

Thermoregulation of the Polar Bear *Ursus maritimus*

(BB)

Examining two case studies:

- The effects of locomotion speed on metabolic rate and body temperature.
- 2. The polar bear pelt - an adaptation for increased solar radiation in an arctic environment
- 3. The heat balance equation as a reference.

Heat of Metabolism

- Main energetic problem for the polar bear is dissipating metabolic heat (Body-to-air temp. differentials of 100 C)
- Why do polar bears have this problem?

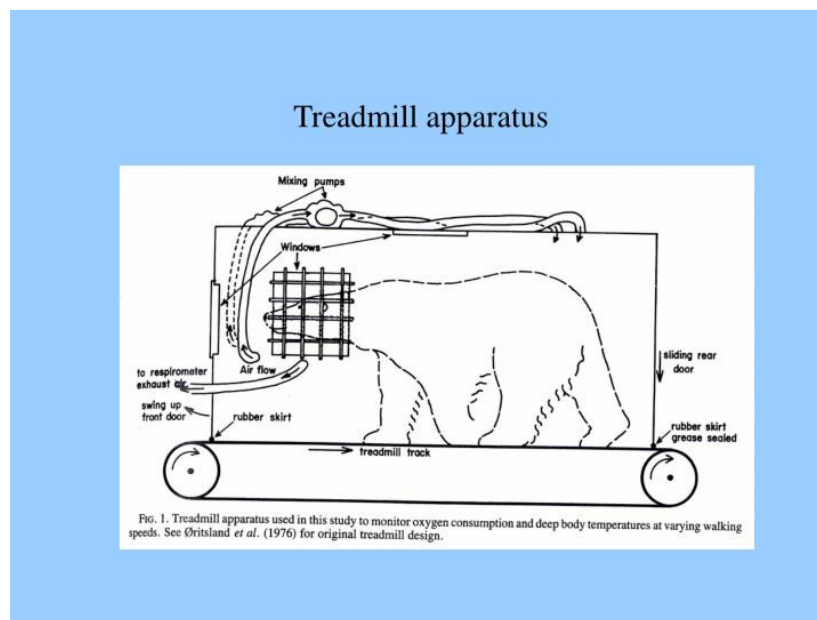
Physiological adaptations to cold environmental temperatures:

- Thick fur (although not as insulating as we might expect!)
- Blubber (up to 11 cm thick)
- Low surface area to volume ratio

Case study 1: Polar bear locomotion: body temperature and energetic cost.

- A study by Hurst et al. 1982 was interested in investigated the effect of polar bear locomotion on metabolic rate and core body temperature.

Treadmill apparatus



Materials and Methods

- Four walking speeds: 1.8, 3.6, 5.4, and 7.2 km/h
- 30 - 45 minute time intervals were used for actual experimental runs.
- Oxygen concentrations measured every 30 seconds from the start of each experiment until one hour after its completion.
- Deep body temperature recorded every 3 minutes, beginning at rest, 10 minutes before each experimental run and ending one hour afterwards.
- Ambient temperature for experiments ranged from -25° to 16°C.

Results: Oxygen consumption/Metabolism

- Rate of O₂ consumption increased significantly with increased walking speed.
- Figure indicates a positive, curvilinear relationship between locomotion speed and metabolic rate.

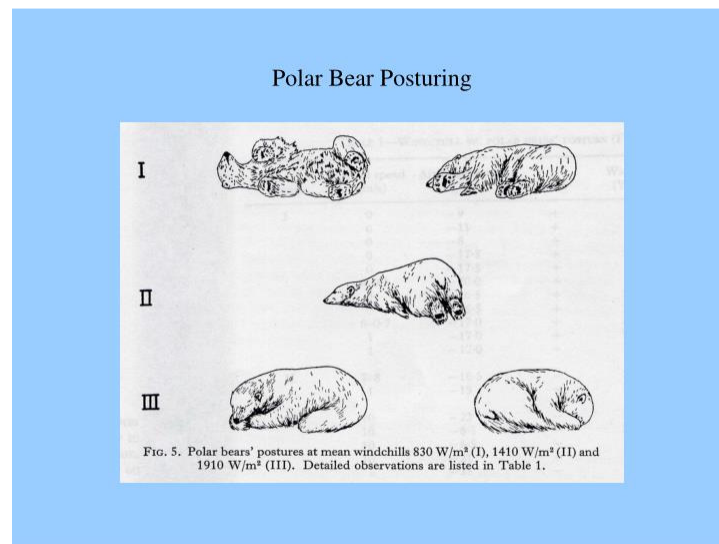
Results: Deep Body temperature • Mean resting deep body temperature before 28 independent experiments was 37.14°C. • Equilibrium deep body temperature increased exponentially with increased walking speed with core body temperature increasing to as high as 39.3°C.

