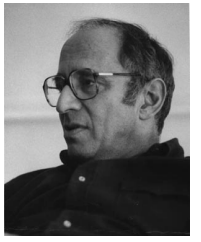
05. Kuhn: Paradigms and Immature Science



Thomas Kuhn (1922-1996)

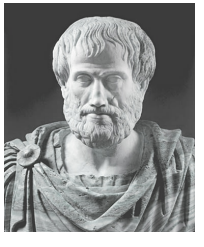
A. Paradigms

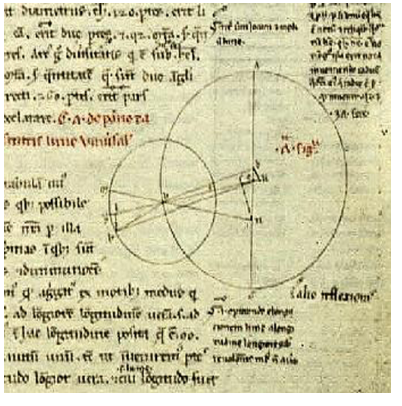
Paradigm (broad sense): a package of ideas and methods which make up a view of the world and a way of doing science.

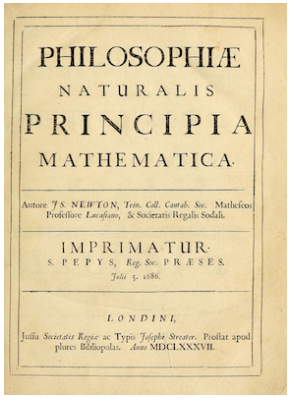
Paradigm (narrow sense): a collection of examples or exemplars that serve as models, inspiring and directing further work.

Examples

- Aristotelian physics (*Physica* ~300 B.C.)
- Ptolemaic astronomy (*Almagest* 2nd cent. A.D.)
- Newtonian dynamics (*Principia* 1687)







Two Characteristics (Kuhn pg. 10):

- "Sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity."
- "Sufficiently open-ended to leave all sorts of problems... to resolve."

Paradigms characterize...

B. Normal Science

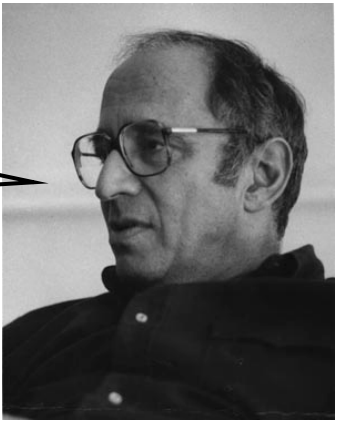
Normal science: Scientific work that occurs within the framework provided by a paradigm.

- *well-organized*
- *agreement on fundamental issues*
- *extension of paradigm to cover "nooks and crannies"*
- *no "critical stances" or "permanent openness"*

Constrast with Popper:

Scientific method is based on an *openness to criticism* (scientists must be willing to change their views in light of falsifying data)!

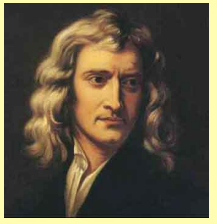
Normal science assumes *no* criticism of fundamental issues!



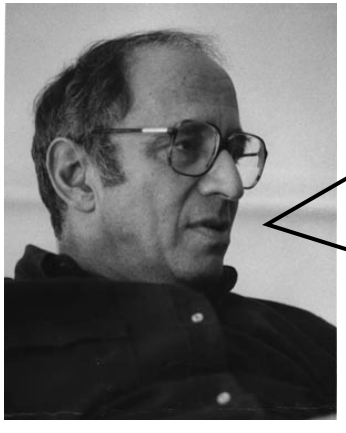
Scientific change proceeds *incrementally* (*via* conjecture and refutation).

Newton Example:

If I have seen further it is by standing on the shoulders of giants.



Myth of humble Newton:
- Appeal to *prisca sapientia*?
- Insult to short rival Robert Hooke?



