CS 420/594

(Advanced Topics in Machine Intelligence)

Complex Systems and Self-Organization

Bruce MacLennan

http://www.cs.utk.edu/~mclennan/Classes/420

Contact Information

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CS 420 vs. CS 594

- CS 420: Undergraduate credit (but graduate students can count one 400-level course)
- CS 594: Graduate credit, additional work

Grading

- You will conduct a series of computer experiments, which you will write up
- Some of these will be run on off-the-shelf simulators
- Others will be run on simulators that you will program
- Graduate students will do additional experiments and mathematical exercises
- No exams

Prerequisites

- CS 420 & 594: None per se, but you will be required to write some simulations (in Java, C++, or whatever)
- CS 594: Basic calculus through differential equations, linear algebra, basic probability and statistics

Textbooks

- CS 420 & 594: Flake, Gary William. *The Computational Beauty of Nature*. MIT Press, 1998
- CS 594: Bar-Yam, Yaneer. *Dynamics of Complex Systems*. Perseus, 1997. This book is available online in pdf format

Contents of Flake CBN

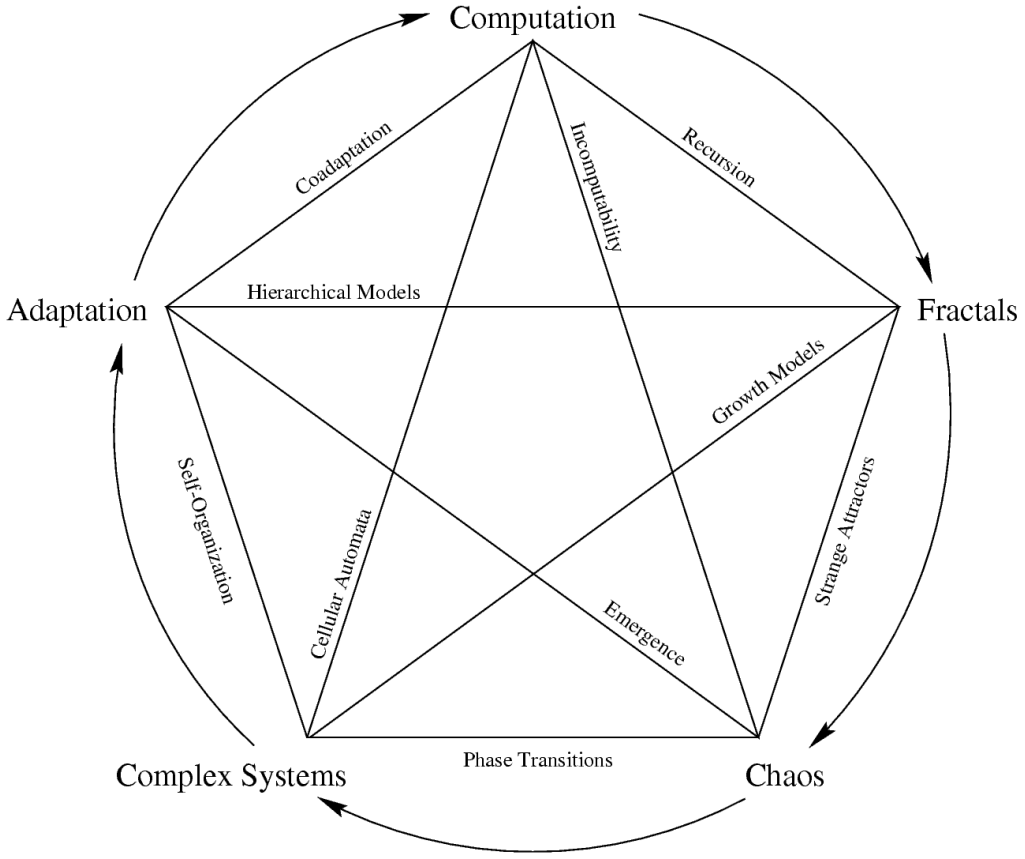


Figure 1.1 An association map of the contents of this book

