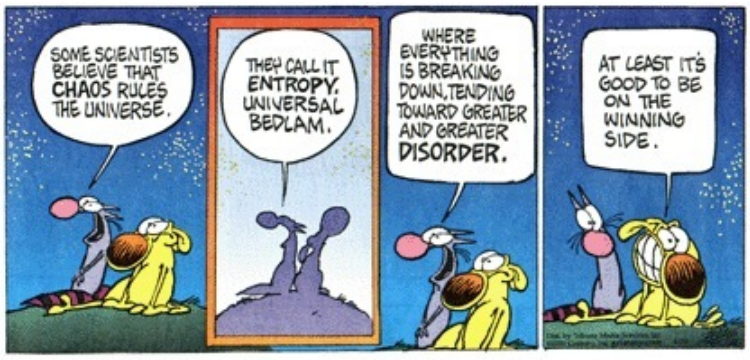
February 4, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music: Zimmer & Howard**

  Agent of Chaos **(from The Dark Knight)**

- **Cartoon: Mike Peters**

  Mother Goose & Grimm



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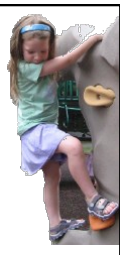
Foothold ideas: Energy



- Kinds of energy (?)
  - Kinetic
  - Potential
  - Thermal
  - Chemical
- First law of thermodynamics
  - Conservation of total energy

Internal energy

Thermal energy entering

Work done on the rest of the world

$$\Delta U_{\text{int}} = Q - W$$

Energy needed to add internal energy at constant pressure (Enthalpy)

$$\Delta H = \Delta U + p\Delta V$$

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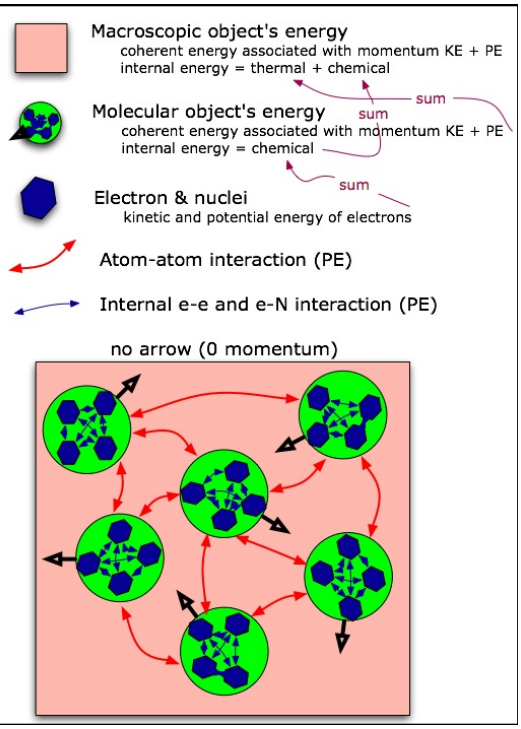
We need to create a system schema for describing energy

- 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).

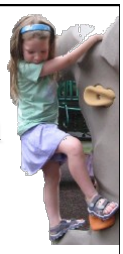
Zooming in on internal energy

(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 $S = k_B \ln(W)$
  - The amount that the energy of a system is spread among the various degrees of freedom
- Change in entropy upon heat flow $\Delta S = \frac{Q}{T}$

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?)