Session 14: Interlude (2)

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Life and knowledge at higher levels of organization

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Tonight

- In the last session I discussed causation, thermodynamics, time, and the impact of the *adjacent possible* on the unfolding now in the emergence of self-maintaining living systems
  - Turbulence
  - Eddies
  - Selection for stabilizing feedback leads to structural memory
- In this session I will explore the emergence of autopoietic cognition at several levels of organization up to human economic and social organizations

INTERLUDE

Cognition, structural/dispositional knowledge, codified knowledge and systems of heredity

Theory of Hierarchically Complex Dynamic Systems and Higher Orders of Autopoiesis

Hierarchy theory

Levels of organization

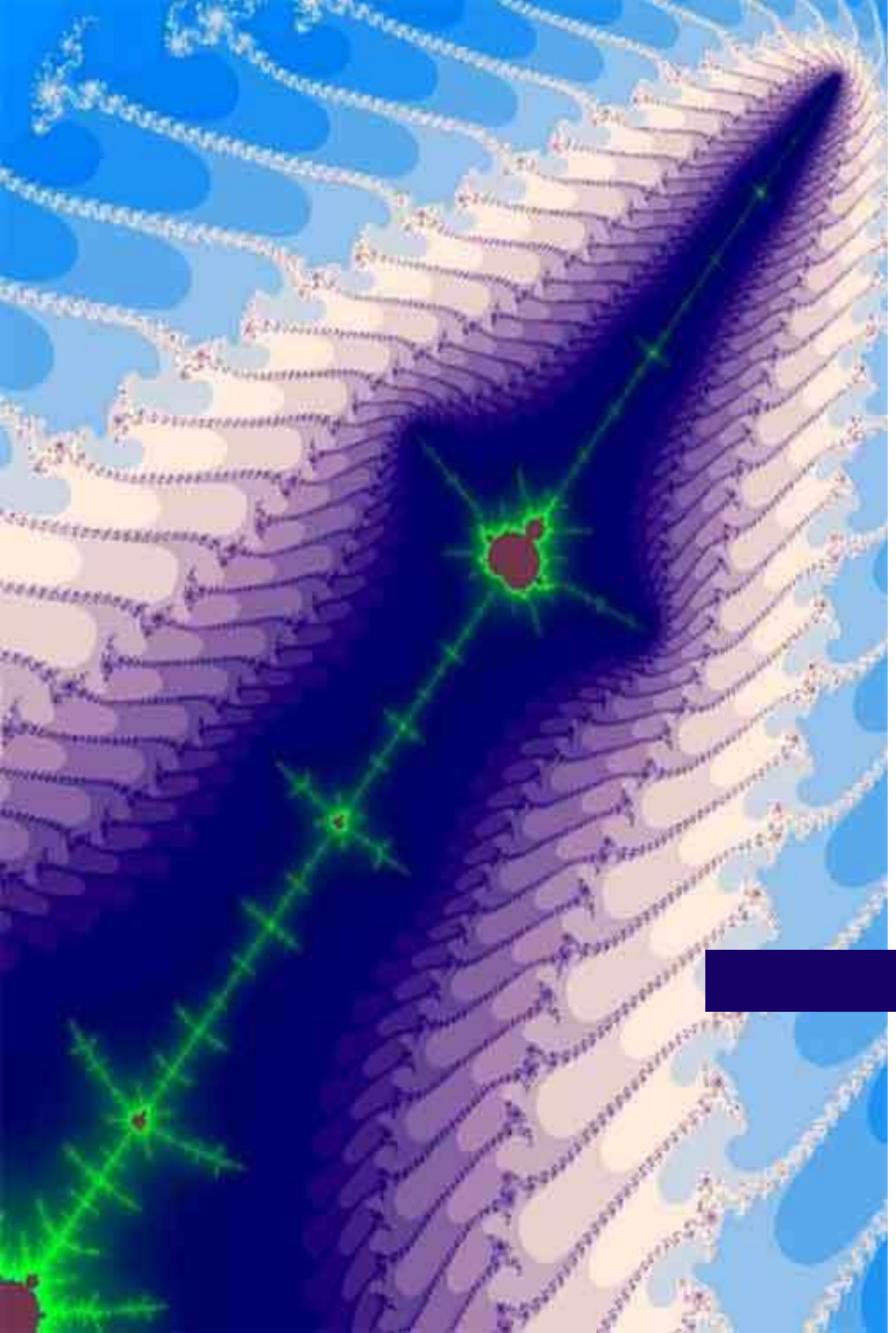
Two views of the hierarchical structure of living systems