What We Will Cover

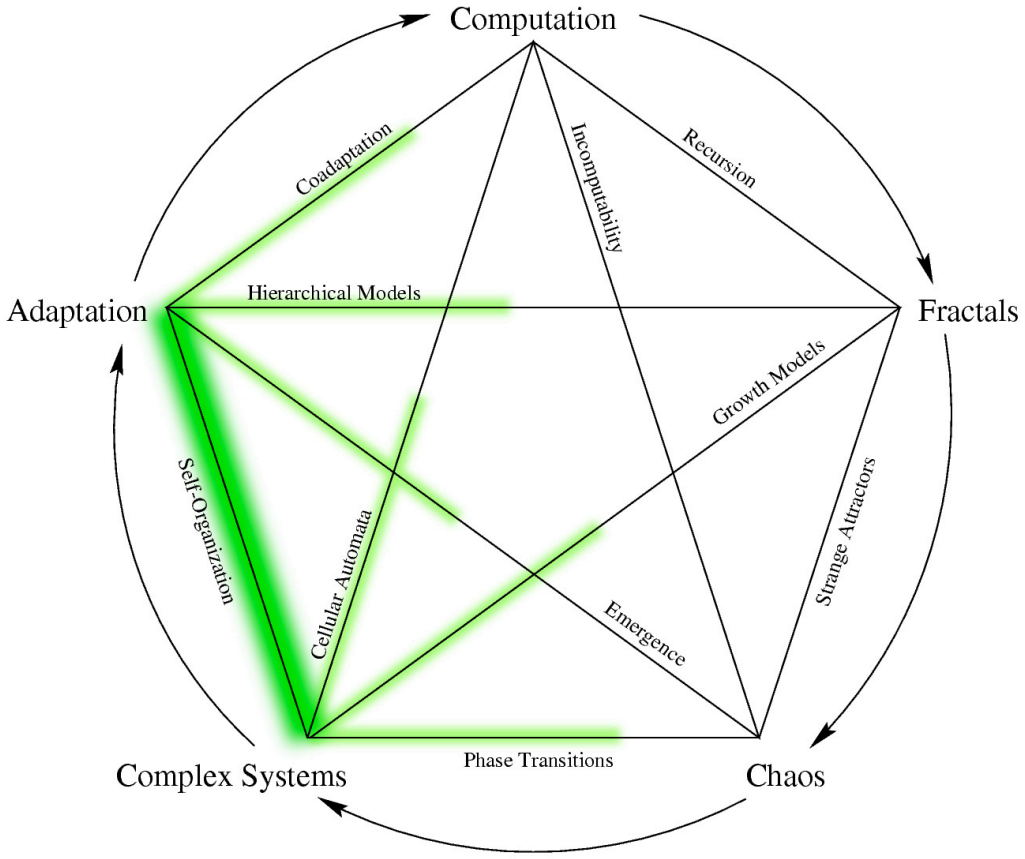


Figure 1.1 An association map of the contents of this book *that we will cover*

Reading for Next Week

- Flake: Ch. 1 (Introduction)
- Flake: Ch. 15 (Cellular Automata)
- 594: Bar-Yam: Sec. 1.5 (Cellular Automata)

Course Web Site

- www.cs.utk.edu/~mclennan/Classes/420
- Syllabus
- Link to Flake *CBN* site (with software etc.)
- Link to Bar-Yam (CS 594) online text
- Links to other interesting sites
- Handouts:
  - assignments
  - slides (after class) in powerpoint, html, other? formats

Discussion

- What is a *complex system*?
- What is an *emergent property*?
- What is *self-organization*?

Weaver's Stages in the Progress of Science

- Simple systems
- Disorganized complexity
- Organized complexity

Complex vs. Simple Systems

- Have many parts
- Parts are interdependent in behavior
- Difficult to understand because:
  - behavior of whole understood from behavior of parts
  - behavior of parts depends on behavior of whole

Examples of Complex Systems

- government
- family
- person (physiology)
- brain
- world ecosystem
- local ecosystem (desert, rainforest, ocean)
- weather
- corporation
- computer
- ant colony
- university

