VIII. Review of Key Concepts

Natural Computation

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

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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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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Biased Randomness

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

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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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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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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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Doing Research in
Bio-inspired Computation

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Keeping Abreast of Research

- An interdisciplinary field, so it's not sufficient to read just computing journals
- <u>General science</u>: to keep abreast of potentially relevant research
- <u>Complex systems</u>: integrative and overarching research
- <u>Specific bio-inspired journals</u>: neural networks, cognitive science, evolutionary computing, artificial life, swarm intelligence, etc.
- There are more journals than you can read, so subscribe to science news feeds, etc.

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General Science Journals

- *Science* (AAAS)
  - via library you have full internet access
  - go to www.sciencemag.org for podcasts, webinars, etc.
- *Nature*
  - via the library you have full internet access
  - go to www.nature.com for podcasts, etc.
  - also *Nature Neuroscience, Nature Reviews Neuroscience*, etc.
- *Science News, Scientific American, Scientific American Mind*, etc.

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Journals Especially Relevant to Bio-inspired Computing

- *Natural Computing*
- *Artificial Life*
- *Adaptive Behavior*
- *Int. Journ. Bio-inspired Computation*
- *Intl. Journ. of Unconventional Computing*
- many neural network journals

- *Physica D*
- *Advances in Complex Systems*
- *Biological Cybernetics*
- *Complex Systems* (Wolfram)
- *Intl. Journ. of Nanotechnology and Molecular Computation* (which I edit)

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Student Course Evaluation!

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