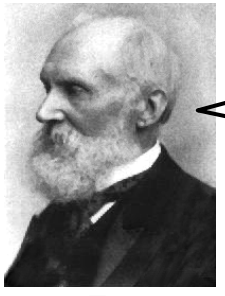
Two types of change in science:

(a) *Change within normal science.*
- incremental
- standards of justification and rationality
- simple notion of progress

(b) *Change associated with "revolutionary science"*
- complete overthrow of dominant paradigm
- no standards
- notion of progress not so simple

Story to Come: Scientific Change According to Kuhn

normal science $\Rightarrow$ *crisis* $\Rightarrow$ *revolutionary science* $\Rightarrow$ *normal science*



William Thomson, Lord Kelvin (1900)

"The beauty and clearness of the dynamical theory which asserts heat and light to be modes of motion, is at present obscured by two clouds."

(a) Black body radiation: need to tweak the theory just a bit!

(b) Ether drift null results: need to make experiments a bit more precise!

Max Planck (1900)

Black body radiation can be theoretically explained if we suppose energy comes in discrete packets.... let's call them "quanta"...

REVOLUTION!

Albert Einstein (1905)

Let's suppose there is no ether... and that measurements of time and space are not absolute...

REVOLUTION!

Story to Come: Scientific Change According to Kuhn

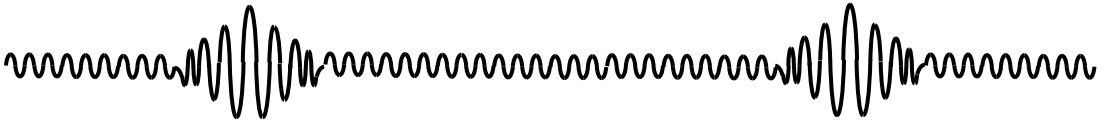
$\circledast$ *normal science* $\Rightarrow$ *crisis* $\Rightarrow$ *revolutionary science* $\Rightarrow$ *normal science*

- What comes before normal science and dominant paradigms?

Example: History of Optics

Current Paradigm: Quantum Field Theory (~1925-present)

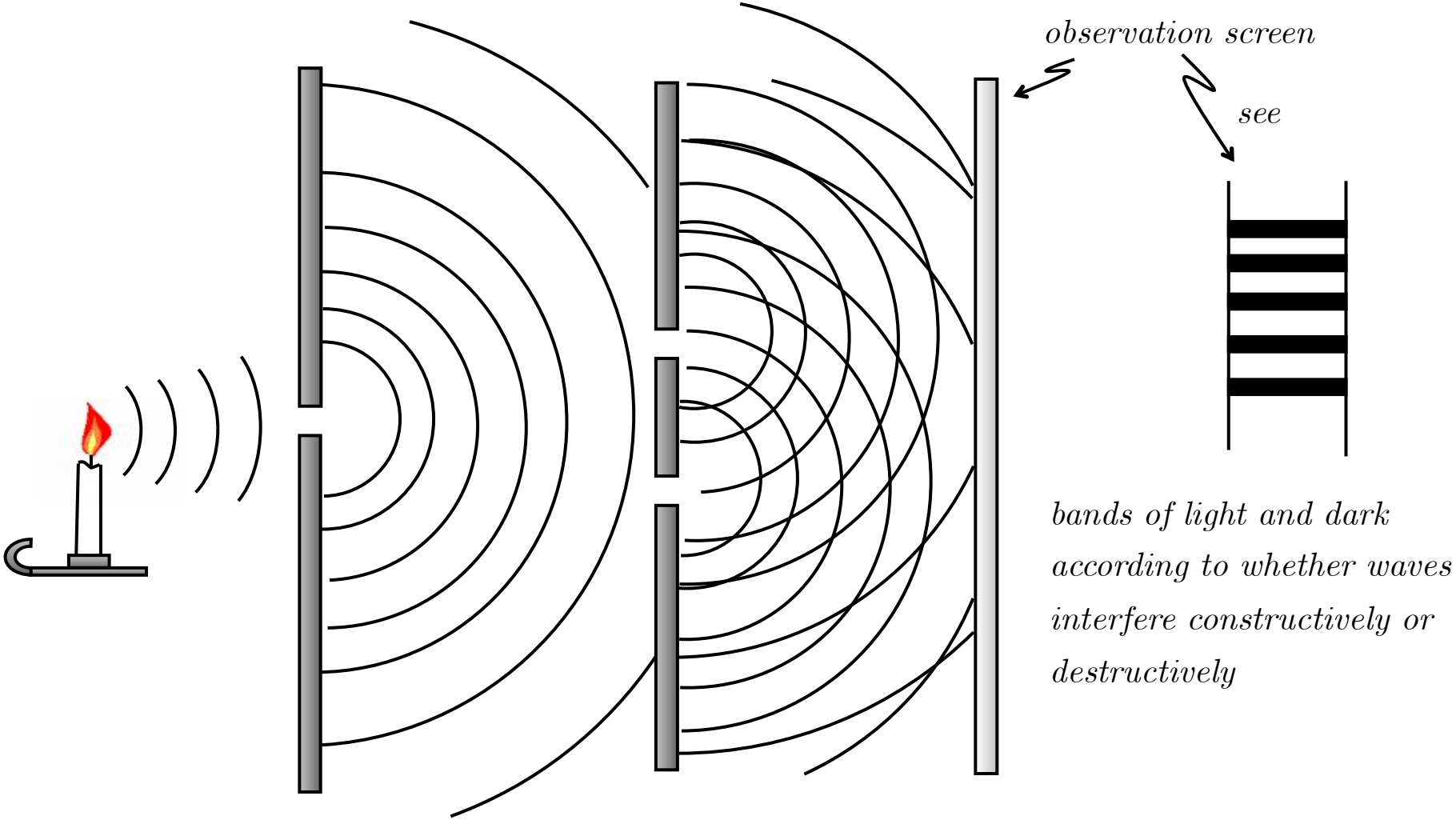
- Light consists of photons: excitations of a quantized electromagnetic field.



