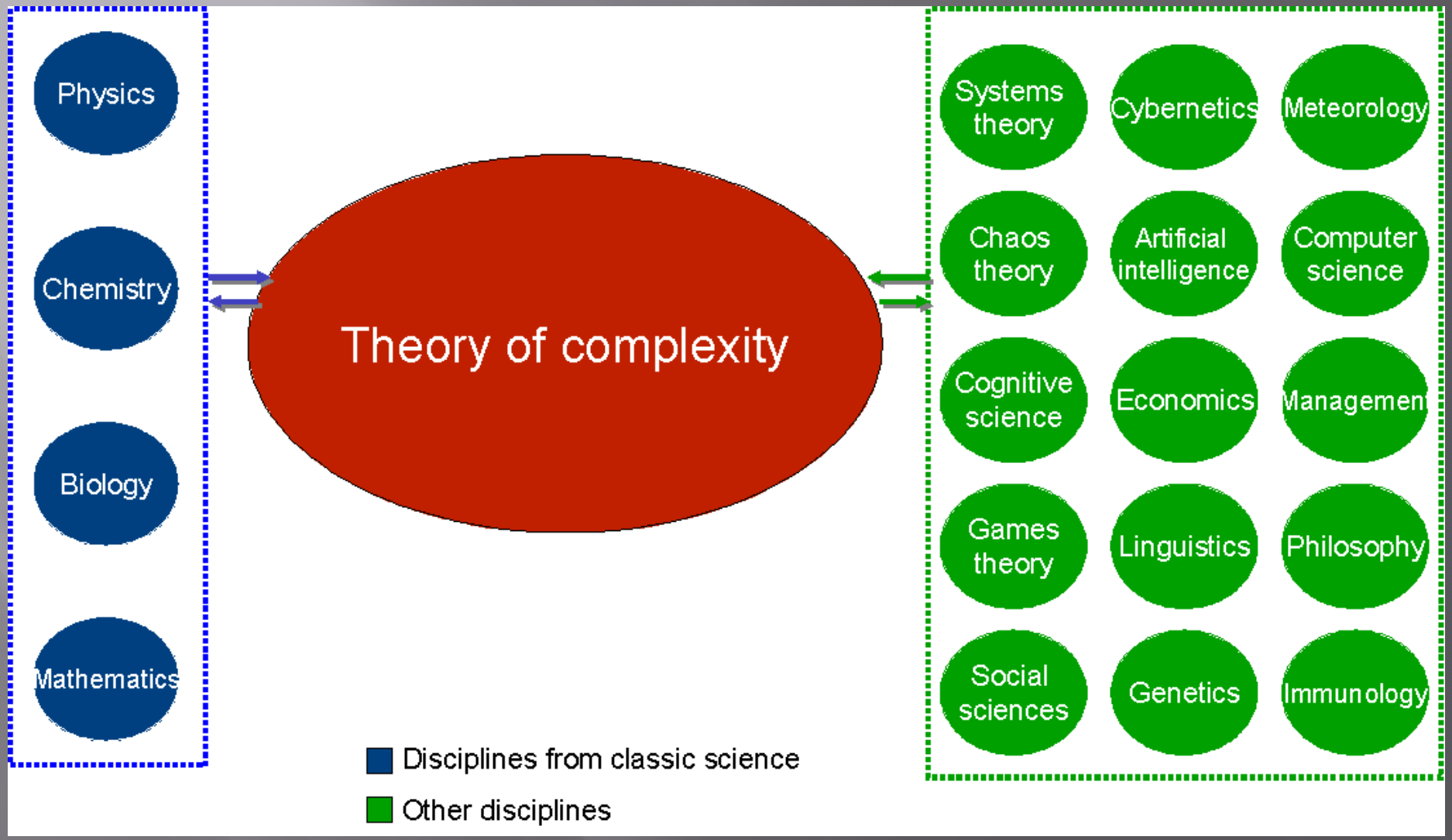
COMPLEXITY AND CRITICAL CARE

Peter R. Holbrook, MD

Professor Emeritus,
George Washington University
School of Medicine
Founder, DiscerningHealth

Disclosure

- Dr. Holbrook is the Founder of DiscerningHealth, a company dedicated to discern the issues in healthcare to facilitate better decision-making


