Temperature Relations

- Altitude – temperatures are usually cooler at higher altitudes (10° / 1000m)
- Aspect – refers to the topography, hills and mountains
  - Creates shading which affects temperatures and moisture on north and south facing slopes
    - Affects species growing in an area
    - Affects flowering dates within a given species (up to a 6 day difference which corresponds to either 162 km northward difference or an increase in elevation of 180 m)
Temperature Relations

- Vegetation – can affect temperature in several ways:
  - Decreased soil heating (shading)
  - Soil absorbs heat, cooling the air around it
  - Transpiration – adds moisture to surrounding air making it harder to warm it
  - Radiation – inhibited by vegetation, causes warmer temperatures in vegetated areas
  - Moderates extreme variations in temperatures
Temperature Relations

Desert shrubs and microclimate.

- Soil surface in full sun heats to high temperatures.
- Shading of soil surface by low shrubs lowers maximum temperatures.
- A layer of leaf litter lowers maximum temperatures even more.
- Greater leaf area and numerous twigs of tall shrubs intercept more light, creating the coolest temperatures.

48°C in bare soil away from shrubs. 29°C in litter under low shrub. 27°C in soil under low shrub. 21°C in litter under tall shrub. 23°C in soil under tall shrub.
Temperature Relations

- **Color of the Ground – obvious**

  Color of the ground and temperature.

  - White sand reflects all wavelengths of visible light.
  - The same amount of solar energy heats up black beaches more than white beaches.
  - Black sand absorbs all wavelengths of visible light.

- **Boulders and Burrows**

  - The seashore isopod encounters substantially different temperatures over distances of a few centimeters.
  - Sun heats exposed surfaces of rocks to temperatures exceeding air temperature.
  - Shaded environments in crevices and under stones are cooler than on exposed rocks.
Temperature Relations

- Aquatic Temperatures – temperatures much more stable than on land because of:
  - High specific heat of water
  - High heat of vaporization
  - High heat of fusion

Aquatic microclimates.

Aquatic environments generally show less temperature variation than do terrestrial environments.

- Daily variation in air: 2.5°C-28°C
- Daily variation in an aquatic weed bed: 7°C-20°C
- Daily variation in a shallow riffle: 9°C-16°C
- Daily variation in a deep pool: 10°C-14°C
Temperature Relations

- **Temperature and Animal Performance**
  - Baldwin and Hochachka – studied trout at the molecular Level – functions of enzymes greatly affected

![Graph showing temperature relations with enzyme-substrate affinity](image)
Temperature Relations

- Studies of Reptiles

  - Angilletta studied fence lizards (Sceloporus undulatus) that live across a large range of geographic locations demonstrating a range of environmental conditions including temperature

    - Used lizards from New Jersey and South Carolina
    - Kept them at a range of temperatures (30°, 33°, and 36°)
    - Fed them crickets that he knew the average caloric content
    - Collected feces and uric acid and determined caloric content
    - Used this to determine metabolizable energy intake (MEI)

\[
\text{MEI} = C - F - U
\]

\[
C = \text{energy consumed (# crickets)}
\]

\[
F = \text{energy in feces}
\]

\[
U = \text{energy in uric acid}
\]
For both populations of lizards, metabolizable energy intake (MEI) was greatest at 33°C.
Temperature Relations

- Extreme Temperatures and Photosynthesis – typically the rate decreases with a decrease in temperature, but not all plants demonstrate the same optimal temperature.

![Graph showing the photosynthetic rate of a boreal moss and a desert shrub as a function of temperature. The boreal moss reaches its maximum at 15°C, while the desert shrub reaches its maximum at 44°C.](image)
Acclimation can also be observed (this is a physiological response not a genetic one) - seen in experiments using *Atriplex lentiformis*, desert shrub.
Temperature Relations

- **Temperature and Bacterial Activity** – also demonstrates a narrow range but can be extreme
  - **Psychrophilic** – cold loving
  
  ![Graph showing growth rate vs. temperature for psychrophilic bacteria. The rate is highest at approximately 4°C.]
  
  Rate of population growth by these antarctic bacteria was highest at approximately 4°C.
  
  Each point represents population size after 80 hours of incubation at a particular temperature.

- **Thermophilic** – heat loving
  
  ![Graph showing sulfur oxidation rate vs. temperature for thermophilic bacteria. The rate is highest at approximately 63°C.]
  
  Rate of sulfur oxidation by these bacteria from a 59°C hot spring was highest at approximately 63°C.
  