Emergence of new levels of living organization in the complex hierarchy of living things

Second Order Autopoiesis: Multicellular Organisms

Third Order Autopoiesis: Colonies and Societies

Human economic and social organizations

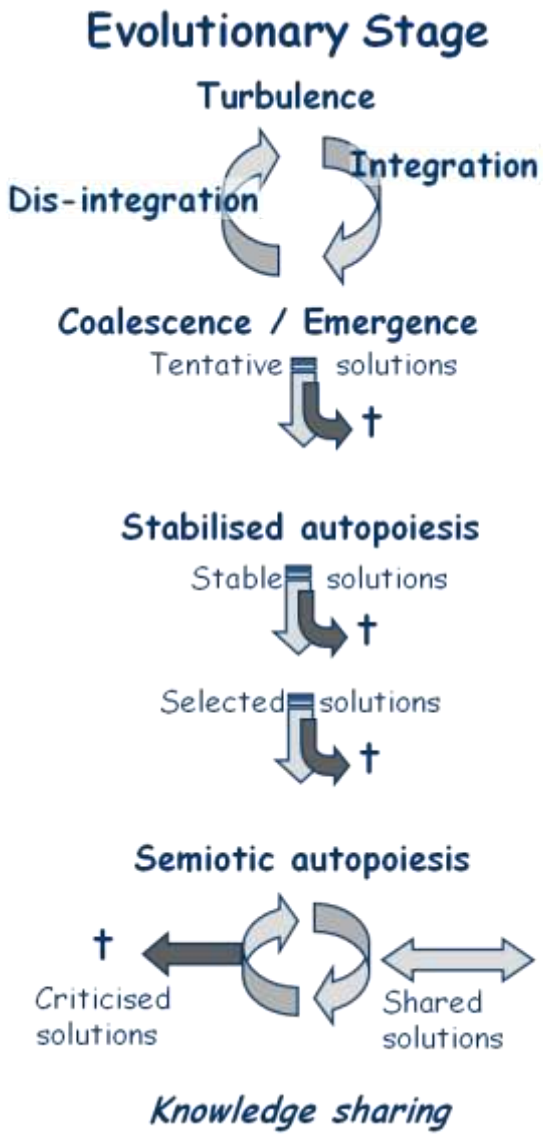


Cognition,
structural/dispositional knowledge,
codified knowledge,
systems of heredity

Re-production

- Knowledge: solution(s) to problem(s) – e.g., capacity to self-regulate
- Two kinds of evolution:
  - Structural : progressive change in the structure through time
  - Epistemic: change in the capacity to regulate/control structural change through time
- Structural knowledge:
  - The most primitive form of knowledge is for the structure of a complex dynamic system to be organized in such a way that its dynamic structure continues to evolve within the bounds of an attractor basin such that its structural continuity does not disintegrate when perturbed by outside forces.
- Natural selection: selective elimination/disintegration of failed solutions
- Reproduction of successful solutions can be as simple as growth of mass associated with fragmentation where at least some fragments retain enough structural knowledge to survive and grow

