Definitions:

SCIENCE: "Devoted to the conceptual enterprise of understanding and describing the physical and biological world."

TECHNOLOGY: "Fabrication and use (of) devices and systems," or "Science plus purpose," or "organization of knowledge for the achievement of practical purposes."

The scientific method

- Identify a problem to be solved
- Construct a hypothesis
- Test the hypothesis through experiment
- If the hypothesis fails, re-evaluate
- If the hypothesis holds after repeated experiments, it becomes a theory (i.e., a model), which should be *descriptive*, *testable* and *predictive*.

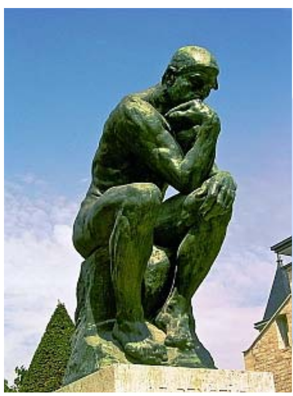
3.2. The Rôle of Science & Technology

Science

- Provides a theoretical foundation for the development of technology.
- Scientific “intellectual capital” usually grows over time, rarely falls.
- Provides a means for analyzing and understanding environmental problems- allowing solutions to be found.
- Unfortunately the majority of the world’s people don’t understand much science- including many intellectuals! (*Two Cultures*).

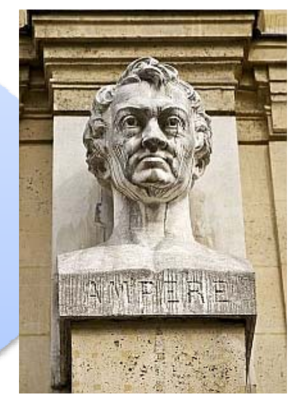
The Two Cultures – C.P. Snow

Many members of the public are weak in science. They have a respect for science & technology, but also a great fear of its effects- particularly rapid change.



Many non-scientist intellectuals fail to understand science, and they foster an atmosphere of fear & suspicion.

Many scientists respond in a way that comes across as arrogant and condescending.



Technology

- Technology has freed humans from mere survival, allowed pursuit of other activities from industry to poetry.
- Results in more comfortable lifestyle, less uncertainty in survival, and higher life expectancy. Can sustain higher populations.
- However more is not always better! Should not be an end in itself!
- Not inherently polluting! However the growth in population & per capita consumption does lead to pollution.

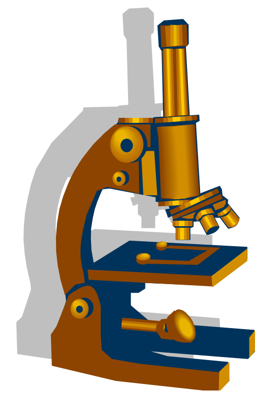
Joseph Schumpeter (1883-1950)

- Czech economist
- Argued that technical progress is the engine of economic growth.
  [No innovation=> no growth]
- Supported “imperfect” markets with oligopolies.
- Cycle of innovation: Oligopolies will keep innovating in order to keep their privileged position (e.g. Microsoft!)

How science & technology can cause harm

- Science may lead to discoveries (nuclear energy) which are then used for negative purposes (e.g., nuclear weapons).
- Technology is developed with a purpose in mind. If the purpose is genocide, then it is clearly harmful.
- Unexpected "side effects" and "revenge effects."

Example: Modern Medicine



EFFECT OF MODERN MEDICINE ON THE ENVIRONMENT:

- Higher life expectancy.
- This means that the Earth's population can grow rapidly without incidents like the "Black Death."
- Far higher population has a much greater impact on the environment.
- Should we ban modern medicine?

We should conclude:

- Science & technology are *tools*. They are not inherently pro- or anti- environment. Only the purposes to which we apply them are.
- Despite this, we need to watch out for unexpected side/revenge effects.

Why not harness science & technology *for* the environment?

- If science is asked to study environmental problems, we can find ways to protect natural capital (see the pike example above).
- Meanwhile we can develop technology with the specific purpose of reducing our environmental impact.

