

VIII. Review of Key Concepts

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Complex Systems

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

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Many Interacting Elements

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

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Complementary Interactions

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

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Emergence & Self-Organization

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

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Pattern Formation

- Excitable media
- Amplification of random fluctuations
- Symmetry breaking
- Specific difference vs. generic identity
- Automatically adaptive

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Stigmergy

- Continuous (quantitative)
- Discrete (qualitative)
- Coordinated algorithm
 - non-conflicting
 - sequentially linked

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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

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Attractors

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

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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

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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

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Biased Randomness

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

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Natural Computation

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

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Student Course Evaluation!

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