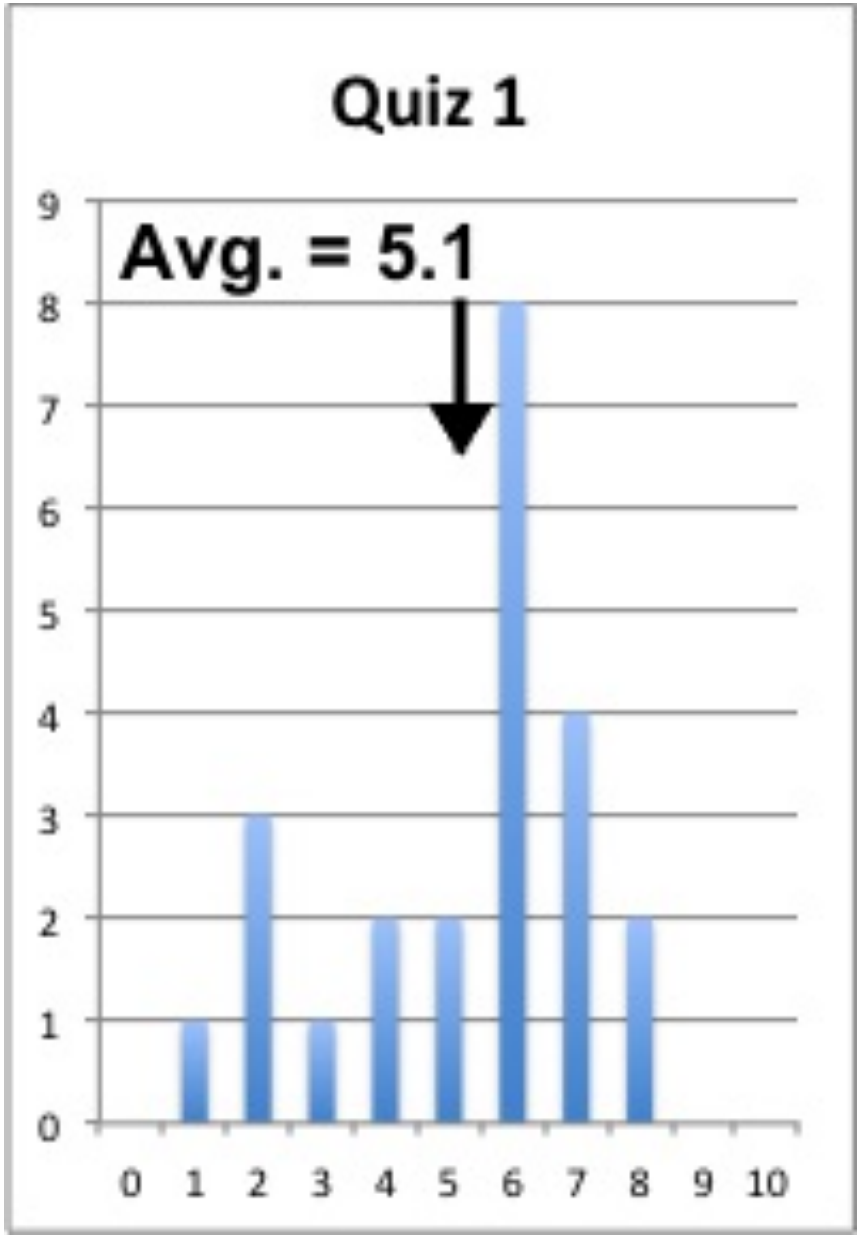
- **Theme Music:**
  Bruce Fowler
  Entropy