Co-emergence of autopoiesis and knowledge



Nature and growth of autopoietic knowledge

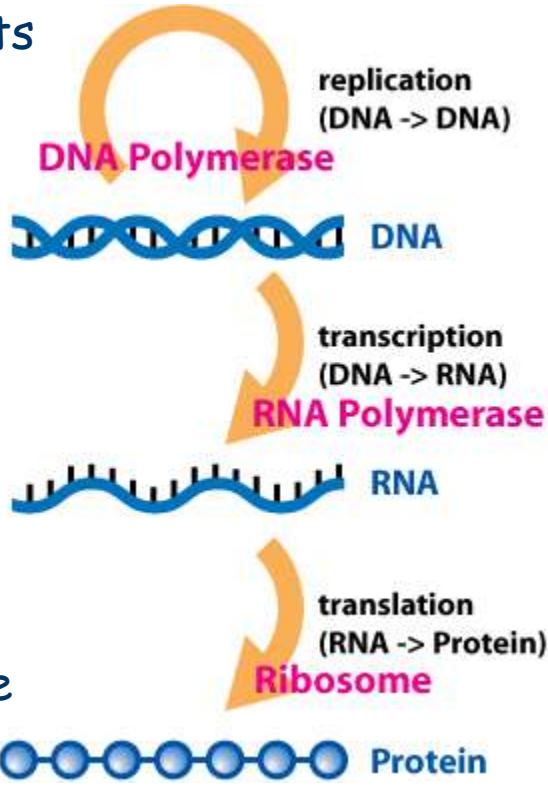
- **Turbulence:** Turbulent flow from available energy (exergy) sources to entropy sinks forces conducting systems to become more organised (state of decreased entropy) – (Prigogine, Morowitz, Kay and Schneider, Kauffman)
- **Coalescence:** Coalescent systems have no past. Self-regulatory/self-productive (autocatalytic) activities that persist for a time before disintegrating leave uncoordinated components whose individual histories may "precondition" them to form autopoietic systems. Each emerged autopoietic system represents a tentative solution to problems of life. Those that dis-integrate lose their histories (heredity/knowledge).
- **Stable Solutions:** Stable systems are those whose knowledge enables them to persist indefinitely. Competition among such systems for resources is inevitable. Survivors thus perpetuate historically successful solutions into their self-produced structure to form structural, dispositional or tacit knowledge (W2). Those failing to solve new problems dis-integrate and lose their histories, i.e., their accumulated knowledge dies with them.
- **Semiotic autopoiesis:** Replication, transcription and translation. With semantic coding and decoding, knowledge can be preserved and replicated in physiologically inert forms for recall only when relevant to a particular problem of life. Such objective knowledge may be shared across space and through time.

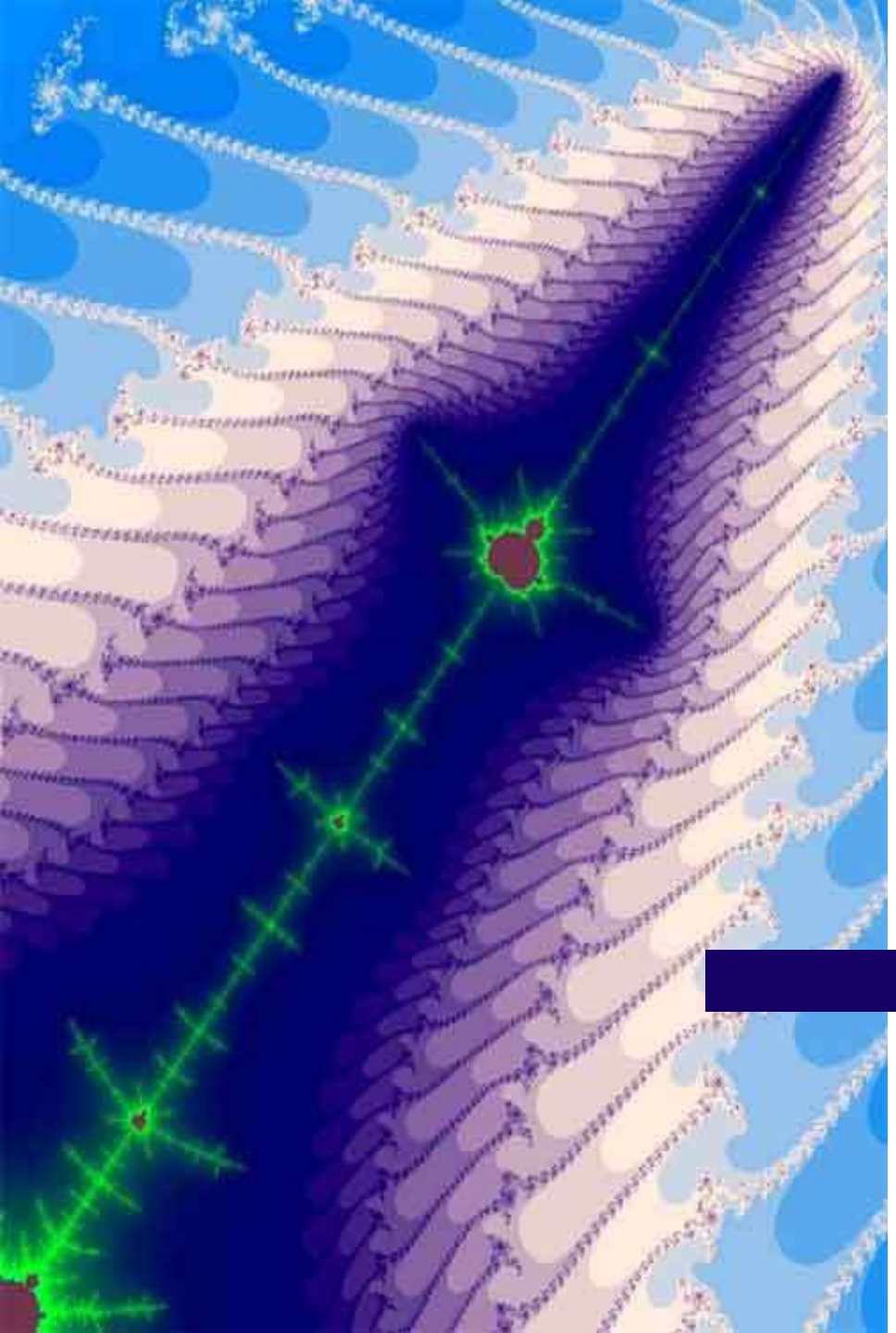
Emergence of self-regulation at the molecular level to form W2