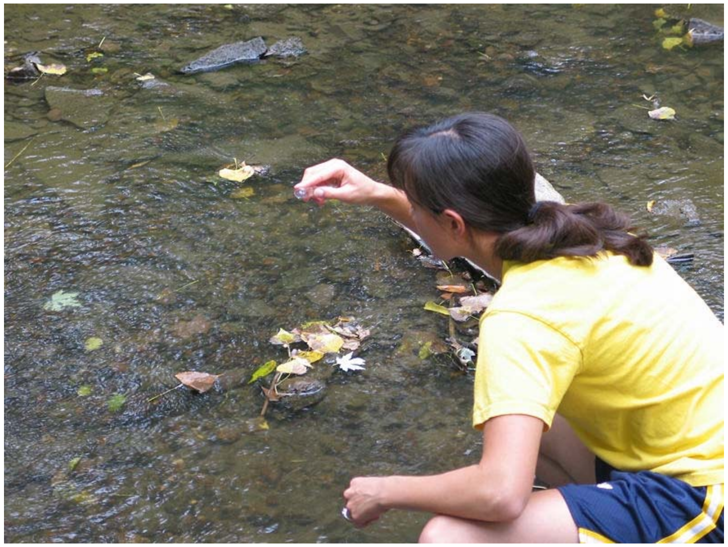
Environmental technology

- New tools for scientists to study the environment (e.g. to detect Al^{3+} levels in water).
- New “green” products, such as biodegradable plastic, fuel cell cars.
- New “green” processes for making things- cleaner chemical processes, energy efficient manufacturing methods, etc.
- New “green” engineering methods- design machinery to be inherently benign/efficient.

3.3. Environmental Sciences

Environmental Science

- Studies the environment, including aspects relating to:
  - Chemistry (e.g. environmental chemistry)
  - Physics
  - Biology (e.g., ecology)
  - Geology
  - Meteorology
- Topics studied include
  - Global warming
  - Acid rain
  - Pollution
  - Biodiversity and conservation
  - Waste management



Iowa state student sampling water from a stream. Picture by Alloquep from Wikipedia, CC licence.

Sustainability science

The US National Academy of Sciences gives three main tasks for sustainability science:

1. Develop a research framework that integrates global and local perspectives to shape a "place-based" understanding of the interactions between environment and society.
2. Initiate focused research programs on a small set of understudied questions that are central to a deeper understanding of interactions between society and the environment.
3. Promote better utilization of existing tools and processes for linking knowledge to action in pursuit of a transition to sustainability.

Sustainability science

- Multidisciplinary approach to solving sustainability problems scientifically. Combines the “hard” sciences such as chemistry with social sciences such as economics and sociology.
- Focuses on the nature-society interface, rather than on the study of nature in isolation.

Environmental chemistry

- Defined as: “The chemistry of surroundings” (vanLoon & Duffy, *Environmental Chemistry*, Oxford, 2000.).
- Environmental chemists study the chemical composition of the environment, and look for the presence of pollutants. They then develop hypotheses and theories to explain the impact of certain materials on the environment.
- Not to be confused with “green chemistry”, which is concerned with pollution prevention.

Environmental chemistry

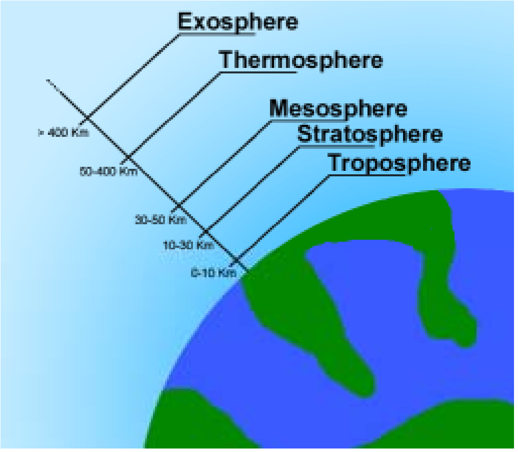
- Environmental chemistry has provided us with an understanding of many key environmental issues:
  - Acid rain
  - The "greenhouse effect"
  - Depletion of the ozone layer by CFCs
  - Dioxins
- Traditionally built upon analytical chemistry, to analyze chemicals in the environment.