  Each point is an average of measurements made on three replicate bacterial cultures grown at a particular temperature.
Temperature Relations

- Balancing Heat Gain Against Heat Loss

Heat exchange between organisms and the environment.

- Heat gain by metabolism ($H_m$)
- Heat gain by radiation ($H_r$)
- Heat loss or gain by convection ($H_{cv}$)
- Heat loss or gain by evaporation of water ($H_e$)
- Heat loss or gain by conduction ($H_{cd}$)
Temperature Relations

Organisms can regulate their temperature in several ways:

Poikilotherms – temperature varies directly with the ambient temperature (cold-blooded)

Others can regulate their temps by varying:

\[ H_{cv}, H_r, H_e, \text{ and } H_m \]

Ectotherms – use external sources of energy

Endotherms – derive energy metabolically

Homeotherms – maintain a relatively constant temperature
Temperature Relations

- Temperature Regulation by Plants

  - Desert Plants – trick is to prevent overheating
    - Can’t use evaporation (?
    - Metabolic heat not important
      - \( H_s = H_{cd} +/- H_{cv} +/- H_r \)
        - Most of the plant is above ground < \( H_{cd} \)
        - Leaves small and spread out > \( H_{cv} \)
        - Leaves oriented parallel to the sun
        - Reflective surface on leaves such as hairs

Heat exchange between organisms and the environment.

- Heat gain by metabolism (\( H_m \))
- Heat gain by radiation (\( H_r \))
- Heat loss by radiation (\( H_r \))
- Heat loss or gain by convection (\( H_{cv} \))
- Heat loss or gain by evaporation of water (\( H_e \))
- Wind
- Heat loss or gain by conduction (\( H_{cd} \))
Temperature Relations

- Arctic/Alpine Plants – much the opposite of desert plants
  - > Hr heating by
    - Dark colors
    - Orient leave perpendicular to sun
    - Low mat type growth directly on the ground
  - < Hcv loss by
    - Being close to the ground decreasing the effects of the wind

Heat exchange by arctic and alpine cushion plants.

Growth form and temperature.

Temperature of willow, with its open growth form, closely matches air temperature.
The cushion plant heats to temperatures far above air temperature.
Temperature Relations

- **Tropical Alpine Plants** – must deal with little seasonal variation and great daily variation
  - Convergent evolution has produced rosette forms or grow in mats
  - Retain leaves for insulation
  - Pubescence acts as insulation
  - Leaves retain water
  - Leaves shaped like parabolic mirrors

- **Temperature Regulation by Ectothermic Animals**
  - Most use external sources of heat
  - Regulate much the same way as plants, but differ in that they can modify their behavior
Temperature Relations

- *Liolaemus* lizards – can live in very cold environments (Andes Mts., 4800 m, temperatures as low as −50°C)

  - PM – use burrows to prevent heat loss

  - AM

    - Pressing flat against the substrate reduces heat loss by convection ($H_{cv}$).
    - Exposing the darkly pigmented back to the sun increases heat gain by radiation ($H_r$).
    - Air temperature = 1.5°C
    - Body temperature = 33°C
    - Perching on a bed of plant material reduces heat loss to the ground by conduction ($H_{cd}$).

Temperature regulation by *Liolaemus multiformis* lizards.
Temperature Relations

- Grasshoppers
  » During development can produce either light or dark pigment

Rearing temperature and the pigmentation of the clear-winged grasshopper.

Grasshoppers reared at low temperatures develop dark pigmentation that is highly absorbent of visible light.

Grasshoppers reared at high temperatures develop reflective, light pigmentation.
Temperature Relations

- Those living in cold environments orient themselves to the sun’s perpendicular rays.

- Grasshoppers with access to light bask, raising their body temperatures about 10°C above air temperature.

- Body temperatures of grasshoppers confined to the shade nearly match air temperature.
Temperature Relations

» Advantages of raising body temperature to 38° – 40° C

Mature faster

Possibly control a pathogenic fungus *Entomophaga grylli*

![Graph showing the relationship between temperature and number of fungi (per µl)].

- The five points indicate the sizes of the fungus population after 10 days of incubation.
- Sample incubated at 25°C attained maximum population size.
- Sample incubated at 35°C did not grow.
Temperature Relations

- Temperature Regulation in Endothermic Animals – use most of the methods previously discussed but take greater advantage of Hm
  - Environmental Temperature and Metabolic Rates
    - Thermal Neutral Zone – range of temperatures where metabolic rate remains constant
    - When outside the thermal neutral zone metabolic rate can change (Ex. humans)
      - Shiver when cold
      - Blood flow – increase or decrease to skin
      - Perspiration (licking and panting in other mammals)
Temperature Relations

- Arctic and tropical species vary in regards to thermal neutral zone

**Temperature and metabolic rate of arctic and tropical mammals.**

- **Tropical species** maintain a constant metabolic rate over a narrow range of temperatures.
- **Arctic species** maintain a constant metabolic rate over a broad range of temperatures.

