversial, in that it must account not only for the abnormal intensity ratio of the oxygen lines but also for the lack of any other emissions (such as the Lyman-Birge-Hopfield bands of N_2) and for the localization in zones near the magnetic equator. The two mechanisms that seem to be the prime contenders are (i) O^+ recombination, by the processes

$$O^+ + e \rightarrow O(^5S, {}^3S) \quad (4) \quad (1)$$

$$O^+ + O^- \rightarrow O(^5S, {}^3S) + O \quad (5) \quad (2)$$

followed by radiative de-excitation to the ground (^3P) state of O, and (ii) excitation of O atoms by low-energy (about 10 ev) electrons, which would excite $O(^5S)$ to a larger extent, relative to the $O(^3S)$ and N_2 excited states, than the higher-energy auroral electrons or day-side photoelectrons (*2*). At present, the recombination mechanism seems most likely (*6*), although the phenomenon still cannot be regarded as well understood.

The results presented here have been necessarily preliminary and qualitative, as the detailed analysis of the images and spectra will require several months.

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Body Temperature of Dermochelys coriacea: Warm Turtle from Cold Water

Abstract. *The deep body temperature of a leatherback turtle,* Dermochelys coriacea, *taken out of cold water, was 18°C above the water temperature. A large size favoring heat retention from muscular activity is probably responsible for this differential. Cooling rates* (k) *in water, measured on a second animal, were in the order of 0.001°C per minute per degree of difference between body and ambient temperature.*

Leatherback turtles, *Dermochelys coriacea*, appear quite often along the coast of Canada and New England, especially at the end of the summer (*1*), yet they do not nest north of Florida. These northern appearances may reflect a regular migration, associated with feeding on jellyfish, rather than occasional stray animals (*1*). If this is so, it becomes of interest to know how these reptiles manage thermally in water of about 12°C (*1, 2*), some 15°C, below that at their nesting beaches (*3*). There are speculations that leatherbacks might be endothermic (*4*), and Mrosovsky and Pritchard (*3*) have predicted that leatherbacks could be 10° to 15°C above ambient temperatures in cold water. Unfortunately, due to their infrequent capture and poor survival in captivity and to the difficulty in handling such massive animals, opportunities for taking measurements on live specimens from cold water are very limited. We report here the first temperature data on leatherbacks kept in cold water; these indicate that this reptile is adapted to maintain its body temperature in northern seas as well as in the tropics.

The first animal studied, a male weighing 417 kg (920 pounds), with a straight-line carapace length of 156 cm, was entangled in a fishing net off Seaforth, Nova Scotia on 26 July 1971 and tethered in a tidal pool until the next day. On 27 July, it was transported to the Fisheries Research Board of Canada Laboratory at Halifax and placed in an indoor tank (3 by 3.7 m, water 1.1 m deep) for the next 24 hours. During this time fresh seawater from the bottom of the harbor was pumped through the aquarium at about 350 liter/min. The temperature of the tank containing the turtle was 7.5°C as measured by a telethermometer (Yellow Springs Instrument model 42 SC). The temperature of the input, monitored continuously (Honeywell Servoline recorder) for several years, virtually never varies more than 1.0°C in 24 hours, and runs 0.5° to 1.0°C cooler than the tank with the turtle. While it was in the tank the animal swam vigorously for long periods at about 40 strokes per minute, raising its head for breathing about two or three times per minute.

The turtle was lifted from the tank in a cargo net at 1600 hours on 28 July, placed plastron down on a cart, and then moved 100 m along a wharf, from which it was immediately transferred onto a wooden shipdeck. The animal lay on its carapace without struggling. From 1700 hours until its liberation at 1820 hours, the turtle was hosed several times with surface seawater (about 17°C) and kept covered with wet burlap. During the time the animal was outdoors before its release there was mild sunshine and some haze; air temperature was about 26°C.

Starting at 1615 hours, temperatures were taken to the nearest 0.25°C with a model 42 SC telethermometer, which was calibrated against ice water during the measurement period. The deep body temperature when first measured was 18°C above the water temperature of the tank from which the turtle had been taken (Table 1).

To assess the significance of this large temperature differential in these circumstances it is necessary to know something about how fast leatherback turtles can cool and warm. For this information we turn to data obtained on a second animal, in which it was possible to monitor temperatures of the animal while it was being cooled.

The second leatherback, a female weighing 134 kg (295 pounds), with a carapace length of 124 cm, was caught in a net on 17 October 1971, about 40 miles northwest of Key West, Florida. After being placed in an outdoor pool the turtle damaged its anterior flippers. From 19 October onward it was harnessed by a nylon net with a line running from the middorsal region to above the center of the pool; this prevented further impact with the walls but left the turtle free to make swimming movements. A blood sample was taken on 20 October. At 1030 hours on 23 October, the turtle with

its harness was transferred to a covered outdoor aquarium (5.6 by 2.4 m, 0.56-m depth of water). Water temperatures were taken with a mercury thermometer. A probe, used with a model 42 SC telethermometer, was inserted to a depth of 11.5 cm through a small hole made to one side of the midline at the summit of the carapace and was left in place thereafter. By this time the animal had been in captivity for 6 days and appeared relatively weak and quiet. Starting at 1130 hours the temperature of the water was lowered by adding some 3000 kg of ice over the next few hours. During cooling, the breathing and swimming rates were generally higher than they had been previously. At 1800 hours the turtle became inactive and died soon after (*5*).