Wave Paradigm (1800's–1900's)

- Light consists of waves in the ether.
- Thomas Young's Double-Slit Experiment (1800)

Thomas Young
(1773-1829)



bands of light and dark according to whether waves interfere constructively or destructively

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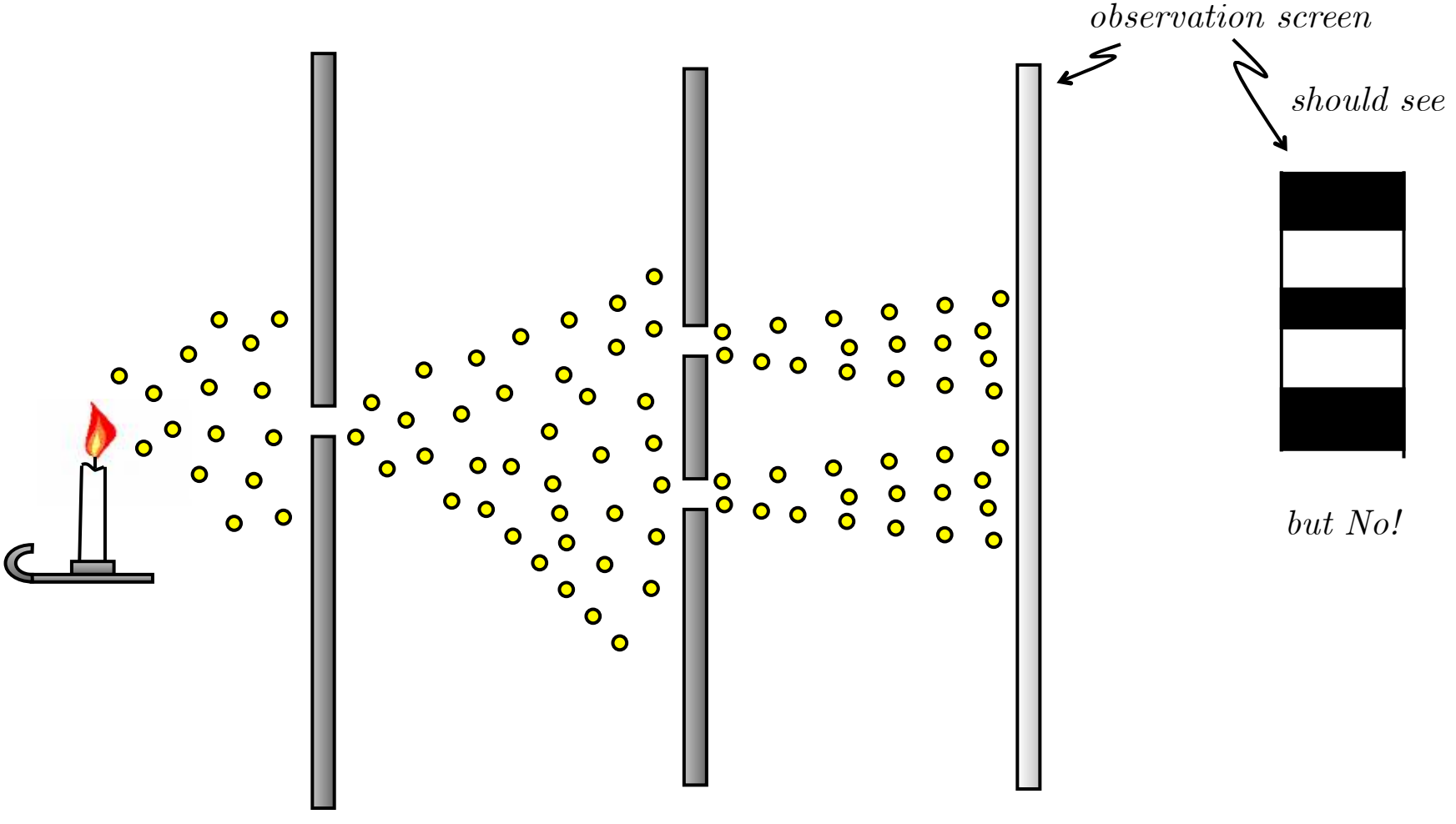
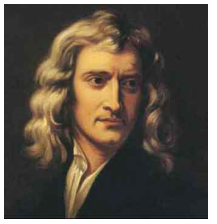
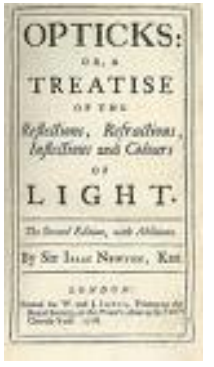