Physics
Chemistry
Biology
Mathematics
Theory of complexity
Systems theory
Cybernetics
Meteorology
Chaos theory
Artificial intelligence
Computer science
Cognitive science
Economics
Management
Games theory
Linguistics
Philosophy
Social sciences
Genetics
Immunology
Disciplines from classic science
Other disciplines

Caveats

- Complexity knowledge is large, expanding
- No unifying/defining theory of complexity is recognized/accepted
- Apparent conflicts with classical physics exist (entropy)
- Many new ideas, fewer solutions

Classical Science

- Isaac Newton (1642-1727)
- Cause and effect, mechanistic, predictable, linear
- Scientific method: Break down problem into component parts, analyze, reassemble; i.e. reductionist
- "If you fully know the past and the extant forces, you can know the future." LaPlace (paraphrase)
- Results over last 350 years impressive

Limitations to Classical Science

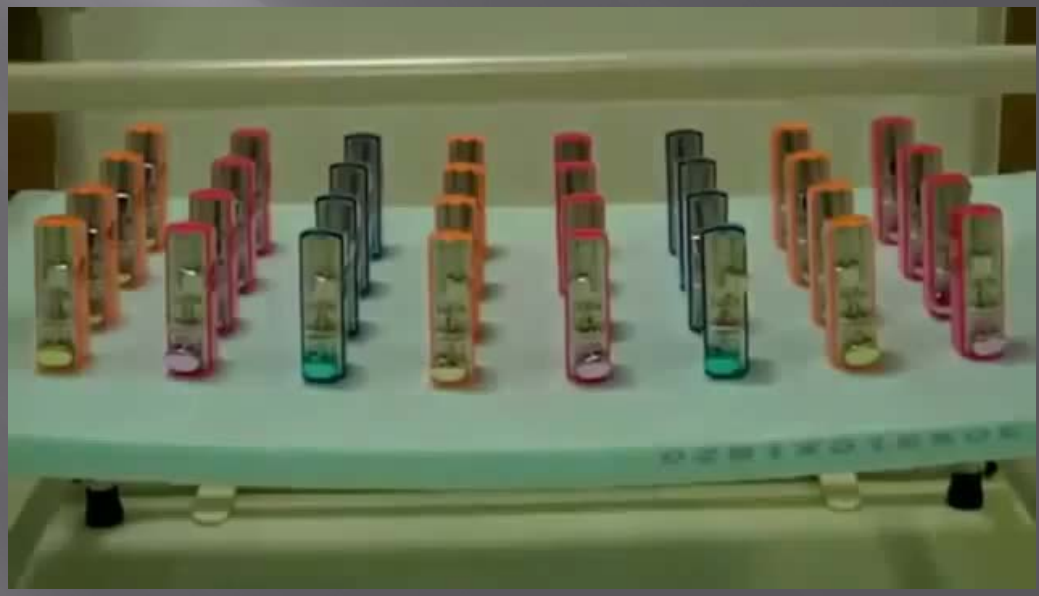
- Variances at the extremes
- Total often greater than sum of parts
- Most of the world is not linear
  - Non elephants.

    Ulam 1991
  - "Every major unsolved problem in science from consciousness to cancer… is non-linear".