Figure 1 shows the cooling curve for this animal. Calculations from various points in the curve gave cooling rates (k) of about 0.001° to 0.0017°C per minute per degree of difference between body and ambient temperature; for the last portion of the curve, when the environmental temperature was steady, k was 0.0015. Since the animal was not in northern waters when captured and died soon afterwards, unnatural patterns of blood circulation might have influenced the rates of heat loss. However, it is unlikely that the k values obtained were greatly affected on this account. Cooling rates of live and dead painted turtles, *Chrysemys picta*, differ only slightly (*6*). Moreover, the value of 0.0015 is consistent with those obtained by extrapolating various data from other aquatic reptiles (*3, 7*). A k of about 0.0015 for leatherbacks in water may therefore be accepted with reasonable confidence.

With this information we return to the first turtle, with a temperature 18°C above the ambient temperature after being 24 hours in cold water. Could this difference have been due to the animal warming up during the hour after being removed from the tank before it was possible to take the first reading? From the equation

$$y_t = y_0 e^{-kt} \quad (1)$$

where y_0 is the initial difference between the temperature of the animal and the environment and y_t is the difference at time t in minutes, it may be calculated that in an hour at a temperature of 26°C out of the water, even if the animal had started at as low as 7.5°C, it would have warmed up less than 2°C in this time. This calculation is conservative because our k values are for water. Moreover, the cloacal temperature was lower than the body temperature (Table 1). This provides evidence against the possibility that the high body temperature was due to heat transfer from the environment, because in that case the temperature of appendages like the tail would have been higher than that deep in the body. The deep body temperature was slightly lower after 2 hours; this suggests that, if anything, heat was being lost to the cooler periphery. Because the animal was inactive at this time a slight heat loss would be expected.

Table 1. Temperatures of a leatherback turtle. Because the tail was 34.5 cm long, the cloacal temperature was from a relatively superficial region. Body temperature was taken through a puncture made in the plastron over the heart for taking a blood sample. The temperature-sensitive tip of the probe was past the thick dermal layer and in the body cavity.

Time after removal from 7.5°C water (min)	Probe tip		Temperature (°C)
	Site	Depth (cm)	
15	Cloaca	14.5	16.75
60	Body	11.5	25.50
120	Cloaca	20.0	19.00
130	Body	11.5	24.75

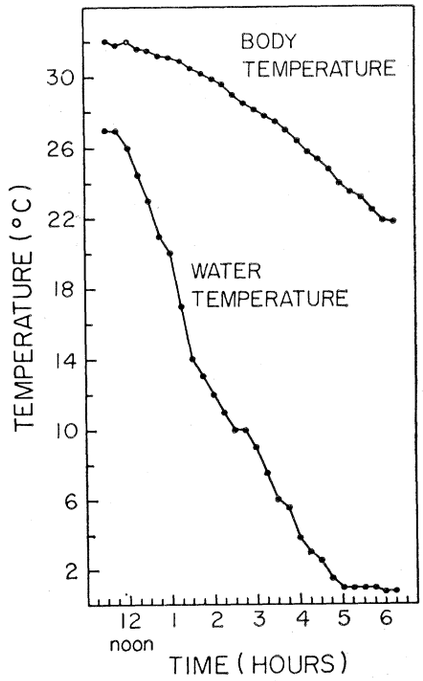

Fig. 1. Body and ambient temperatures for a leatherback turtle during cooling in water.

These points are consistent with several other examples of thermal inertia in large animals (*8, 9*).

With a large inertia another possibility is that the turtle had in some way become heated up before or during transport to the 7.5°C tank and that 24 hours had not been sufficient time for it to equilibrate. However, even if the turtle had in some way become as warm as 37.5°C, it may be calculated from Eq. 1 that, with a k of 0.0015, after 24 hours in 7.5°C water, its body temperature would have been only 11.0°C by passive cooling (*10*). If the turtle started at 37.5°C, then a k of 0.00035 would have been required for a drop to 25.5°C in 24 hours. However, both a starting temperature as high as 37.5°C and a k as low as 0.00035 are unlikely. Therefore, since the body temperature of 25.5°C cannot readily be attributed either to inadequate time to equilibrate or to warming up before the first temperature reading was taken, the high value must have been due largely to the turtle's having been able to maintain its temperature in the cold water.

