VIII. Review of Key Concepts

Complex Systems
- Many interacting elements
- Local vs. global order: entropy
- Scale (space, time)
- Phase space
- Difficult to understand
- Open systems

Many Interacting Elements
- Massively parallel
- Distributed information storage & processing
- Diversity
  - avoids premature convergence
  - avoids inflexibility

Complementary Interactions
- Positive feedback / negative feedback
- Amplification / stabilization
- Activation / inhibition
- Cooperation / competition
- Positive / negative correlation

Emergence & Self-Organization
- Microdecisions lead to macrobehavior
- Circular causality (macro / micro feedback)
- Coevolution
  - predator/prey, Red Queen effect
  - gene/culture, niche construction, Baldwin effect

Pattern Formation
- Excitable media
- Amplification of random fluctuations
- Symmetry breaking
- Specific difference vs. generic identity
- Automatically adaptive
Stigmergy
- Continuous (quantitative)
- Discrete (qualitative)
- Coordinated algorithm
  - non-conflicting
  - sequentially linked

Emergent Control
- Stigmergy
- Entrainment (distributed synchronization)
- Coordinated movement
  - through attraction, repulsion, local alignment
  - in concrete or abstract space
- Cooperative strategies
  - nice & forgiving, but reciprocal
  - evolutionarily stable strategy

Attractors
- Classes
  - point attractor
  - cyclic attractor
  - chaotic attractor
- Basin of attraction
- Imprinted patterns as attractors
  - pattern restoration, completion, generalization, association

Wolfram’s Classes
- Class I: point
- Class II: cyclic
- Class III: chaotic
- Class IV: complex (edge of chaos)
  - persistent state maintenance
  - bounded cyclic activity
  - global coordination of control & information
  - order for free

Energy / Fitness Surface
- Descent on energy surface / ascent on fitness surface
- Lyapunov theorem to prove asymptotic stability / convergence
- Soft constraint satisfaction / relaxation
- Gradient (steepest) ascent / descent
- Adaptation & credit assignment

Biased Randomness
- Exploration vs. exploitation
- Blind variation & selective retention
- Innovation vs. incremental improvement
- Pseudo-temperature
- Diffusion
- Mixed strategies
Natural Computation

- Tolerance to noise, error, faults, damage
- Generality of response
- Flexible response to novelty
- Adaptability
- Real-time response
- Optimality is secondary

Student Course Evaluation!