    Strogatz 2003
- Serious challenges: Relativity and quantum physics

Inanimate

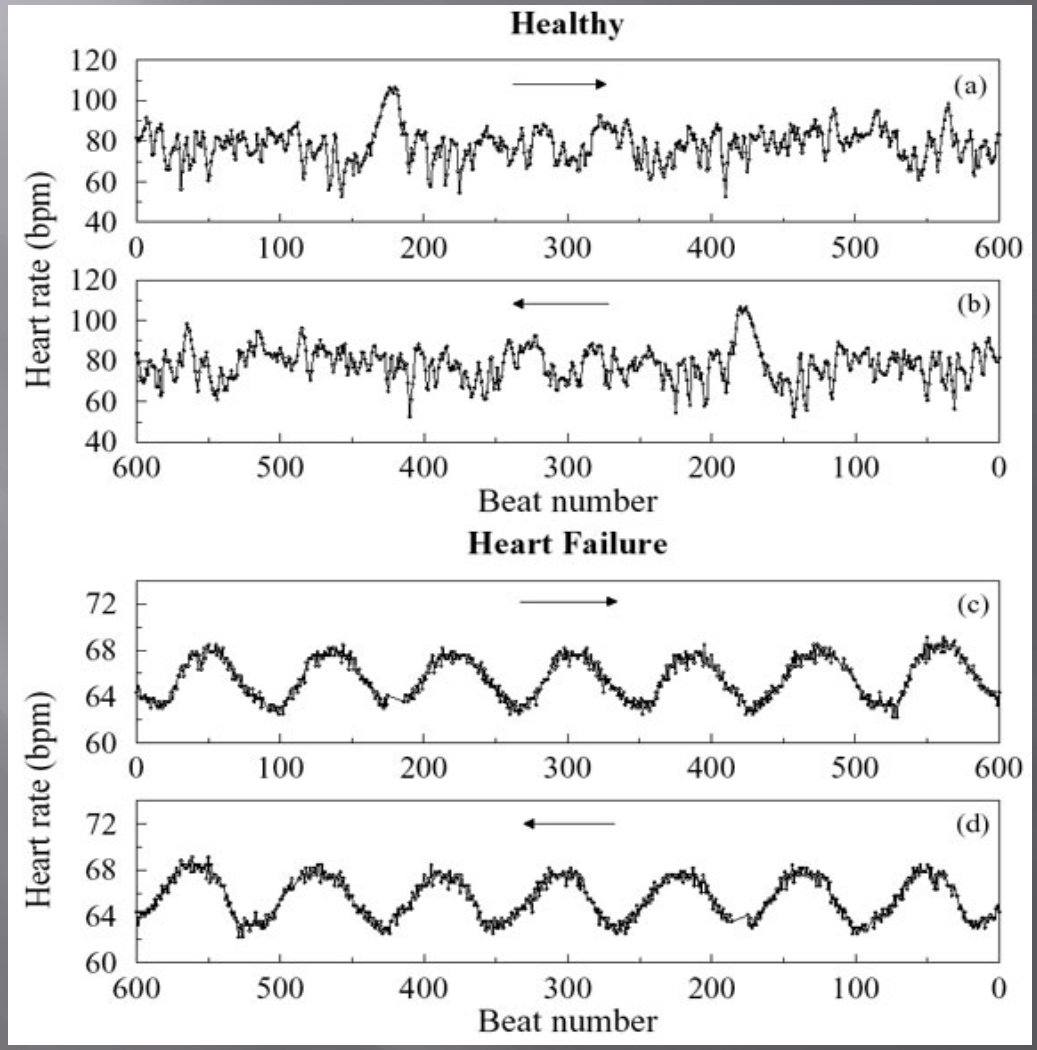
- Independent agents
- No central control
- Able to interact
- Information processing
- Emerging phenomenon
- Synchronization



