Note on calorimetry experiment: We know carbs have ~4 food cal/gram
fats have ~9 food cal/gram
We measured ~3-4 food cal/gram - pretty close!
(lower because of heat loss to surroundings)

History of Energy Usage

prehistoric man: ~100 W food
~100 W fire

ancient Egypt: + building, glass blowing

China 100 BC: + transportation

Europe 1300: + more heating (Europe is cold!)

England 1880: Industrial Rev — + production

N. America 1990: + transportation

Industrial Revolution: "We have all these machines and no
good way to power them!"

Rotational Machines:
- grinding
- pump
- lathe
- spinning wheel
- potter's wheel
- winch (lifting)

Linear Machines:
- hammer mills
- bellows
- reciprocating pump
- saw
- loom
- sails

L7 All this stuff used wind, water, animal, or human power
Breakthrough: 1. heat $\rightarrow$ work barrier
   2. work $\rightarrow$ electricity $\rightarrow$ work

- talk about these later

Heat Engines:

Step 1: "pull" machine

Step 2: Watt's engine: add second cylinder to cool steam
   "push" machine

Step 3: eliminate cooling step
   - light
   - open system (requires input water)
   - fast
   - wasteful of energy
   - powerful

Step 4: "double action steam engine" (see slide)

- used for transportation: trains!