The nexus of biology and computing

Small scale and complexity are forcing advances in computational methodologies

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Bio – Melanie Swan

- Educational background:
  - BA French & Economics, Georgetown University
  - MBA Finance & Accounting, Wharton, Univ. of Pennsylvania
  - Current course work in Physics & Computer Science

- Professional experience
  - Futurist: speaker, researcher, business advisor
  - Hedge Fund Manager: Wall Street, proprietary

- Current projects
  - OpenBasicResearch.org
  - del.icio.us for people
  - Issues in running Historical Simulations

- Interests: science fiction, travel
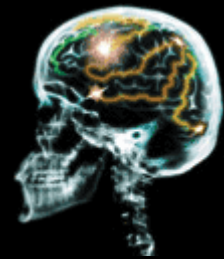
Summary: Seven principles suggest future advances in computational methodologies

1. **Approaches to computation** – approaches of parallelism
2. **Architecture** – modularity, simplicity and ubiquity of structure
3. **Goals** – broadly defined objectives to drive higher value results
4. **Modulation mechanisms** – information modulation
5. **Prediction mechanisms** – probabilistic models
6. **Unconscious processing** – unobtrusiveness computing
7. **Multidisciplinarity** – adjacent discipline integration

1. Approaches to computation

- Traditional: Von Neumann

  - Linear

- Current and future: non-Von Neumann

  - Cellular, tissue, systemic, holistic focus

  - Parallelism and multicores in hardware and software

  - DNA computing

  - Quantum computing

  - Genetic computing

  - Evo-devo: blend of bottom up emergence / top down design

- <u>Suggests biological and other approaches facilitating parallelism are required for molecular scale computing</u>
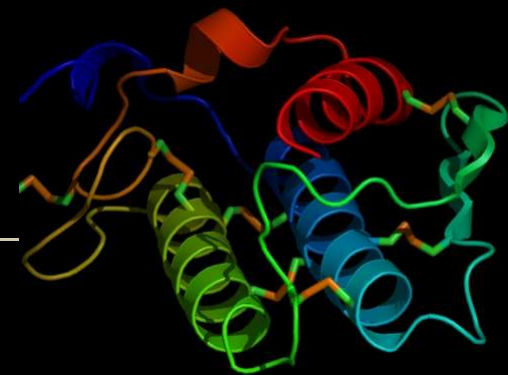
2. Architecture
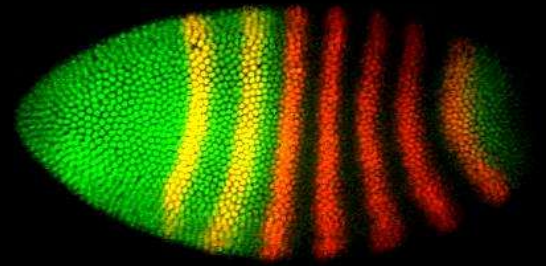
- Conservation
  - Across simple and complex organisms
  - Across processes within one organism
  - Across time, evolution
- Structure
  - Same loose administrative over-structures, diverse applications
- Redundancy in architecture and process
- Massively distributed individual agents

- <u>Suggests modularity, simplicity and ubiquity of underlying structure</u>

3. Goals

Systemic, holistic	Traditional, singular
▪ Clusters of functionality, capability, redundancy ▪ Loose process, many outcomes ▪ Service paradigm ▪ Focus on obtaining useful information	▪ One precise goal or outcome ▪ Tightly directed process coupled to outcome ▪ Task paradigm ▪ Exclusive focus on THE solution

▪ <u>Suggests more broadly defined objectives drive higher value results</u>

4. Modulation mechanisms
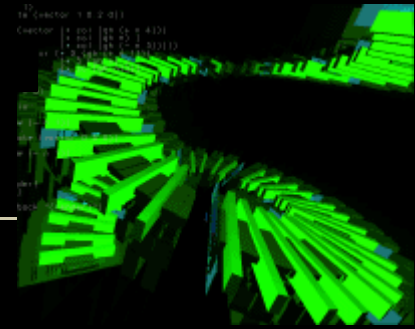
- Short and long-term memory:
    - An implemented evaluation of the importance of information
- Brain automatically modulates importance
- Computing can better modulate information with attributes signaling relevance, value, accuracy, etc.
    - Repetition, time-based algorithms
    - Web 2.0 marks relevance and importance
        - Scientific Research 2.0 – digg for PubMed, RSS peer feeds, collaborative research paper commenting and annotation

- <u>Suggests much higher levels of information modulation with relevance attributes</u>

5. Prediction mechanisms

- Prediction is a strong biological mechanism
- Explosion in predictive, probabilistic, statistical, Bayesian papers and applications
  - Numenta
  - Google
- Key parameters of successful probabilistic model implementation
  - Large data corpus
  - Abstraction processes