Synchronization

- Pacemakers (cardiac, respiratory)
- Peristalsis
- Circadian rhythms
- Seizures

Cardiac rhythm and health

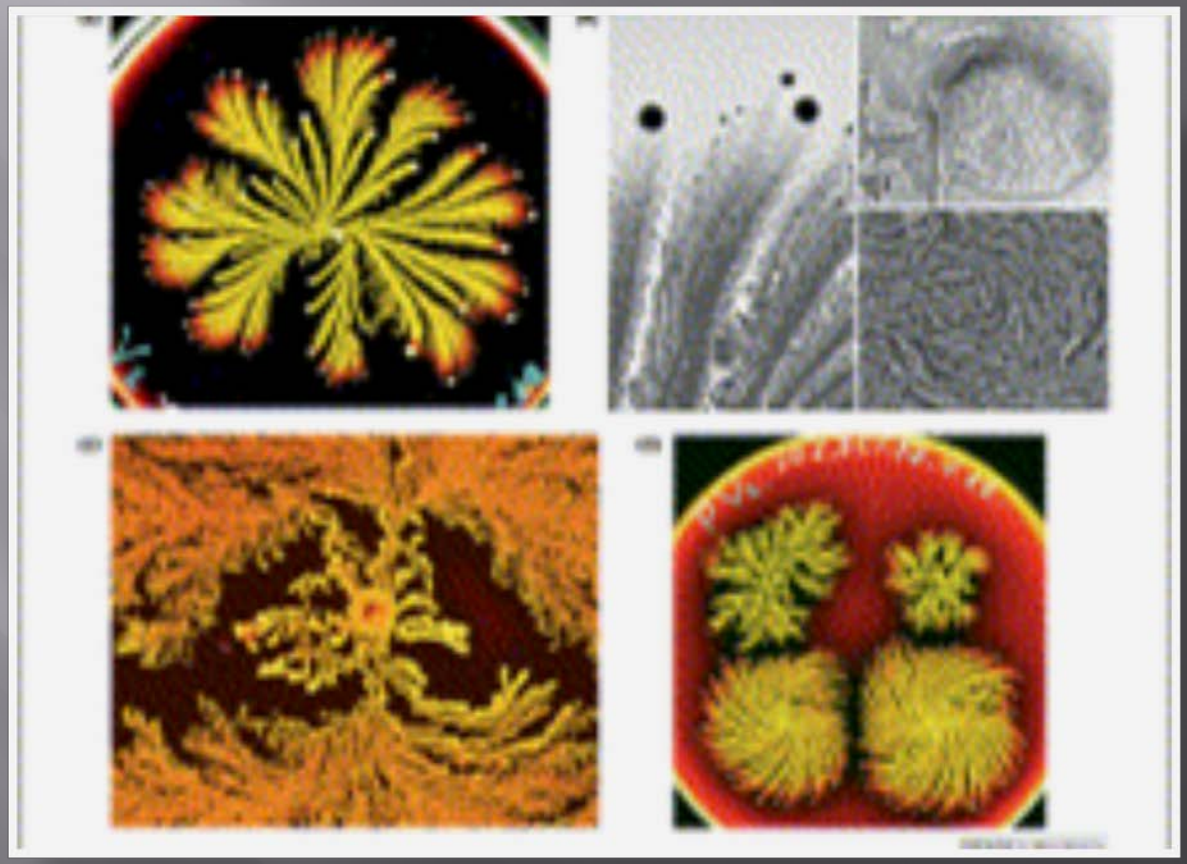


Animate

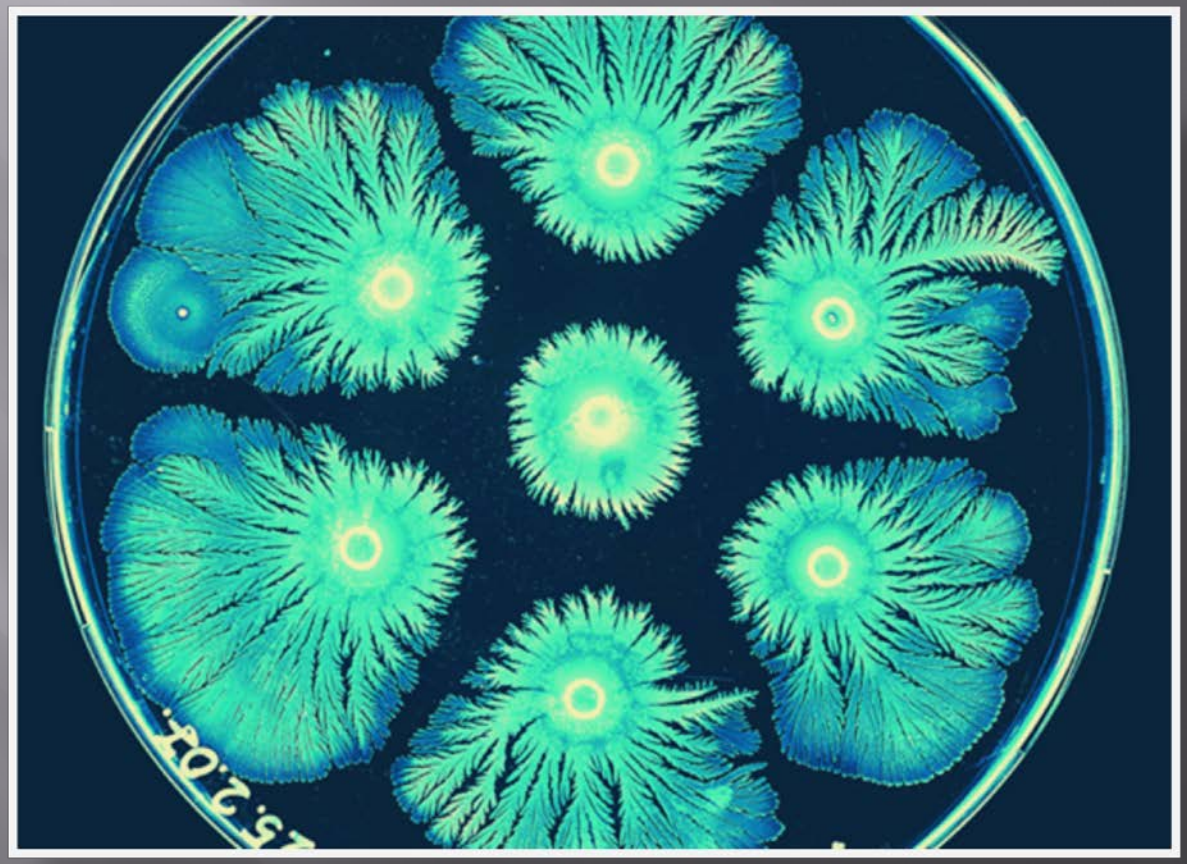
Paenibacillus dendritiformis

Ben-Jacob, Biology and Science, 2010