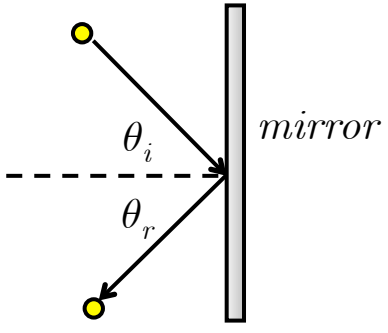
Particle Paradigm (1700's–1800's)

- Light consists of particles. (Newton 1704 *Optiks*)

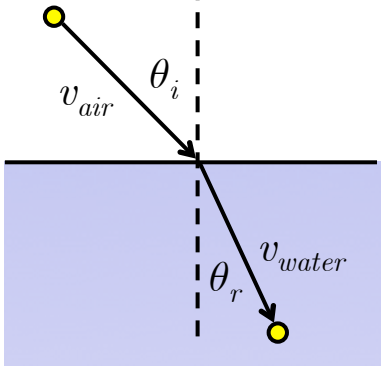


Isaac Newton
(1643-1727)





- Reflection: $\theta_i = \theta_r$
- *Explanation*: Light particles scatter elastically.



- Refraction: $\sin(\theta_i)/\sin(\theta_r) = v_{water}/v_{air}$
- *Explanation*: Light particle is attracted more towards water particles at interface and thus speeds up.

Pre-Newton

- No dominant paradigm
- Many competing paradigms
  - Descartes' (1637) disturbance in the plenum.
  - Hooke (1660's), Huygens (1678) wave theories.
  - Gassendi (1660's) particle theory.

Rene Descartes (1596-1650)

Christiaan Huygens (1629-1695)

Pierre Gassendi (1592-1655)

} ***Immature Science***

Characteristics of Immature Science

- Competing views need to derive everything from scatch.
- All facts seem equally relevant.
- Collections of facts with no explanatory framework: compendiums and beastiaries.

Transition to Normal Science

- One paradigm must seem better than its rivals.
- Should not explain all the facts: should be potentially useful.
- Should suggest which experiments and directions of research are worth pursuing.

