Fluxes

Hand out pieces of metal, wood, insulation...
All are essentially the same temperature.
But some feel colder than others! Why?!!

* Humans sense the **change** in their tissue temperature, not the absolute temperature.

* This change in tissue temperature is closely related to or caused by the flux of heat (energy) away (or to) the body.

* A **flux** is the rate of transfer of a quantity such as mass across a defined surface.

Note: must define the sign/direction of fluxes

Simple Flux Models

Energy Flux = \( g \ (T_s - T_a) \)
- \( g \) = conductance
- \( T_s \) = surface temperature (human tissue in example)
- \( T_a \) = ambient temperature (metal in example)

Mass Flux = \( g \ (C_s - C_a) \)
- \( g \) = (another) conductance
- \( C_s \) = concentration at surface
- \( C_a \) = ambient concentration

We will use these models extensively!
A large flux can be caused by...
* a large temperature (concentration) difference
* a modest temperature (concentration) difference
and a large conductance

What is happening in the case of the metal and wooden objects?

Same temp difference ($\Delta T$),
- wood $\rightarrow$ small conductance, small flux, tissue not cooling rapidly
- metal $\rightarrow$ large conductance, large flux, tissue cooling rapidly, "feels cold"

Show Wikipedia thermal conductance table

Graphical Relationship

Between Flux, Conductance, and Temperature Difference

Flux, $\frac{W}{m^2}$

Conductance, $g$

Temperature Difference, $\Delta T$

Units of $g$?

$[g] = \left[ \frac{\text{flux}}{\Delta T} \right] = \frac{W}{m^2 \cdot K} = W \cdot m^{-2} \cdot K^{-1} = \frac{W}{m^2 \cdot K}$
Discussed syllabus
ecosystem, community and environment functioning as a unit.

ecology: study of the interrelationships between organisms and their environment

Microenvironments: ecosystems typically consist of several of these, which are local areas where air temperature, humidity, wind speed, radiation, etc. are distinctly different from other local areas.

Energy exchange, or flow (or hindrance of flow) of energy is often responsible for microenvironments. There are 4 primary mechanisms of energy flow:

1. **Conduction**: transfer of energy by direct molecular interaction between 2 substances from the substance with a higher temperature to substance of lower temp.
2. **Convection**: transfer of energy by a moving fluid
3. **Radiation**: transfer via electromagnetic waves or photons which does not require an intervening medium.
4. **Latent heat**: transfer when energy is absorbed or released through a change of phase (liquid -> vapor) of water

Mass and momentum exchange also occur in microenvironments. Mass -> water, carbon

Momentum -> kinetic energy from wind
Conservation of Energy and Mass

Energy and mass conservation principles are powerful concepts that can be used to quantitatively describe microenvironments. For example, we can use the conservation of energy law (energy cannot be created or destroyed, must be conserved) to find the fluxes of energy between a canopy of vegetation and the atmosphere:

\[
\begin{align*}
R_n &= \text{net radiation} \\
&= (\text{solar in} + \text{atmos in}) - (\text{solar out} + \text{emitted}) \\
H &= \text{sensible heat flux} \\
&= \text{energy flow due to conduction and/or convection} \\
\Lambda E &= \text{latent heat flux} \\
E &= \text{rate of evapotranspiration/condensation} \\
M &= \text{energy generated by plant metabolism} \\
W &= \text{rate of heat storage in the canopy} \\
G &= \text{flux of energy into the soil}
\end{align*}
\]

By conservation:

\[
R_n - H - \Lambda E + M - W - G = 0
\]

If we can measure some, model some, then we can solve for the other variables.

Much of this course is finding the simplest possible model that can accurately represent these complex processes but still give good quantitative predictions.
Models and Scale

Aspects that must be considered before choosing or formulating a model:

* What complexity is desired?
* How accurate must the predictions be?
* What resources (e.g., computing) are available?
* What data are available?
* At what scale must the phenomenon be modeled?
* Are the relevant substances/bodies homogeneous or heterogeneous at that scale?
* What physics apply at that scale?

Units

When using quantitative models, units are critical.
50 what? 50 K? 50 $\frac{W}{m^2}$?
We will use the SI system.