Paenibacillus dendritiformis colony under stress



Ben-Jacob, Scientific American, 2009



Colony achievements

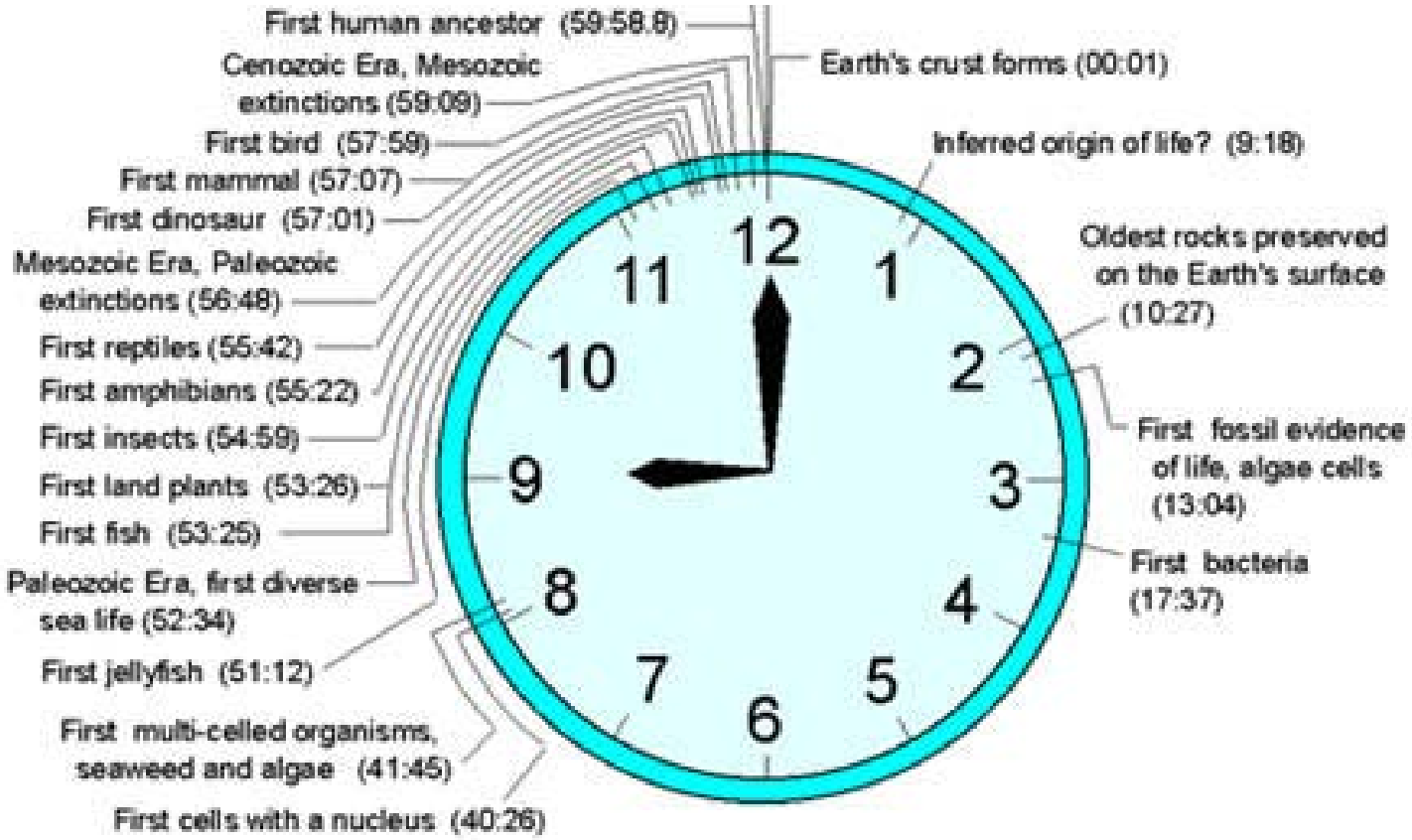
- Information sensing
- Information processing
- Signal broadcasting
- Computation
- Differentiation
- Communication, at distance
- Cooperation
- Antibiotics
- Time travel

