Supplemental Handout- Geog. 120/101
The Scientific Method/ Systems Theory

Introduction to the Scientific Method

**What is the Scientific Method, and how is it applied to answer questions and solve problems in the real world?*

Scientific Method» Systematic process through which scientists attempt to answer questions and solve real world problems through experimentation and data analysis.

Scientific Method Procedure:

1. Define your question—what is it that you are trying to figure out?

2. Formulate hypothesis—develop a simple, testable explanation for the question at hand (hypothesis must be falsifiable—capable of being false, as well as true).

3. Perform experiment to test hypothesis—collect and analyze experimental data.

4. Interpret data and draw conclusions—data either supports hypothesis, or does not support hypothesis.

5. Use conclusions to develop new questions and formulate new hypotheses—for data supported hypothesis, use conclusions as the starting point to formulate additional questions and hypotheses that extend from original question; for unsupported hypothesis, redefine your question and formulate a new hypothesis to be re-tested.

Global Warming Example:

1. The Earth appears to be warming up; let's look at global temperature patterns during the 20th century to see if there's been a warming trend.

2. Hypothesis: The Earth's temperature, on average, has been trending upward during the 20th century.

3. Experiment: Collect and analyze global temperature data for the 20th century.

4. Interpret data and draw conclusions: Data supports hypothesis.

5. Additional questions: Why has the Earth's temperature, on average, been trending upward during the 20th century?

   What effects might this trend have on natural systems? human systems?

   Can this trend be slowed or reversed?

Additional hypotheses: The upward temperature trend is due to the rapid accumulation of greenhouse gases such as CO_2 and CH_4.

The upward temperature trend is causing a shift in migratory patterns among North American bird species.

The upward temperature trend is accelerating.

If the evidence supports multiple hypotheses from the vast majority of experiments on a given subject, then the hypotheses, taken as a whole, may be elevated to a ***scientific theory***.

Scientific Hypotheses, Theories, and Laws

**How are hypotheses, theories, and laws defined for scientific applications, and how are they utilized within the context of the Scientific Method to answer questions and solve real world problems?*

Hypothesis» A generalized statement used to explain an observed phenomenon. Hypotheses must be testable, falsifiable, and based on observed phenomena or extensions of scientific theories.

Theory» A set of hypotheses that are logically bound together to form a widely accepted scientific principle supported by empirical evidence. Scientific theories are ways of explaining *how* and *why* things happen, and as such, may change over time as new evidence accumulates. Scientific theories are not based on unsubstantiated *guesses* or *hunches*; instead scientific theories are dynamic, multi-faceted, and empirically based explanations for how the world works. Scientific theories that have been confirmed by repeated scientific experiments over many years, and have become universally accepted by the scientific community may be elevated to a ***scientific law***.

Law» Long-standing, universally accepted scientific principle supported by unequivocal empirical evidence. Scientific laws tend to have universal applications; that is, they always work the same way under the same conditions. For example, the law of gravity applies universally to any object on Earth that has a mass, and will have the same influence under the same conditions no matter where on Earth you are.

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Systems Theory

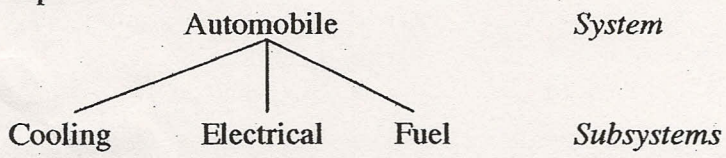
**What is Systems Theory, and how is it utilized for understanding the complex relationships that drive the physical processes on Earth?*

Systems Theory» A logically bound set of scientific principles that demonstrate the complexity and interdependence among Earth's biological, physical, and sociological components.
Systems Theory demonstrates how everything on Earth (and in the Universe) is intimately connected, and how changes at one level within a *system* will ultimately affect every other level of that *system.*

***System»* A group of interrelated things all working together.**

Systems can combine to form larger systems or be broken down into smaller systems, or "subsystems" of the larger system.

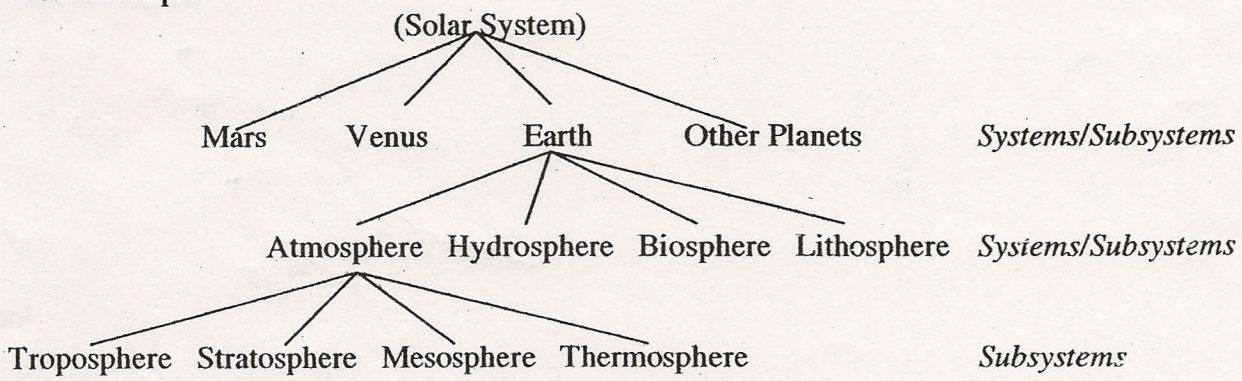
Automobile Example:



If any of these subsystems are altered, the system as a whole may shift to a new operational level (likely a diminished operational level from our perspective).

**How does Earth operate as a system? As a subsystem?*

Earth Example:



Open vs. Closed Systems

Open System» **Any system that freely exchanges energy, matter, information, etc. with other systems.**

Closed System» **Any system that does not freely exchange energy, matter, information, etc. with other systems.**

Earth is considered to be an **open system in terms of energy**, and a **closed system in terms of matter**. Why?