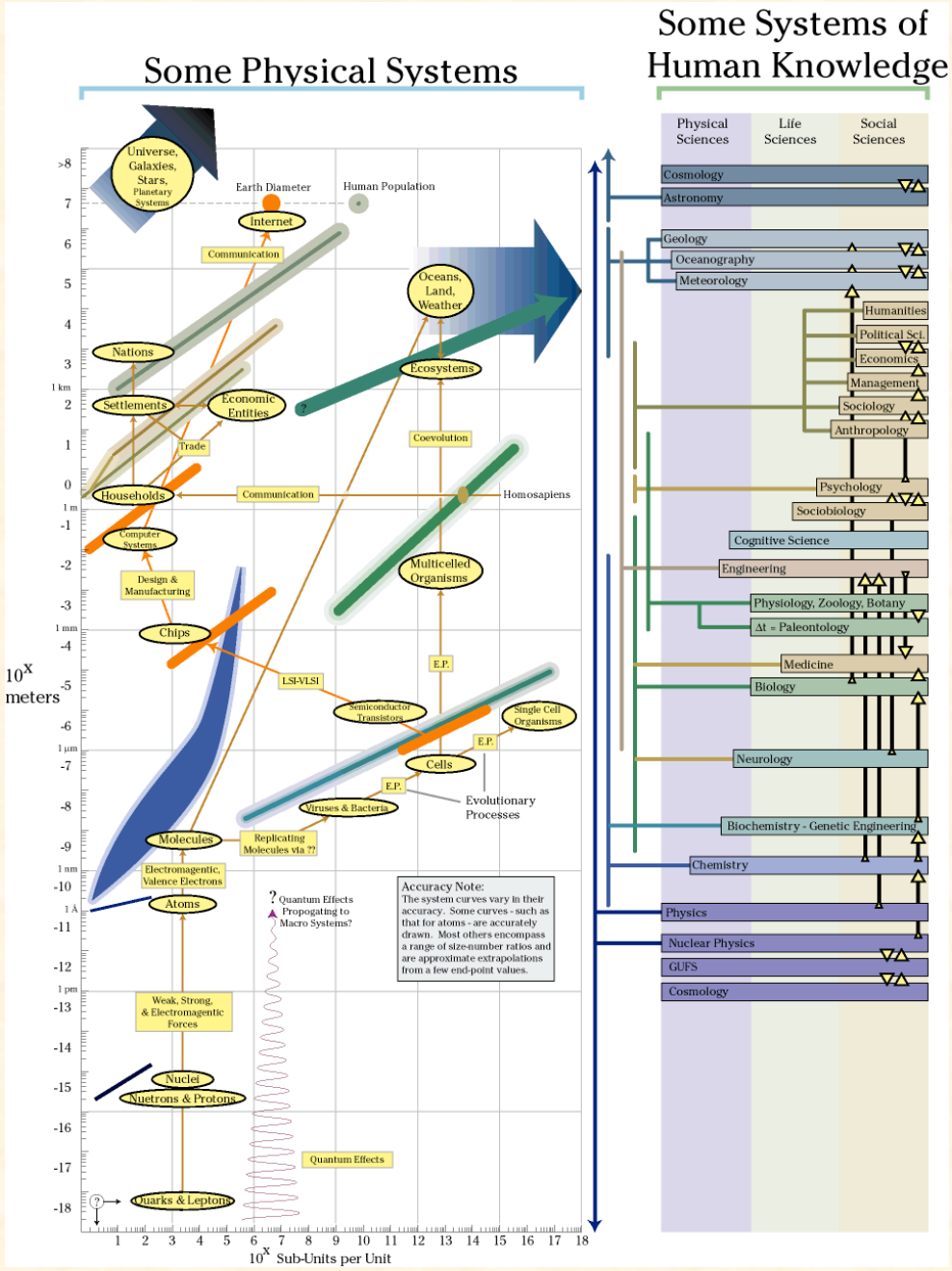


Fig. from NECSI

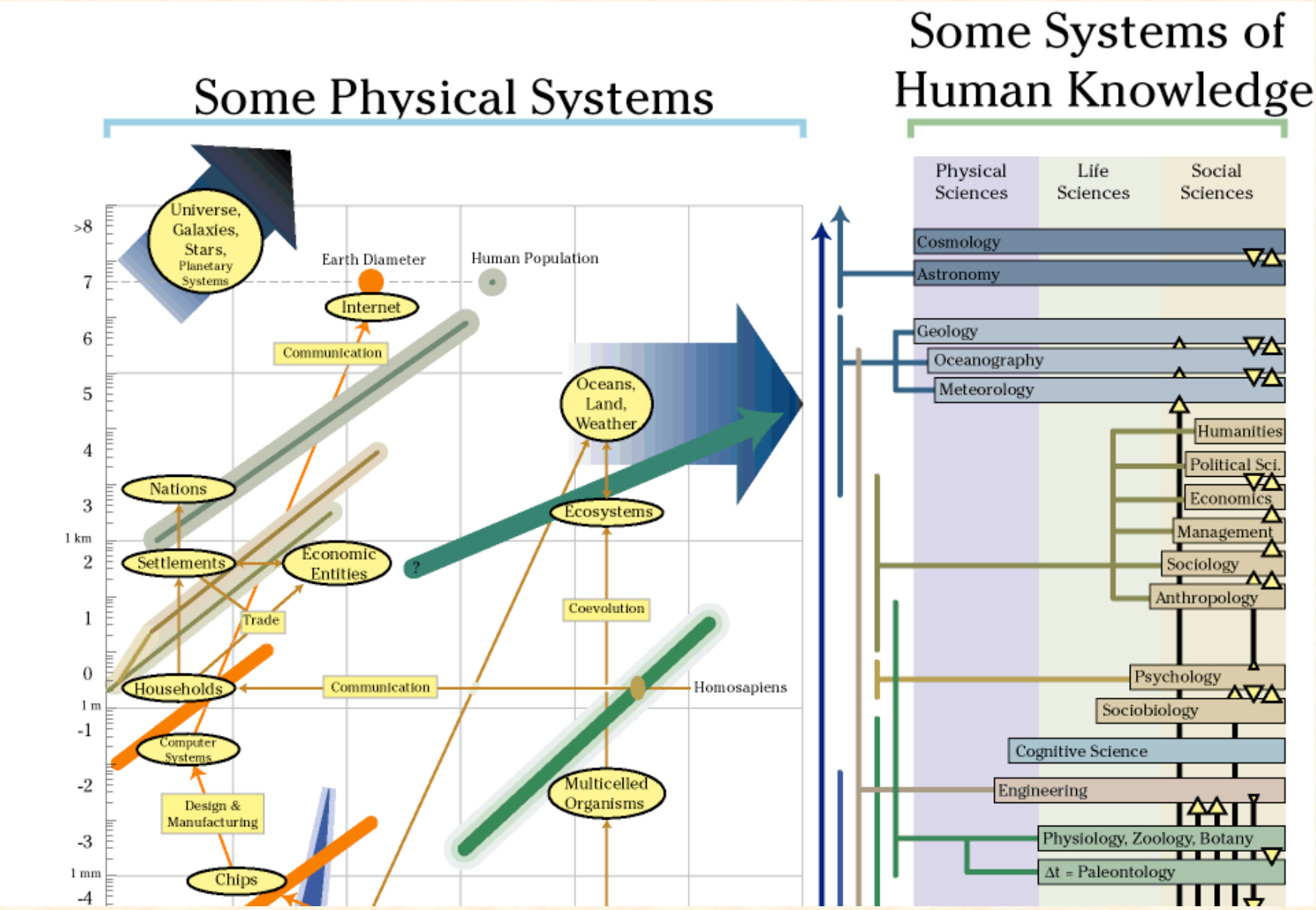


Fig. from NECSI

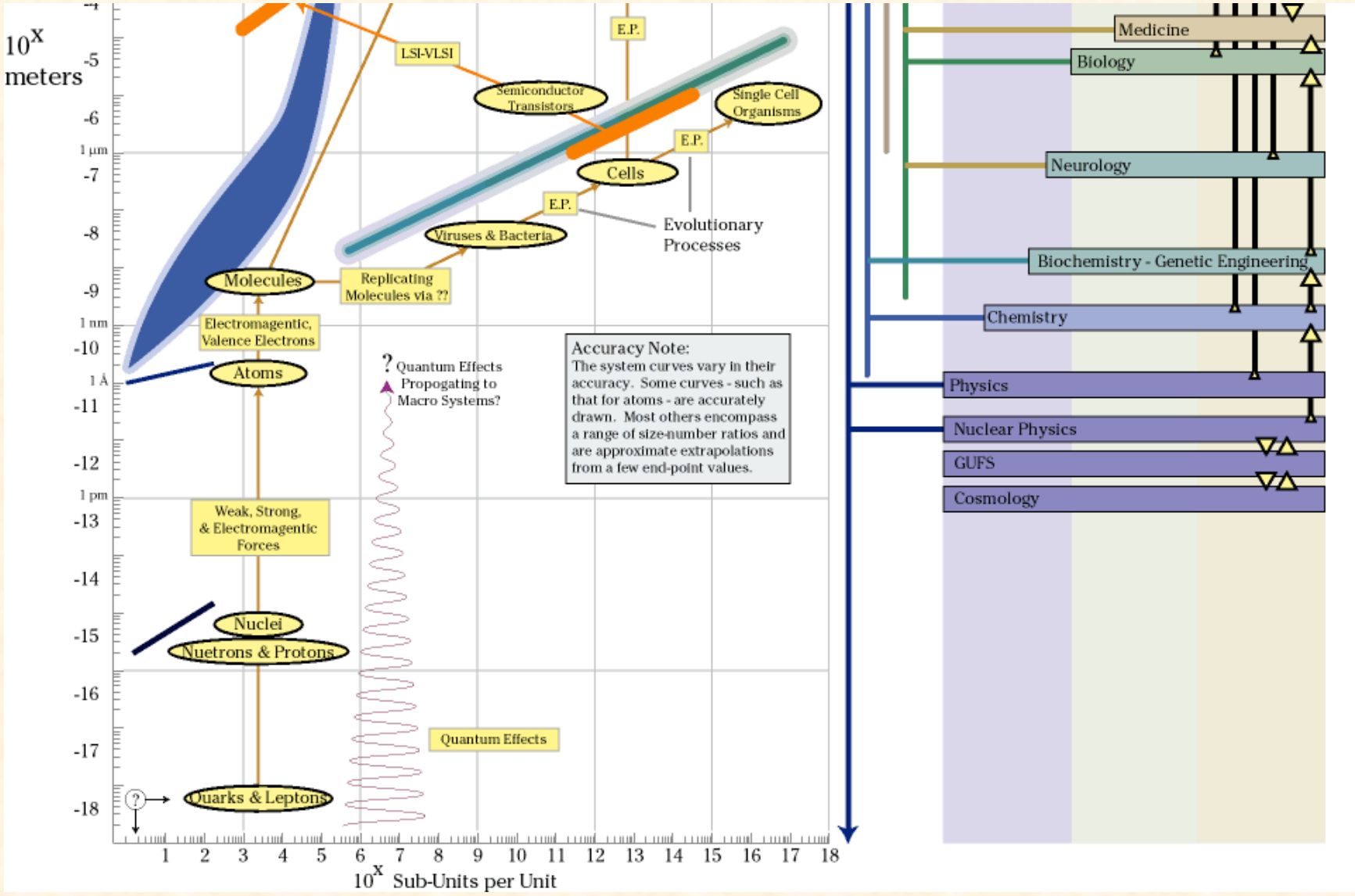
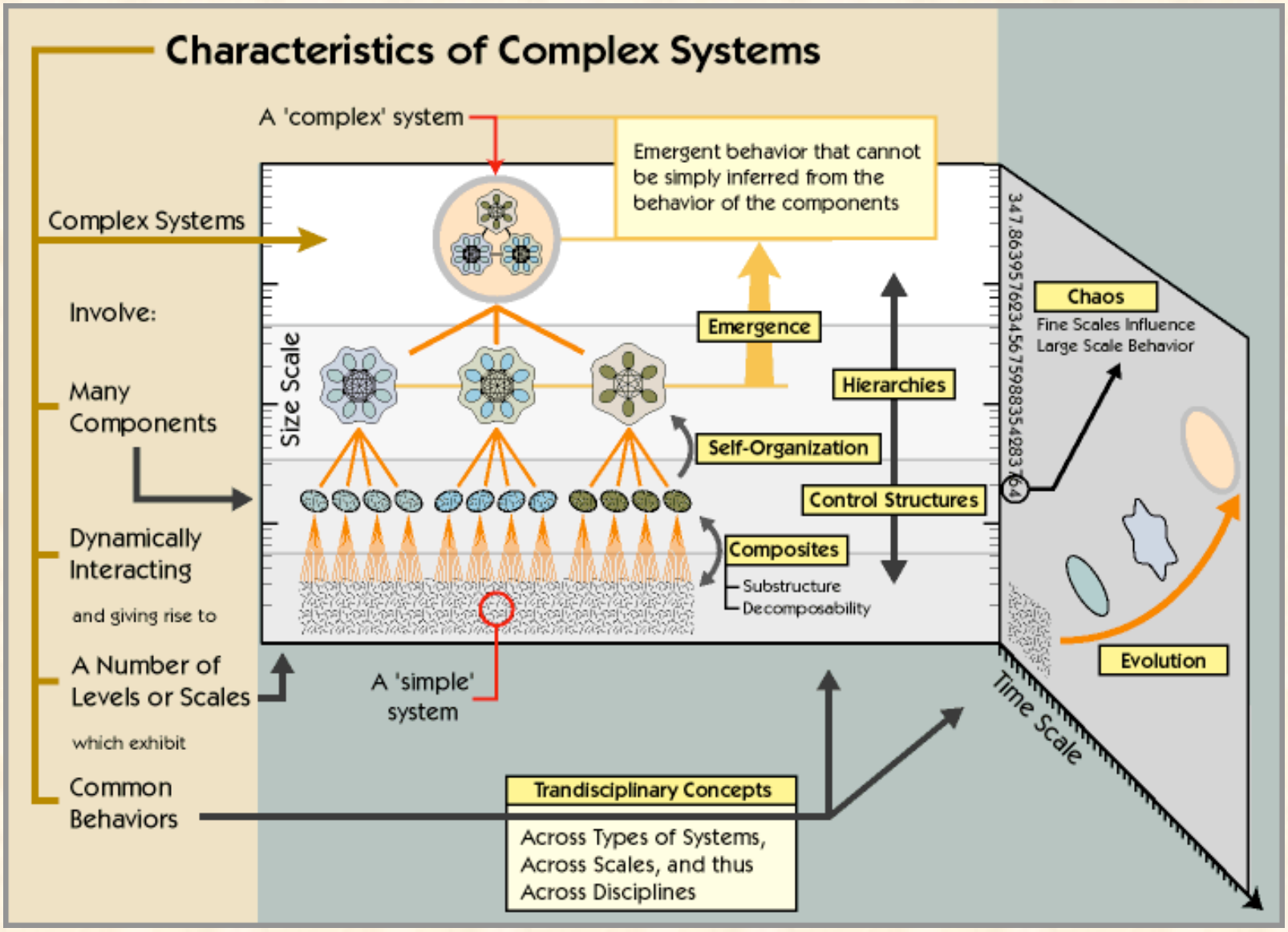


Fig. from NECSI

What are the *universal properties* shared by all complex systems?

Central Properties

- Elements (& their numbers)
- Interactions (& their strengths)
- Formation/operation (& their timescales)
- Diversity/variability
- Environment (& its demands)
- Activities (& their objectives)


Characteristics of Complex Systems
A 'complex' system
Emergent behavior that cannot be simply inferred from the behavior of the components
Complex Systems
Involve:
Many Components
Dynamically Interacting
and giving rise to
A Number of Levels or Scales
which exhibit
Common Behaviors
Size Scale
Emergence
Hierarchies
Self-Organization
Control Structures
Composites
Substructure
Decomposability
A 'simple' system
Trandisciplinary Concepts
Across Types of Systems, Across Scales, and thus Across Disciplines
Time Scale
347.8639576234567598835428364
Chaos
Fine Scales Influence Large Scale Behavior
Evolution