How did they do that…?

- … with multiple independent agents?
- … without a "brain", "planner", or "boss"; No central nervous system, no central control?

- Answer? Genetic mechanisms (DNA, RNA, proteins)

- Success? Life has spread everywhere: thermal vents, under ice, hospital rooms



Earth history in one hour


Scott Sebring

- Unique environments
- Biomes evolve for all
- 1-3% mass, 90% of DNA
- GI biome essential for digestion – the “extra organ”
- Bacteria manifest both Individual and colony behavior

Human view of bacteria

- Reductionist
- Germ theory of disease
- One (dumb) bug, one good drug
- Misuse antibiotics
- Abhor bacteria
- Force antibiotic resistance
- Altered biomes create additional problems

Human created pathology

- Opportunistic, multiple drug resistant organisms (MRSA, *C.dif*)
- Hospital acquired infections
- Allergic phenomena
- Skin conditions

Biomic therapy

- Recurrent *C. difficile* Infection
  - Fecal bacteriotherapy.fecal microbiota transplantation (Eat poo!)
  - 92% effective (87% after one dose)
    - Gough, Clinical Infectious Diseases, 2011
- Mouth cleaning of pacifiers
  - Reduced asthma, eczema, sensitization
    - Hesselmar, Pediatrics, 2013
- Vaginal birth vs. C-section
  - Reduced food allergy
    - Kopel, Ped Allergy and Immunology, 2008
- Terminal wipe down with local biome?