Conclusions • Energetic cost of locomotion greater than predicted. • M.R. increased 2X the estimated value. • M.R. at 7.2 km/h was 13X basal M.R. • Rates of temp and M.R. increase reflected in behavior. • Susceptibility to overheating is mitigated by relatively sluggish locomotion (economics of transport) and limited hunting strategies. Implication • Such dramatic increases in body temperature and metabolic rate with increasing walking speed present potential health risks for polar bears. In combination with other thermal barriers--thick fur, blubber, and low surface area to volume ratio, steep increases in metabolic rate and temperature could cause thermal stress and hyperthermia, even at cool environmental temperatures. Thus, humans may be endangering polar bears during pursuit, especially during warmer, summer months.

Heat Loss • In order to combat heat gains during activity, polar bears utilize physiological and behaviorally adaptation for losing heat.

Increased Conductive and Convective Heat Loss • Polar bears have several adaptations to facilitate heat loss by conduction and convection. • Though thick, polar bear fur shows high thermal conductivity (i.e. loses heat rapidly). • They possess two semi-circular sheets of highly-vascularized, striated muscle in the latissimus region. • Polar bears will also assume different postures depending on the ambient temperature. • Polar bears swim.

Polar Bear Posturing



Solar radiation • Case study 2: Light collection and solar sensing through the polar bear pelt (Tributsch, 1990) • The investigation of several optical and physical properties of the polar bear pelt

Materials and Methods • Pelt samples (intact hair and skin) were taken from several European museums. • Scanning light microscopes to help measure the refractive index and wavelength of hair • UV-lasers that excite luminescent light particles trapped in the hair to measure heat production • Values were compared with those

found for the white hair of other animals. • Researchers built models to simulate how hair collects light via scattering and luminescence processes.

Physical properties of Polar Bear Hair • Translucent hairs scatter sun light within the hair core where it is either: • (a) reflected back to the environment or • (b) converted into luminescent light which produces heat. Cross sections of polar bear (A and B), pig (B and C), horse (D) and goat (E) hair.

Scattering

Two Courses for UV Light This is explained by asymmetry of hair properties, meaning that depending on the direction of light particles hitting the hair, it will produce different effects. • Scattered UV light entering near the hair base, perpendicular to the hair axis (60°-90°) becomes excited, produces luminescence and funnels heat toward the skin surface. • In contrast, light entering parallel (0°) to the hair axis tends to be absorbed at the hair ends and yields little heat by the time luminescent light reaches the base of the hair.

Form and Function Heat pump Coloration Thermoregulating System Orientation and Navigation

Heat Pump • Properties of the polar bear pelt appear to provide a unique balance between maintaining camouflage in the arctic environment and harnessing solar radiation to heat subcutaneous and skin surface layers. Although the pelt's "heat pump" feature does not appear to contribute to a substantial total body heat increase, it does the job of heating the peripheral skin surface that is in direct contact with cold ambient air. • Tributsch's hypothesis is supported by other experts that have indicated that bears suffer from cooling of peripheral tissues during cold ambient temperature. • Øritsland found that skin temperature varied between 25°C and 36°C with the coolest areas being the extremities (elbow, knee, wrist, and ankle area). • Subcutaneous-to-skin surface temperature measurements have shown differences as large as 10-14°C depending on wind chill.

Coloration • As stated, visible light is scattered from hair cores and reflected back into the environment, giving the pelt its mostly "white" appearance. • However, strong absorption of UV light accounts partly for the yellowish appearance of pelts and for the "black" appearance when photographed in UV light. • Polar bears appear more yellow during the summer due to greater intensity of solar radiation and thus greater UV absorption.

A complete thermoregulating system • The heat pump feature is only part of what appears to be a larger thermoregulating system--combining the heat dissipating function of the latissimus sheets and insulating features of their hair and black skin.

Mechanism for orientation and navigation • Tributsch's suggests that the pelt may also assist in orientation and navigation. The presence or absence of diffuse sun light has shown to have significant affect on skin surface temperatures. The sun's rays and their reflection off surrounding objects will create a temperature pattern on the skin which the bear can use to sense direction and sources of heat. • Skin surface temperature variation may have been the driving natural force for this mechanism.