The underlying mechanisms are probably heat production through muscular activity and heat retention aided by a large body mass. An Indian python weighing only 50 kg is capable of maintaining itself 7.3°C above the ambient temperature by muscular contractions at brooding time (*11*). Skipjack tuna, weighing 1.64 kg, are commonly 9°C warmer than their environment (*12*), and large bluefin tuna, 181 to 363 kg, can be as much as 21.5°C above the ambient temperature (*9*). The data for leatherbacks reported here and those from the tropics (*3*) show relations of body to ambient temperature that are similar to those of bluefin tuna (*9*). Countercurrent flows, like those in tuna, may also exist in leatherbacks, but thermal profiles of the major muscle masses would be required to substantiate this.

Reptiles in a cold atmosphere are able to maintain high body temperatures by using external sources of heat. When leatherbacks are in the ocean, their darkly pigmented dorsal surface should favor the absorption of solar radiation. However, for reptiles kept indoors in a cold environment, as in the present case, an 18°C differential between body and ambient temperature is spectacular.

It is possible that the activity of this turtle was partly stimulated by the con-

ditions of confinement as well as by the cold water. However, reports of leatherback turtles in temperate waters do not suggest that these animals are usually lethargic at sea (*1*, *2*). Although it remains possible that *Dermochelys* seen off Nova Scotia are carried out of their normal areas by the Gulf Stream (*13*), the smaller marine turtles are reported less frequently in northern waters (*1*, *14*). The thick, fibrous, oil-saturated layer below the epidermis might put the leatherback at some advantage over other marine turtles with respect to insulation. Thick peripheral layers are important in the thermal equilibrium of mammals such as seals and polar bears (*15*). These various considerations, taken together with the great temperature difference found here, suggest that large *Dermochelys* may be adapted thermally for existence in reasonably cold water.

Bogert (*13*) has pointed out that there is an upper limit in bulk beyond which behavioral means, such as moving into the sun, are inadequate for the regulation of body temperature because it will take too long for the animals to warm up. This limitation may have restricted the dinosaurs to uniformly warm climates and may be responsible for the fact that most large reptiles today are tropical (*13*). However, if regulation is achieved by muscular activity and some heat retention, rather than by behavioral means, then large bulk becomes an advantage. Our data show that the largest living turtle, *Dermochelys*, is indeed capable of maintaining a considerable differential between its body temperature and the ambient level in a situation where behavioral regulation is not possible. This finding is relevant to speculations about the thermal existence of large extinct reptiles (*16*) and the present distribution of *Dermochelys*. Now it would be interesting to know how long the leatherback turtle, with its periodic appearances in temperate waters, is capable of maintaining such differentials.

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Bone Resorbing Activity in Supernatant Fluid from Cultured Human Peripheral Blood Leukocytes

Abstract. *A new soluble mediator was found in supernatant fluid from cultures of human peripheral blood leukocytes that were stimulated by phytohemagglutinin, or by antigenic material present in human dental plaque deposits. This soluble factor produced bone resorption in organ cultures of fetal rat bones as measured by increased release of calcium-45, and also increased the number of active osteoclasts.*

The supernatants of stimulated leukocyte cultures contain soluble mediators with a variety of biological activities, which are secreted by activated lymphocytes (*1*). Antigens present in bacterial culture filtrates of organisms common to the oral cavity stimulate lymphocytes, from subjects with periodontal disease, to proliferate in vitro (*2*). We have established a direct correlation between the degree of in vitro reactivity of lymphocytes to antigens in dental plaque deposits (Ag) and the severity of periodontal disease. We have also shown that supernatants from human peripheral blood leukocyte cultures stimulated with Ag contain a mediator, lymphotoxin, which is toxic to human gingival fibroblasts (*3*). In periodontal disease, as in other types of chronic inflammation, bone is frequently resorbed in areas adjacent to inflammatory sites. We have now found that supernatants of leukocyte cultures stimulated by Ag or by phytohemagglutinin (PHA) induce osteoclastic resorption of fetal rat bone in organ cultures.

Replicate cultures of 2×10^6 peripheral blood leukocytes from four human subjects were established in a volume of 1 ml of Roswell Park Memorial Institute medium (RPMI) 1640 with 20 percent plasma, as previously described (*3*). Subjects A and D had destructive periodontal disease; subjects B and C had asymptomatic minimal gingivitis, as do most adults. Cultures were either unstimulated, or stimulated with an ultrasonicated solubilized fraction of pooled Ag or PHA (*4*) for 6 days at 37°C in a humidified atmosphere of 5 percent CO_2 in air. After the cultures were sedimented (200*g* at 22°C), the supernatants were aspirated, appropriately pooled, filtered (0.45-μm Millipore filter), and stored for up to 30 days at −20°C. The sedimented leukocytes were exposed to tritiated thymidine ([^{3}H]TdR) in order to measure the increase in DNA synthesis (*5*).

The technique for measuring bone resorption in organ culture has been described (*6*). Paired shafts of the radius or ulna of 19-day rat fetuses, labeled by injection of the mother with ^{45}Ca on the previous day, were incubated in 0.5 ml of medium at 37°C in an atmosphere of 5 percent CO_2 in air. One shaft was incubated in control medium (*7*); the other was incubated in test medium consisting of the super-