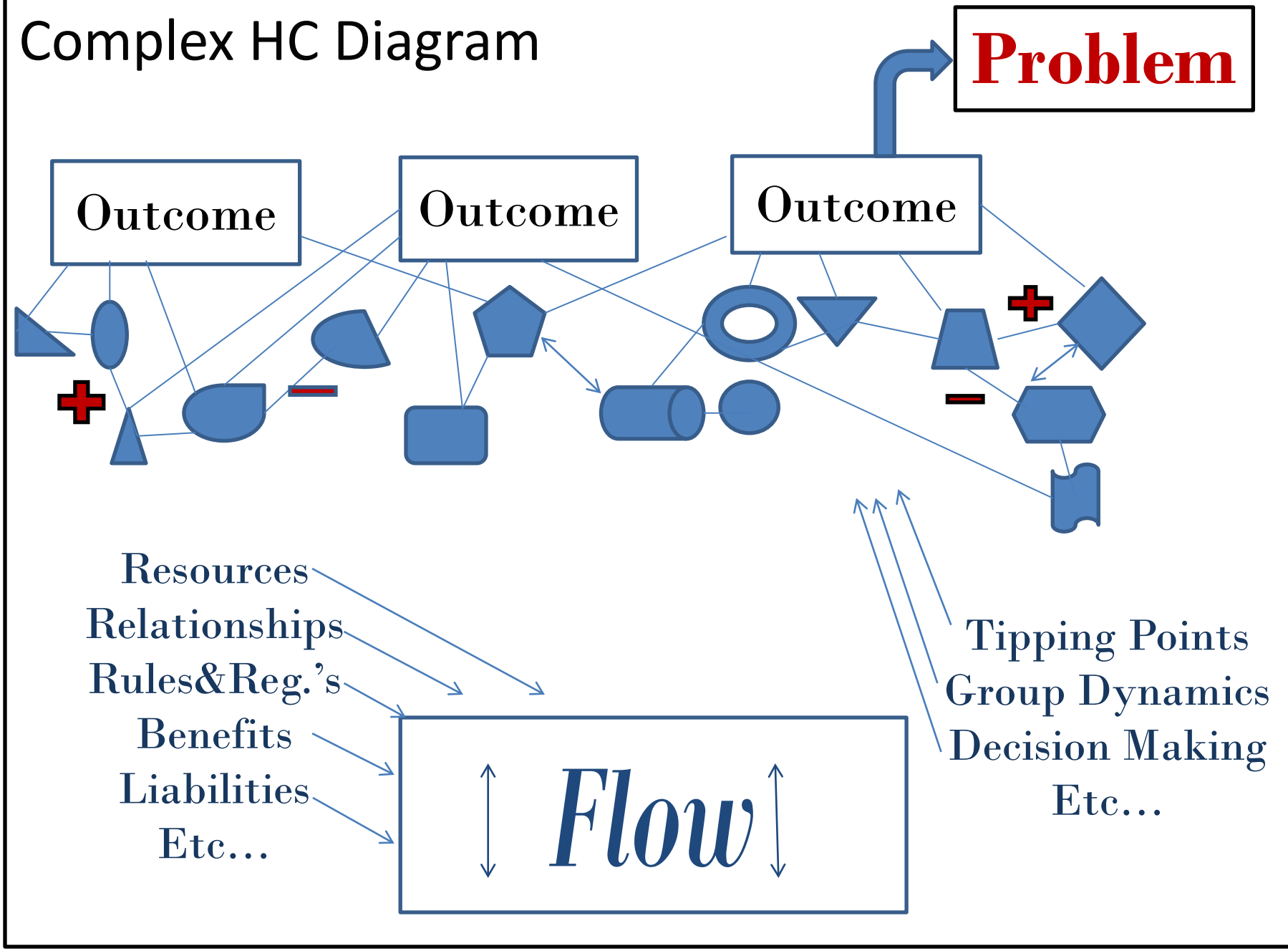
Complexity begets complexity

- Amazing properties even in prokaryotes
- Prokaryotes become Eukaryotes become multi-cellular organisms become complex individuals with specialized tissues, organs.
- Only then a central nervous system and "central control"
- Individuals form complex adaptive systems (family units, tribes, alliances, nations, …)
- Individuals join many complex adaptive systems (work, social, special interest groups …)
- Each grouping imposes restrictions, but "wild type" is not forgotten
- Each system creates new emergent behavior

Complex Adaptive Systems

- Multiple Independent agents
- Able to interact
- Self organize
- No central control
- Emergent Phenomena