- **Sloth**
- **Night monkey**
- **Human**
- **Marmoset**
- **Ground squirrel**
- **Polar bear club**
- **Eskimo dog**
- **Arctic fox**

Axis: Environmental temperature (°C)

Values range from -30°C to 40°C.
Temperature Relations

- **Aquatic Birds and Mammals**

  - living in water presents a new dimension
    - High specific heat
    - Conductive heat loss is increased (20x if water is still; 100x if water is moving)

  - How do they thermoregulate?
    - Small respiratory surface since they breath air directly
    - Well insulated with fat, those areas that are not demonstrate a counter current circulation pattern

![Diagram of dolphin thermoregulation](image)

- Blubber insulates body of dolphin but does not extend into flipper.
- Body = 37°C
- Seawater = 14°C
- In each of many blood vessels, heat flows from warm incoming blood to cool returning blood due to conduction ($H_{cd}$) and convection ($H_{cv}$).
Temperature Relations

- Warming the Swimming Muscles of Large Marine Fish

*Water temperature and body temperature of a bluefin tuna.*

Body temperature of this bluefin tuna was 10° to 15° higher than the temperature of the water.
Temperature Relations

- Warming Insect Flight Muscles

Thermoregulation and circulation in *Manduca sexta* (1).

Temperature of thorax stabilizes at 44°C.

Narrow beam heat lamp is used to heat thorax.

Live, tethered moth (circulation intact)

Temperature of abdomen increases.

Thorax overheats.

Dead moth (no circulation)

Temperature of abdomen does not change.

A first experiment showed that a live moth keeps its thorax from overheating, while the thorax of the dead moth overheats.

Thermoregulation and circulation in *Manduca sexta* (2).

A second experiment showed that tying off the circulation between the thorax and abdomen of a free-flying moth causes the thorax to overheat.

Temperature of thorax stabilizes at 42°C.

Abdomen heats up.

Free-flying moth (circulation intact)

Metabolic heat from contraction of flight muscles.

Thorax overheats.

Abdomen remains at air temperature.

Free-flying moth (circulation to abdomen blocked)

Moth overheats to 46°C and falls to the floor unable to continue flying.
Temperature Relations

- **Temperature Regulation by Thermogenic Plants**

  Eastern skunk cabbage, an endothermic plant.

  - Air temperature = -15°C
  - Snow is melted by radiation and conduction.
  - High metabolic rate of spadix generates sufficient heat to melt snow.
  - Starch is translocated from the taproot to the spadix.

  ![Diagram of Eastern Skunk Cabbage with labeled parts]

  - Spadix
  - Spath
  - H<sub>m</sub>
  - H<sub>r</sub>
  - H<sub>cd</sub>
  - Taproot
  - Starch

  ![Graph showing the relationship between air temperature and metabolic rate]

  - Spadix of eastern skunk cabbage has higher metabolic rates at lower temperatures.
  - Average linear relationship between air temperature and rate of oxygen consumption.
Temperature Relations

- Inactivity – it is obvious that some organisms will regulate temperature by simply becoming inactive.

In the morning, when air temperature is 25°C and sand temperature is 35°C, all beetles are in the sun. As sand temperatures approach 70°C, most beetles are in the shade. Tiger beetles' avoidance of high temperatures.
Temperature Relations

- Reducing Metabolic Rate
  - Hummingbirds
    - have a typical body temperature of 39° C
    - Use high calorie foods to maintain this temp.
    - If food supply is low or cool temps enters a state of torpor (metabolic rate drops and bird temps can go as low as 12° C)

Nectar availability and broad-tailed hummingbirds' use of topor.

Day
- The amount of nectar available to a broad-tailed hummingbird determines whether it goes into topor during the night.
- If nectar is scarce, topor
- If nectar is adequate, no topor

Night
- A hummingbird in topor has a low metabolic rate and so uses little energy.
- To meet its energy demands, a hummingbird that does not go into topor must consume large quantities of nectar just before roosting.
Temperature Relations

- Hibernation – a prolonged state of reduced metabolism (months), during winter (ex. Arctic ground squirrel, body temp gets as low as 2° C)

- Estivation – occurs during summer (ex. Long-neck turtle, metabolic rate can drop by 28%)