I. A very brief history of science
   1. Aristotle (384-322 BC) studied “natural philosophy” and laid the foundations for “classical” science (and philosophy) and “empiricism”
      a. First laws of motion (based on elements – wrong!)
      b. Example: vole population dynamics
      c. Syllogism – A logical argument using deductive reasoning and overlapping propositions to come to a conclusion.
   2. The plague in Europe (1348) caused a decline in science but this was followed by the enlightenment and scientific revolution (obviously LOTS happened between Aristotle and 1348 but for brevity we will move on for now).
   3. Rene Descartes (1596-1650) formalized the scientific method
      a. The Discourse on the Method outlined a foundation for modern natural sciences (doubt everything, use reason).
      b. Rationalism – use logical, math and proofs to make conclusions.
      c. Descartes was also one of the early proponents of reductionism.
   4. Isaac Newton (1642-1726) is the seminal figure in the scientific revolution.
      a. Developed classical mechanics and the basis for modern physics.
      b. Three laws of motion allowed for basis for understanding the physical world scientifically through math (he also invented calculus).
      c. The clockwork universe was an idea directly following Newton’s laws – the behavior of the universe and its parts are predictable (like a clock).
      d. Pierre-Simon Laplace took these ideas to the logical conclusion (determinism): if you know the precise location and velocity of every particle in the universe, one (Laplace's demon) could predict everything.
      e. Lots of scientists felt that by the end of the 19th century all essential physics problems had been solved.

II. Reductionism
   1. Epistemological reductionism – one body of knowledge (e.g. physics) can be understood by reducing it through the use of another (e.g. math)
   2. Ontological reductionism – complex things don’t exist, only the smaller constituent parts (metaphysics)
   3. Methodological reductionism – “…the idea that complex systems or phenomena can be understood by the analysis of their simpler components.”
      a. Paraphrasing Descartes, ‘start with simple to understand the complex’
      b. Hugely successful! Newton!
      c. But also with some significant limitations.
         i. For example, in medicine, an overly simplistic emphasis on small pieces (e.g. genes, mutations, proteins) could lead to costly (in terms of money and lives) errors.
         ii. Many advocate for a systems approach to medicine.
         iii. The whole is more than the sum of its parts (emergence) – for example, sodium and chlorine are volatile elements on their own, together they are salt (which is yummy).
III. Complexity Definition

1. The word “complexity” comes from a Latin term meaning “interwoven”.
2. “Complex system: a system in which large networks of components with no central control and simple rules of operation give rise to complex collective behavior, sophisticated information processing and adaptation via learning or evolution.”
3. Ants provide an excellent case study for the study of complexity.
   a. Alone they are simple beings which follow simple rules (chemical trails), together they form complex societies.
   b. They’re great problem solvers – how to get food over this chasm?
4. Lots of examples of complex systems (which we will detail later on).
   a. Insect colonies (e.g. ants)
   b. The brain – neurons themselves will provide little info as to how we think, it’s the connections (the neural network) that’s important.
   c. Immune system – fight off infections using simple rules.
   d. Global economy – best examined as a complex system with critical players in the network (remember Lehman Bros?).
   e. World wide web – how many friends do you have on Facebook?

IV. Features of complexity

1. Collective complex behavior – individual constituent parts following simple rules with no central leader which collectively lead to complex behavior.
2. Signal information and processing – use and receive information from the internal and external environment.
3. Adaptation – behavioral change (through adaptation or learning) which improves survival and success.
5. Emergence – whole more than the sum of parts.
6. Non-linear/butterfly effects – small changes in initial conditions can have big impacts on later states.

V. Understanding ecology as a complex system

1. Ecologists see lots of patterns in nature and are constantly trying to discover “universal laws” (Newton envy!).
2. Sometimes the complexity should not be ignored however.
   a. In Yellowstone wolves are known to impact vegetation (improve tree growth) through the hunting of elk (who eat trees).
      i. Many efforts to use wolves as a means of restoration.
      ii. But this ignores the reality of the situation (many factors).
3. Recent efforts in ecology have urged an embracing of an “elegant chaos”.
4. Some have argued that we cannot predict climate change and so we should not act enact climate change policy. But actually there is a “simplicity amid complexity” and patterns do emerge from climate change modeling.
5. We can even turn the butterfly effect on its head and study how small changes in butterfly orientation may impact its response to climate change.
6. The Aleutian Islands are a relatively simple ecological system. But even in this simple system there lies a complex food web.
7. Complexity is what makes science so great! Embrace it! In this course we will show you how.