- <u>Suggests greater development and application of probabilistic models</u>
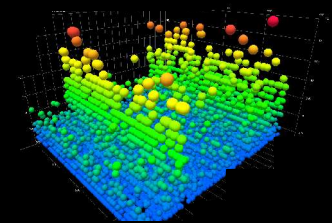
6. Unconscious processing
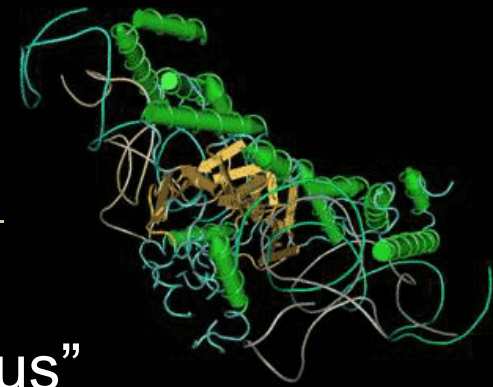
- Brain processes mainly unconsciously
- Some computer processing is "unconscious"
  - AI, virus scans, ajax websites
- Other computer processing is very obvious
  - Memory, processing, storage
  - Heat, power, battery
  - Connectivity
- Processing will become less conscious
  - Wearables, pen computing, visualization, simulation
  - Ubiquitous embedded chips, sensors, connectivity

- <u>Suggests a focus on less obtrusiveness computing</u>

7. Multidisciplinarity
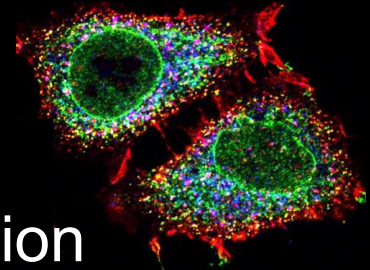
- Cross-field collaboration and new area definition
    - Molecular cognition, molecular science of behavior
- Systems biology
    - Quantitative measurement and mathematical analysis
    - Systems level studies: focus on quantitative aspects and interactions among elements
    - Need to standardize: an eigenvalue by any other name
- Multidisciplinary cataloging of all biological information
    - E.O. Wilson Encyclopedia of Life

- Suggests greater integration of adjacent disciplines in pursuit of open research questions

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7. **Multidisciplinarity**

   – adjacent discipline integration
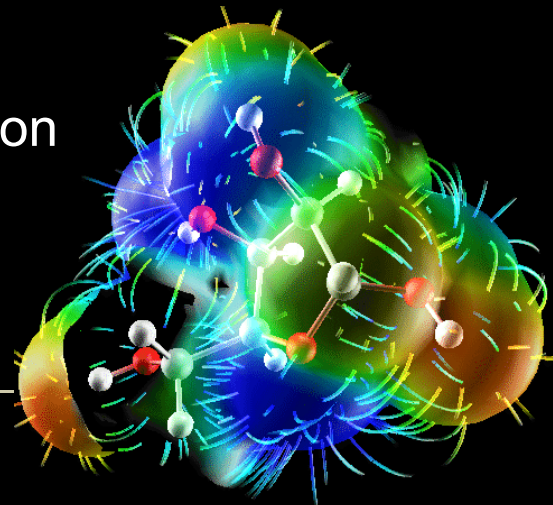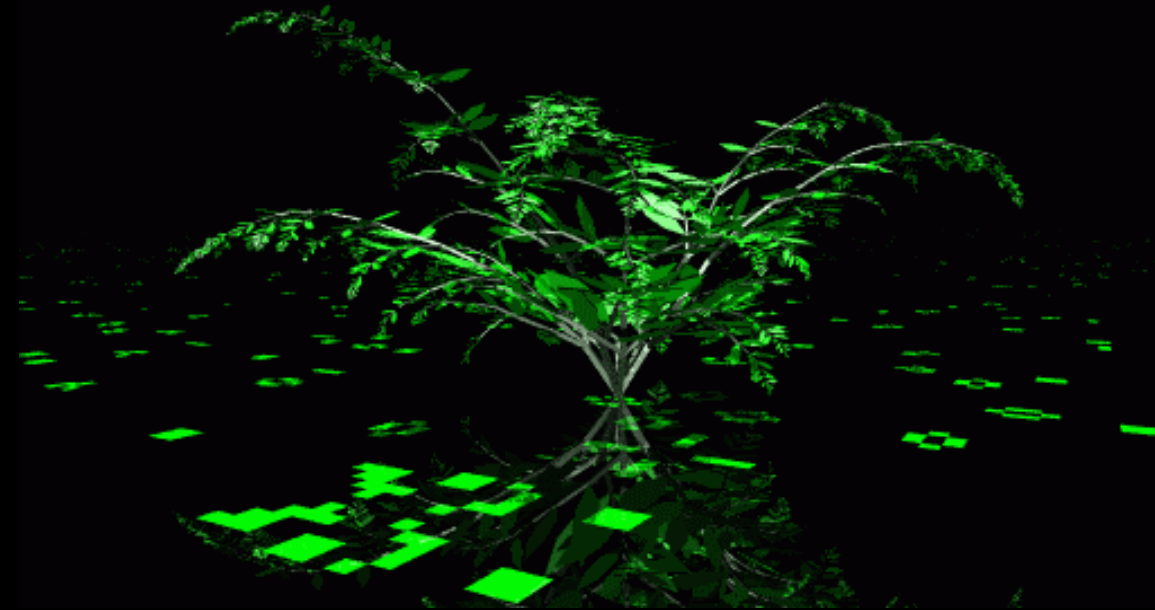
Thank you

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