1. Reductionism: A VERY successful story
   - Nature is simple: the art of modeling
     search for the basic constituents
     search for the fundamental laws

But...we have found limitations of reductionistic approach:
   - **kinetic theory of gases**: hopeless to describe each molec.
     systems with many interacting particles/parts
   - **the 3 body problem**: add a 3rd planet and Newtonian orbits are hopelessly complicated
     behavior is deterministic but **chaotic** (unpredictable)

Poincarè (1892): If can’t solve 3-body problem, can’t prove stability of solar system...

Determinism of classical physics does not lead to an ordered cosmos!
A Cosmos Full of Patterns

• The Seductive Beauty of Symmetry

Symmetry is so clever... How Does it Emerge?
• What about the brain and the weather? Complicated systems cannot be described by reductionism…
• WHY?
  because behavior is not repeatable:
  run 100 experiments and get 100 different results!
  ➞ complexity leads to uncertainty
• WHY?
  because complicated systems have nonlinear behavior:
  ➞ no exact solutions in most cases
  ➞ sensitivity to initial conditions
  ➞ interactions w/ “environment” are crucial

Need a new science of chaos and complexity!
2. CHAOS

- Chaotic behavior consequence of nonlinearities in system
- Chaos is due to sensitivity to initial conditions
- Chaos is unpredictable but deterministic (use computers)
- Chaos can lead to order through self-organization:
  - Regular patterns emerge out of chaotic background
- Chaos can lead to complexity
3. Complexity

- Hard to define: an *emergent property* of
  a) many-particle systems: gases, many electron atoms (unpredictability)
  b) nonlinear systems interacting w/ environment: ordered structures, patterns
Consciousness, life, weather, phase transitions are complex systems

- Need a new language: global properties, qualitative description
  no exact predictability
- physics of self-organizing systems