Theme Music: Zimmer & Howard

Agent of Chaos (from The Dark Knight)

Cartoon: Mike Peters

Mother Goose & Grimm

Some scientists believe that chaos rules the universe.

They call it entropy, universal bedlam.

Where everything is breaking down, tending toward greater and greater disorder.

At least it's good to be on the winning side.
Foothold ideas: Energy

- Kinds of energy (？)
  - Kinetic
  - Potential
  - Thermal
  - Chemical

- First law of thermodynamics
  - Conservation of total energy

\[
\Delta U_{\text{int}} = Q - W
\]

\[
\Delta H = \Delta U + p\Delta V
\]
We need to create a system schema for describing energy

- Consider a macroscopic object.
- Construct a system schema representation that shows the various places energy can reside in its internal structure (where “internal energy” can live).
Zooming in on internal energy

(a generalization of the system schema)

As the system moves, energy is moving randomly among these locations ("bins").
Foothold ideas: Thermal Equilibrium & Equipartition

- Degrees of freedom – where energy can reside in a system.

- Thermodynamic equilibrium is dynamic – Changes keep happening, but equal amounts in both directions.

- Equipartition – At equilibrium, the same energy density in all space and in all DoFs.
Foothold ideas: Entropy

- Entropy – an extensive measure of how well energy is spread in an object.

- Entropy measures
  - The number of microstates in a given macrostate
  - The amount that the energy of a system is spread among the various degrees of freedom

- Change in entropy upon heat flow

\[ S = k_B \ln(W) \]
\[ \Delta S = \frac{Q}{T} \]
Foothold ideas:
The Second Law of Thermodynamics

- Systems composed of a large number of particles spontaneously move toward the thermodynamic (macro) state that correspond to the largest possible number of particle arrangements (microstates).
  - The 2nd law is probabilistic. Systems show fluctuations – violations that get proportionately smaller as N gets large.

- Systems that are not in thermodynamic equilibrium will spontaneously transform so as to increase the entropy.
  - The entropy of any particular system can decrease as long as the entropy of the rest of the universe increases more.

- The universe tends towards states of increasing chaos and uniformity. (Is this contradictory?)