Archimedes, Greek Engineering and the Bathtub

Domenico Fetti, 1620
Last time ...

- Plato’s distinction between form/matter
- Aristotle’s distinction between celestial/terrestrial physics
- God-talk returns with Plato’s demiurge and Aristotle’s prime mover
Why study physics?

- The assembly-line metaphor
  - “Pure” physics produces “applied” physics that produces technological innovation
  - Knowledge yields economic utility

- The cathedral metaphor
  - “Pure” physics is an expression of cultural creativity like art or music and has no direct economic utility
  - Knowledge for its own sake
    - But did medieval cathedrals have economic utility?
Task of lecture

- Survey Greek and Roman technological innovation
- Examine attitudes of Greek philosophers toward technology
- Review several Greek “mechanics”
- Consider interactions between Greek physics and technological innovation
“Failure” of Greek technology?

- No major technological innovation from -3000 to 1200 in the West
  - Economies remained agricultural
  - Households remained unit of production
  - Muscle power remained primary motive power
  - Only new Greek technologies were toys and mechanical amusements
  - Five simple machines analyzed by Greeks all had been invented by earlier societies, except screw
  - No horseshoes, stirrups, horse collars, cast iron, windmills, thermometers, mechanical clocks
Critique of “failure” thesis

- Does stasis need explanation as “failure”?
  - Major technological revolutions are rare

- Many technological advances come not from invention but from new application of existing technologies

- Some Greek innovations not applied
  - Water wheel and windmill
  - Screw presses for extracting juices
  - Glass-blowing and glass lenses

- Romans later applied Greek innovations
  - Military technologies (crossbow, catapults)
  - Hydraulic concrete used as building material
  - Civil engineering of roads
Greek philosophy & technology

- **Mechanics as art[ificial], not natural**
  - Physics = logical propositions from which statements about reality (nature) can be deduced
  - Mechanics = knowledge about machines, i.e., arrangements of bodies that control motions artificially and "violently"

- **Greek thinkers devalue mechanics**
  - Plato: mechanics as "corrupter and destroyer of pure excellence of geometry," useful only for military arts
  - Aristotle: to dwell on utility is "bad taste"
  - Plutarch: even Archimedes regarded work on "needs of life" as "ignoble and vulgar"

- **‘Engineer” not a recognized social role**
  - “Architects” like Vitruvius (fl. 25 BCE) closest role
Aristotle on architects

“We think that architects [master craftsmen] in all fields are more honorable and know more and are wiser than the artisans because they understand the reasons for the things done, while the artisans do things, just like some inanimate objects, without knowing how to do the things they do .... Artisans accomplish their work through customs .... As more and more arts [technai] were discovered, some pertaining to necessities and some to pastimes, the inventors of the latter were always considered wiser than the inventors of the former, because their knowledge was not oriented towards utility.” (Metaphysics 981a-982a)
Archimedes of Syracuse, 287-212 BCE

- Heroic tales of technical prowess
  - Launched a great ship
  - Archimedean screw
  - Burning mirrors
  - Defensive military technologies

- Mathematical contributions (≠ physics)
  - Areas and volumes of figures
  - New method of geometrical proof
  - Develops system of large numbers
  - Law of the balance ($D_1 W_1 = D_2 W_2$)

- “Eureka”--psychology of discovery
  - Density = mass / volume
Ctesibius of Alexandria, fl. 270 BCE

- “... had reputation of delighting in mechanical contrivances” (Vitruvius)
- Son of a barber--invented air pump after crafting counter-weighted mirror for father’s barbershop
- Wrote lost book on inventions, unrelated to physics
  - Air pump with valves for musical organ
  - Water clock with clepsydra (constant flow)
  - Automata added to water clock
  - Tried to make compressed-air catapult
Ctesibius’s inventions (later renditions)

Clepsydra

Hydraulis = water organ
Hero of Alexandria, fl. 60 AD

- Wrote book on mechanics
- *Pneumatika* full of plans - gadgets
  - Steam-powered theater, rotating sphere
    - Failed steam engine or anti-Aristotle demo?
      - Motion needs external mover?
      - Air causes circular motion?
  - Cranes and sledges for transport
  - Five simple machines analyzed
  - Dioptra for surveying (graduated circles)
  - Water pumps to fight fires
  - Odometer
  - Plane and curved mirrors

  ➤ But unclear whether Hero’s devices were built or influenced later technologies
Explaining the Greek “failure” to innovate technically

- Contempt for the mechanical arts?
- Conservative transmission of technical knowledge (by exact copying)?
- Lacked incentives for economic efficiency?
  - Respect for landed wealth
  - Only states had fluid resources
  - Availability of cheap labor, both slave and “free”
- No ideology of “progress” before Jewish prophets and Constantinian Christianity?
  - Contradictory voices re change over time