Environmental chemists frequently use GC-MS to analyze samples. The technique can detect very low concentrations of pollutants.
Picture: NINT

Environmental chemistry

The topic is usually broken down into three main areas of focus:

1. The atmosphere
   – Includes the greenhouse effect, and all forms of air pollution (ozone, acid rain, etc.)
2. The hydrosphere
   – Studies topics such as water pollution, water purification, pH, etc.
3. The terrestrial environment
   – Includes soil science, rocks, mining, etc.



Picture by Bredk.
From WM Commons

Ecology

- Defined as: "The study of the interrelationships among plants and animals and the interactions between living organisms and their physical environment."*
- Studies topics such as biodiversity and population dynamics.
- An ecosystem is the unit of ecology, containing the biological and physical components in relation to one another.

*Turk, Wittes, Turk & Wittes, Environmental Science, 2nd. Ed., Saunders, 1978.

The kelp forest exhibit at the Monterey Bay Aquarium. Picture by Stef Maruch , CC licence, from WM Commons

Conclusion

- Science provides us with:
  - Environmental data
  - Theories based on these data that aid our understanding, and which can predict effects such as global warming.
- Thus, science provides a rational framework for nearly all environmental debate.
- Once we understand the science, technology may provide a solution to the environmental problem. Technological solutions will be covered in depth later in the course.

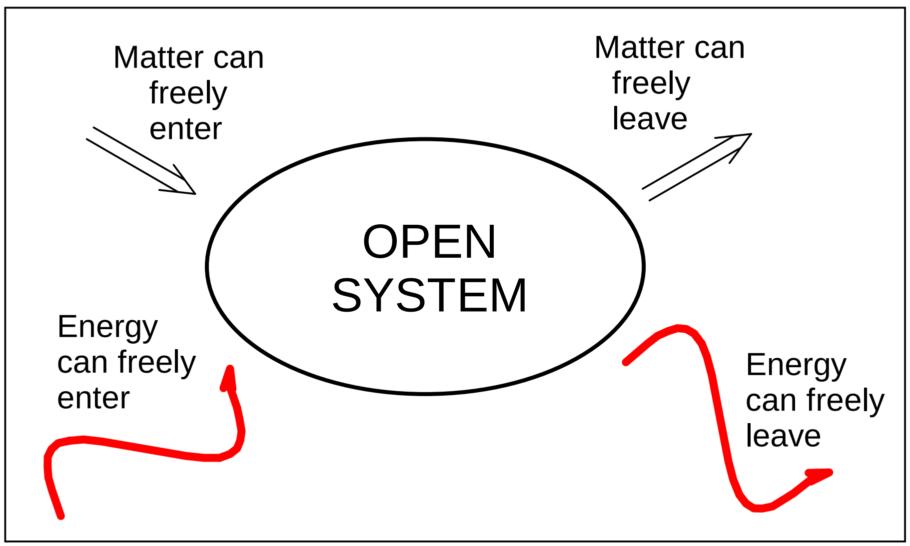
Unit 3
Science & Technology

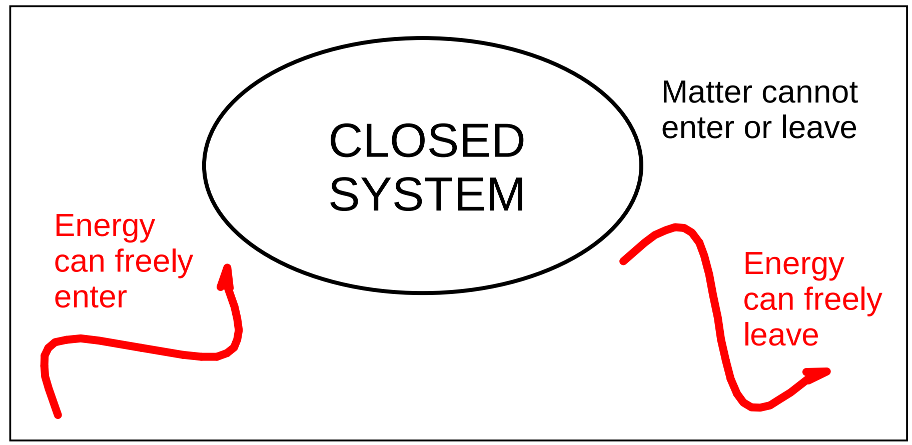
PART TWO:

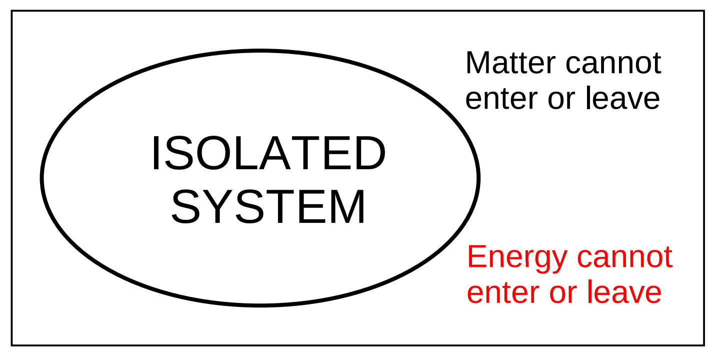
MATTER, ENERGY & THERMODYNAMICS

First, a definition

A **thermodynamic system** is a collection of matter & energy with a physical boundary. There are three types:







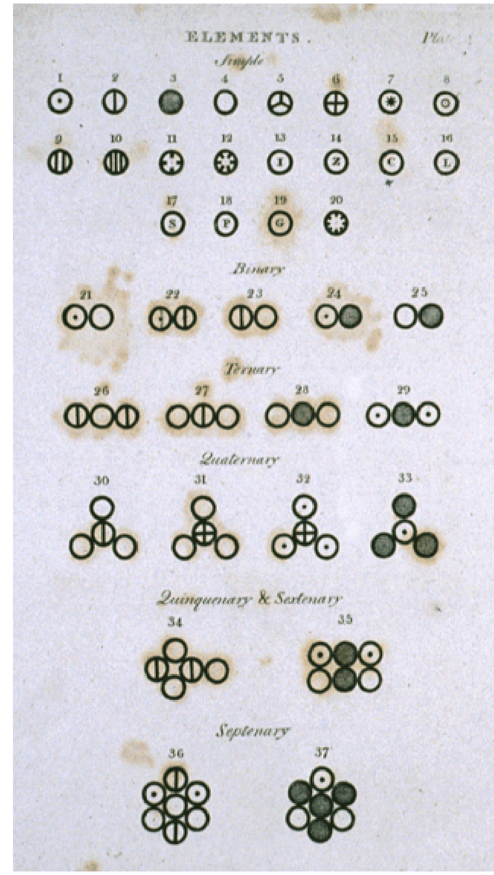
MATTER

What is matter made of?

- According to Dalton's Atomic Theory, matter is composed of **atoms** – small indivisible particles.*
- All atoms of a given **element** are alike - thus a carbon atom is always the same.

We now know these statements are simplifications, but for ordinary chemical processes this simple theory approximates to the truth.

- There are only about 90 different elements commonly found on Earth. All common substances are built from these elements.
- Dalton's theory was built upon several basic chemical laws, some of which are useful for this class



From Dalton, *A New System of Chemical Philosophy*, 1808

Law of Constant Composition

- A pure substance will always have the same composition.
- This means that the proportions of the elements in the substance will always be identical. In this form, it is often referred to as the **Law of Definite Proportions.**

For example methane (CH_4, natural gas) always contains 25% hydrogen by mass, and 75% carbon by mass.

Law of Conservation of Mass

- When any chemical or physical process occurs in a closed system, the total mass involved remains the same.
- When we observe mass to be lost, this is from mass lost out of the system, i.e., the system is not closed. For example, carbon dioxide and steam are lost into the air when wood is burned.

Again, this is a slight simplification that is still true for ordinary processes. Strictly speaking it is matter-energy that is conserved.

Priestley's reversible formation of mercury(II) oxide from mercury & oxygen helped in formulating this law. Picture by MaterialScientist

ENERGY & THERMODYNAMICS