Organism – Environment Interactions

Physical, abiotic

Lots of interactions –
- Acquiring water
- Acquiring food
- Loss of water, carbon
- Exchange of energy

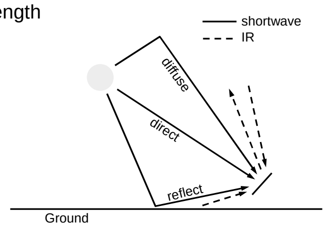
How does the physical environmental affect the exchange of matter and energy?

Energy exchange:
- Radiation
  - Solar
  - Thermal (IR)
  - Photoelectric
- Thermal (heat flow)
  - Conduction
  - Convection

What environmental variables are important?

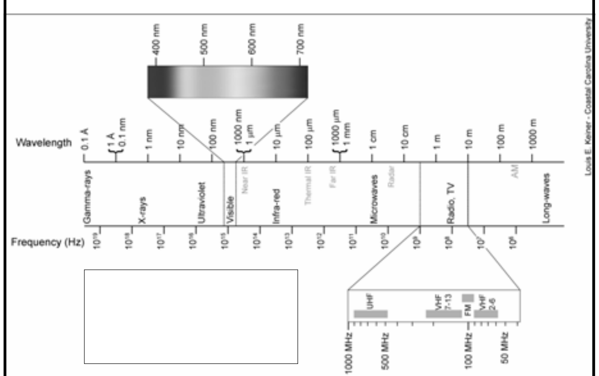
Radiation
- visible, short wavelength
- IR, long wavelength

Temperature
Humidity
Wind speed
Pressure



Other exchanges:
- Convection
- Metabolism
- Evaporation

The Electromagnetic Spectrum



Radiation emitted – Stefan-Boltzmann Law

$$Q = \varepsilon\sigma T^4$$

Total energy flux
(W / m^2)

emissivity (0-1)

S-B constant
5.67e-8 W m^{-2} K^{-4}

Kelvin
°C + 273.15

SI unit of power
(energy flow rate)
= J/s

For blackbody (perfect absorber & emitter), ε = 1

Energy Budgets

All objects are in a state of continuous exchange of energy with their environment

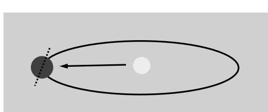
Consider only steady-state budgets

- Flows are constant
- T is constant
- Not considering heat storage
- Occurs under steady environments conditions or if object responds very fast

If flows are constant :

Energy in = Energy out

Sample – Global Energy Budget



$$S\pi r_{earth}^2 = \sigma T^4 4\pi r_{earth}^2$$

$$T^4 = \frac{S\pi r^2}{\sigma 4\pi r^2} = \frac{S}{\sigma 4} = \frac{1380}{(5.67e-8)4}$$

$$T = 279\ \mathrm{K} \approx 6\,^\circ\mathrm{C}$$

Pretty close! – greenhouse gases?

Radiation budgets and emissivity

Radiation absorbed = Radiation emitted

$$\underbrace{Q_{incid} * (1-R)}_{\text{High for black paint, Low for white paint, Low for chrome}} = \varepsilon\sigma T^4$$

High for paint
Low for chrome

	ε	R	Q_a	T
black	0.89	0.08	460	36ºC
white	0.89	0.75	125	-50ºC
chrome	0.10	0.55	225	173ºC

Emissivity very important for surfaces to dump energy!

Lizard Energy Budget

Steady-state budget: energy in = energy out

1) Radiation input will be set

2) Radiation out from S-B Law (Q_{out})

$$Q_{out} = \varepsilon\sigma T^4$$

3) Convection (C)

$$C = h_c (T_r - T_a)$$

air temperature

body surface temperature

Convection coefficient

$$h_c = k_1 \frac{\sqrt{V}}{\sqrt{D}}$$

Wind speed

Body size

4) Metabolic energy (M)

$$M = 0.0258 e^{T_b/10}$$

** - Units of W/kg, multiply by mass / surface

5) Evaporative cooling (E)

sweating or panting

- depends on animal
- panting from inside
- sweating from outside

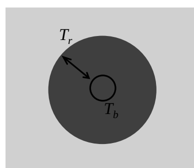
Convert to energy units, multiply by latent heat of vaporization

$$\lambda E = \begin{cases} 0.27 & T_b \le 20 \\ 0.08\, e^{0.0586 T_b} & 20 < T_b < 36 \\ 0.00297\, e^{0.1516 T_b} & T_b \ge 36 \end{cases}$$

** - Units of W/kg, multiply by mass / surface

Dealing with insulation

Interested in body core temperature, but exchanges are at the surface



At steady-state :

Energy flow thru insulation = Energy produced inside

$$M - \lambda E = \frac{T_b - T_r}{I}$$

Insulation resistance :

large, furry – 1.0 m^2 ºC W^{-1}
lizard – 0.002 m^2 ºC W^{-1}

Total Lizard Budget

$$M - \lambda E + Q_a - \varepsilon\sigma\left[T_r + 273.15\right]^4 - h_c\left[T_r - T_a\right] = 0$$

Want T_b ?

$$M - \lambda E = \frac{T_b - T_r}{I}$$

Solve for T_b, substitute, giving:

$$M - \lambda E + Q_a - \varepsilon\sigma\left[T_b + 273.15 - I\left(M - \lambda E\right)\right]^4 - h_c\left[T_b - T_a - I\left(M - \lambda E\right)\right] = 0$$