- *Optics Example:*
  - Newton's *Optiks* (1704). Provides theoretical framework (Newton's theory of motion) within which optical phenomena can be explained.
  - Prestige of Newton.

Potential Problem:

What is the relation between a paradigm and a scientific community?

- paradigm = what members of a scientific community share.
- scientific community = community united under a single paradigm.

- Kuhn (postscript):
  - identify scientific community *first* (role of sociology)
  - *then* identify paradigms
- scientific community = "practitioners of a scientific specialty"
  - similar educations
  - professional initiations
  - common literature

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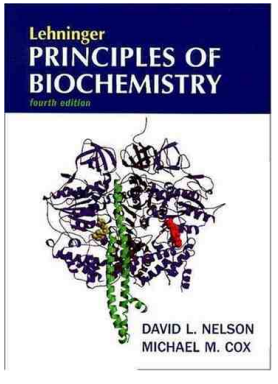
School of Engineering

Establishment of Normal Science

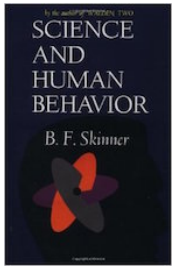
- Social function of a paradigm (Kuhn pg. 11):
  - indoctrination of students into scientific community
  - same models
  - same problems
  - same methods

- Role of textbooks
  - serve as independent explanations of fundamental principles.
  - practitioners of paradigm don't have to always start from scratch.



- Professional reputation
  - based on extending paradigm to new areas, not on reproducing fundamental results (so don't write textbooks for a living).

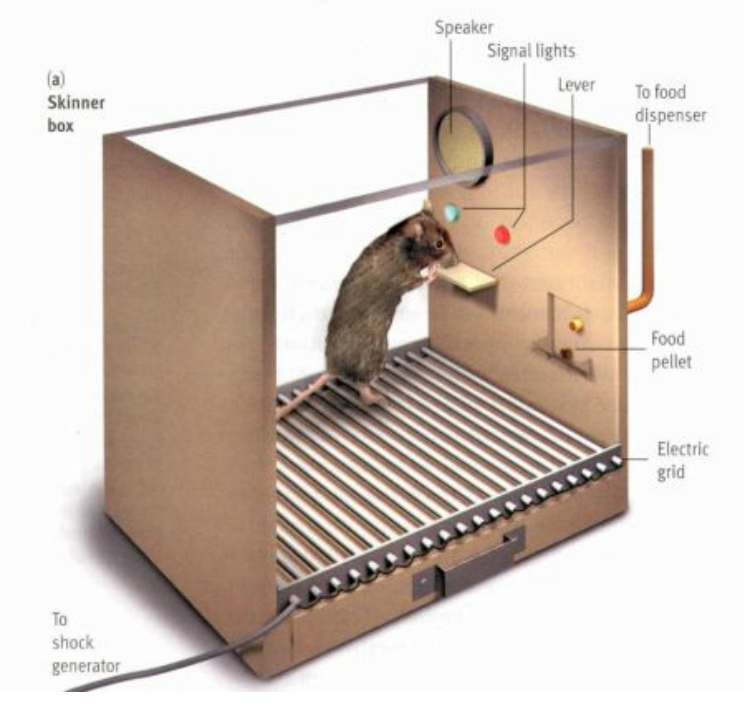
Normal Science Example



Skinner, B. F. (1953) *Science and Human Behavior*

- 1950's. Behaviorism paradigm in psychology.

> *Claim*: Learning proceeds by *reinforcement:*
> - positive reinforcement establishes behavior
> - negative reinforcement eliminates behavior



- *Extreme form*: *All* human behavior can be explained in terms of *purely observable* responses to reinforcement.
  - *In particular*: *There are no such things as unobservable mental/cognitive states.*
- *Thus*: *"x* feels pain" means "*x* exhibits certain behaviors"

> *Question:* How should we perform operations on newborns?

- Extreme behaviorist:
  - *Newborns cannot verbally communicate.*
  - *To say "Newborn is in pain" means "Newborn exhibits certain behaviors".*
  - *Thus: Just use muscle relaxant as anesthetic.*