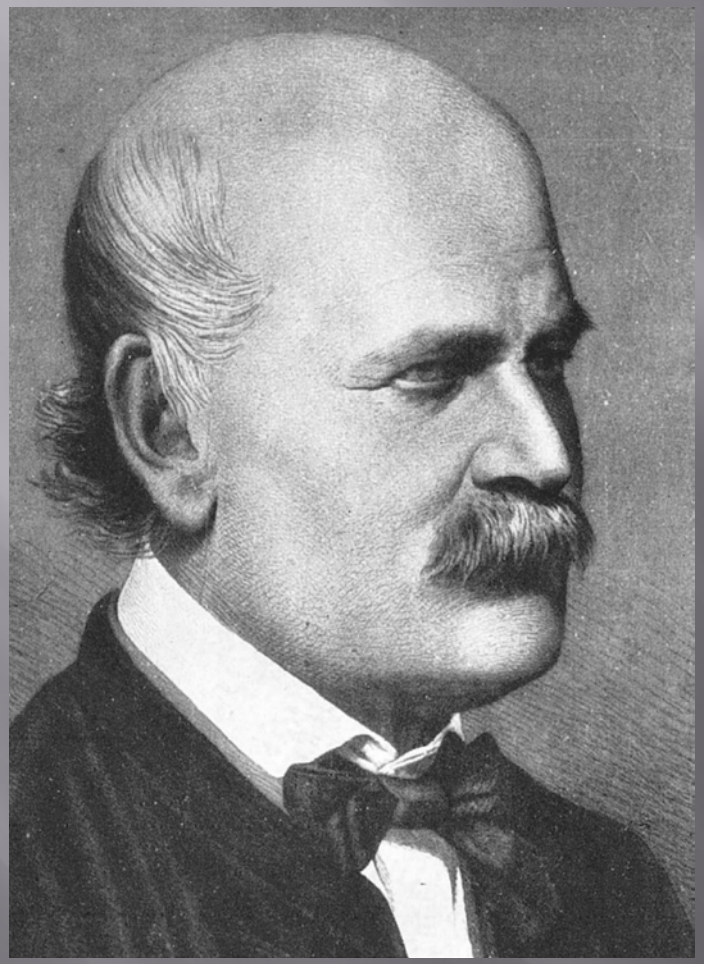
Complex HC Diagram



Complex Healthcare Examples

- Hand washing
- Errors
- Expense
- Population health
- Refractory decisions

Hand washing



- Semmelweis, 1847/65
- Multiple observations:
  - People don't consistently wash
  - Docs worst
  - Programs always succeed
  - Results never last
- ***Lesson:*** If it is refractory, it is probably complex

Errors

- Very few individual mistakes, never intentional
- Many systemic errors
  - Circadian rhythms
  - Trainees and education
  - Alarm fatigue
- Overanalyze the mistakes, under-study near misses; ignore normals
- Thousands of normals intermingle with a few bad outcomes
- ***Lesson:*** Big data sets will be required. Statistical mechanics. <u>What</u> is more important than <u>why</u>

Expense

- Why does health care cost so much?
  - Because it can!
  - Money was part of the initial flow; Cost control was not
  - Restraint elicits negative feedback
- But, money flow is receding

- ***Lesson:*** Complex systems are not in equilibrium; depend on continuous flow

Population Health

- Population health was not in the initial flow which resulted in the sickness care system
- Now, reduced reimbursement for readmissions or changes in money flow related to sustained health

- ***Lesson:*** Nudge the flow. Small adjustments to the contents of the flow can have big results

Refractory Decisions

- Agents may not know why they took an action
  - Peer pressure
  - Tipping points
  - Resource pressure
  - Interpersonal issues
  - Unrelated issues

- Don't get mired in metadata. Don't interview starlings.

Complexity and Critical Care

- Pathologic process - complex system
- The physiologic responses - complex systems
- The ICU itself - complex adaptive system nestled within another complex system (the hospital) nestled within …

Intensivists and complexity

- Increase the flow rate (fluids)
- Minimize deleterious feedback loops (work of breathing)
- Alter the flow contents (remove toxins, add therapeutic agents)
- Eliminate system conflicts (sedation/paralysis)
- Titrate positive and negative feedback
- Formulate problems in complex fashion

Why do some issues go away?

- Linear solutions work
  - Prevention
    - *H. influenza* epiglottitis
    - Sudden Infant Death Syndrome
    - Near Drowning
    - Motor vehicle trauma
    - Reye Syndrome

Why do some issues persist?

- Linear solutions don't work
  - Opportunistic, hospital acquired, "superbugs"
  - Sepsis - Looking for the magic bullet
  - Inherently complex issues: e.g. Respiratory/cardiac/immune failure

Resistance to complexity

- Not how we think
- Not at human scale
- Not yet familiar with the tools
- Multi and cross disciplinary
- Questions established dogma

Complex adaptive system Observations

- If it is refractory, it is probably complex
- What is more important than why. Big data sets will be required. Statistical mechanics
- Complex systems are not in equilibrium; depend on continuous flow
- Nudge the flow. Small adjustments to the contents of the flow can have big results
- Don't interview starlings. Don't get mired in metadata

Don’t just DO something!

Stand there …

…and think of complexity