- **Cartoon:**
  S. Harris

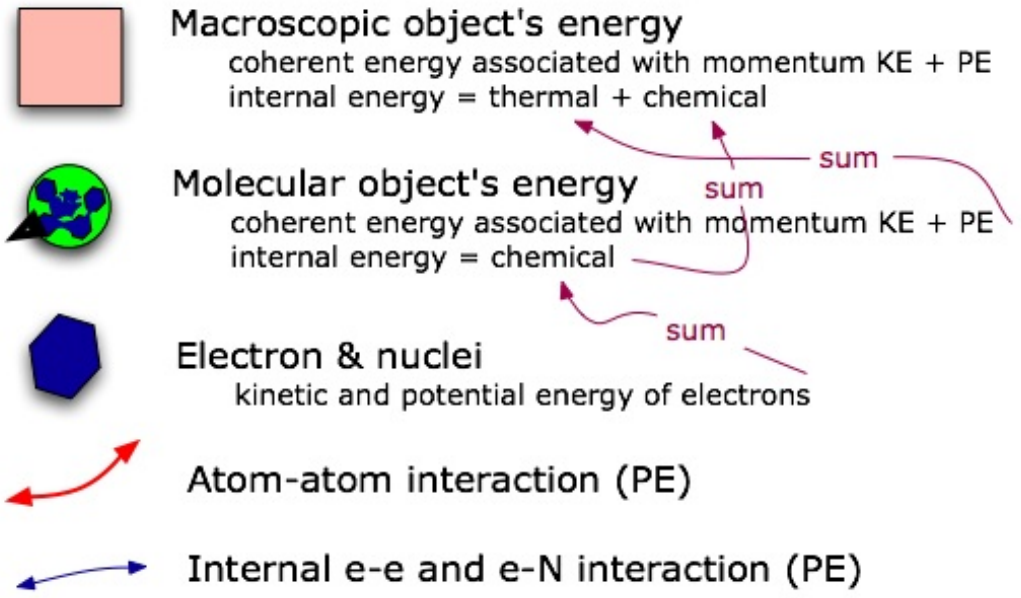
	1.1	1.2		1.3E	1.3Q	1.3W
A	17%	9%	>	26%	39%	43%
B	35%	83%	=	48%	35%	30%
C	61%	9%	<	26%	26%	22%
D	48%	22%				
E		78%				

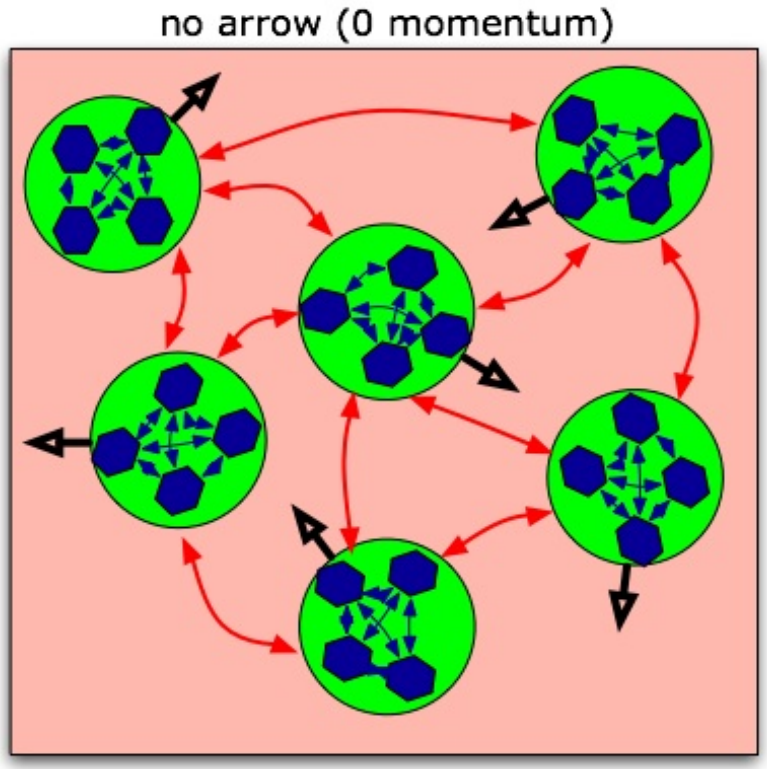


Zooming in on internal energy

(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 a system.
- 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?)

Reading question

- In the reading you said that energy always flows from the hot object to the cold and not vice versa. But then you said when we zoom in and look at individual molecules, energy is continually exchanging among the molecules, and there are fluctuations, with some molecules having more energy than others. If this is the case, why don't we say there is an exchange of energy between the hot and cold molecules but the cold molecules end up absorbing the most energy? Do the hot molecules really not absorb any energy from the cold molecules?

Reading questions

- When discussing degrees of freedom, is a degree of freedom simply equal to the possible direction of motion of an object/molecule?
- If there is no thermodynamic equilibrium in living organisms...how can we use thermodynamic equilibrium and equipartition in Biology?
- If all the microstates are equally probable, why then does one macro-state show up more than another?