- (Turbulence and Coalescence in W1)
  - Unguided replication of structure
    - Selection for molecular mixes that catalyze more molecules that work well together = "Constitutional inheritance"
    - Conglomerations of molecules catalyzing the of similar conglomerations messy and unlikely to replicate with high accuracy
    - With no "formal" genetic system
  - Dynamic structure based on interacting molecules not necessarily stable through time.
    - Flux of activation energy through system increases exergy in system
    - Lipid bilayers self-assemble
    - Concentration of amphoteric polypeptides with catalytic properties
    - Concentration of catalytic/autocatalytic nucleotide polymers
- (Emergence of self-stabilized autopoiesis forms W2)
  - Natural selection favors self-regulatory feedback
    - Structure organized to buffer/mitigate perturbations (cybernetics)
    - Emergence of autopoietic "cognition"
  - Feedback control knowledge embodied in autopoietically organized dynamic structure = "***constitutional inheritance***"

Codification of self-regulatory knowledge in self-replicating macromolecules forms W3

- Emergence of self-catalyzing polymers with enzymatic properties
  - Selection for reliable encoding of structural and process knowledge
  - Evolution of replication, transcription, translation
- Scenario
  - Proteinoids & nucleic acid polymers can have enzymatic properties
  - Such polymers form in conducive environments
    - Tendency for complimentary pairing of RNA/
    - DNA nucleotides ~ template-based replication
    - Tendency for collective autocatalysis
  - Natural selection on constitutional inheritance any functions improving the fidelity of autopoietic reproduction
    - Particlar sequences of nucleotides favor the catalysis of particular sequences of amino acids
    - Continued selection leads to the establishment of a particular DNA/RNA encoding system
  - Continued selection leads to high fidelity code
- *Selection turns chaotic variation into code*





Genetic and other systems for managing hereditary knowledge

Knowledge management at the molecular level: genetic systems and systems of heredity

- **Genetic system** (Glossary of Genetics and Cytogenetics, 1976)

  [A]ny of the species-specific ways of organization and transmission of the genetic material… which determine the balance between coherence and recombination of genes and control the amount and type of gene combinations. Evolution of genetic systems means the evolution of those mechanisms effecting and affecting genetic variability. Factors which characterize a [genetic system] include the mode of reproduction, the type of population dynamics (breeding size, sex ratio, degree of panmixia), the mode of chromosome organization (genetic information all in one linkage group or distributed to several such groups), the chromosome cycle…, the recombination index, and the presence or absence of genetic and chromosomal polymorphism.

  - ***The genetic system and its components determine the capability of a population to undergo evolutionary changes. Any genetic system is under genetic control*** [and thus the genetic system itself is subject to evolutionary change – my emphasis]

- Extending the idea to other **systems of heredity**
  - *Non –genetic means for the ~ reliable sharing and transmission of survival knowledge between individuals within or between generations, e.g., the cultural transmission of knowledge by demonstration, words, writing or other means of communication.*

Evolution in the age of molecular panmixia

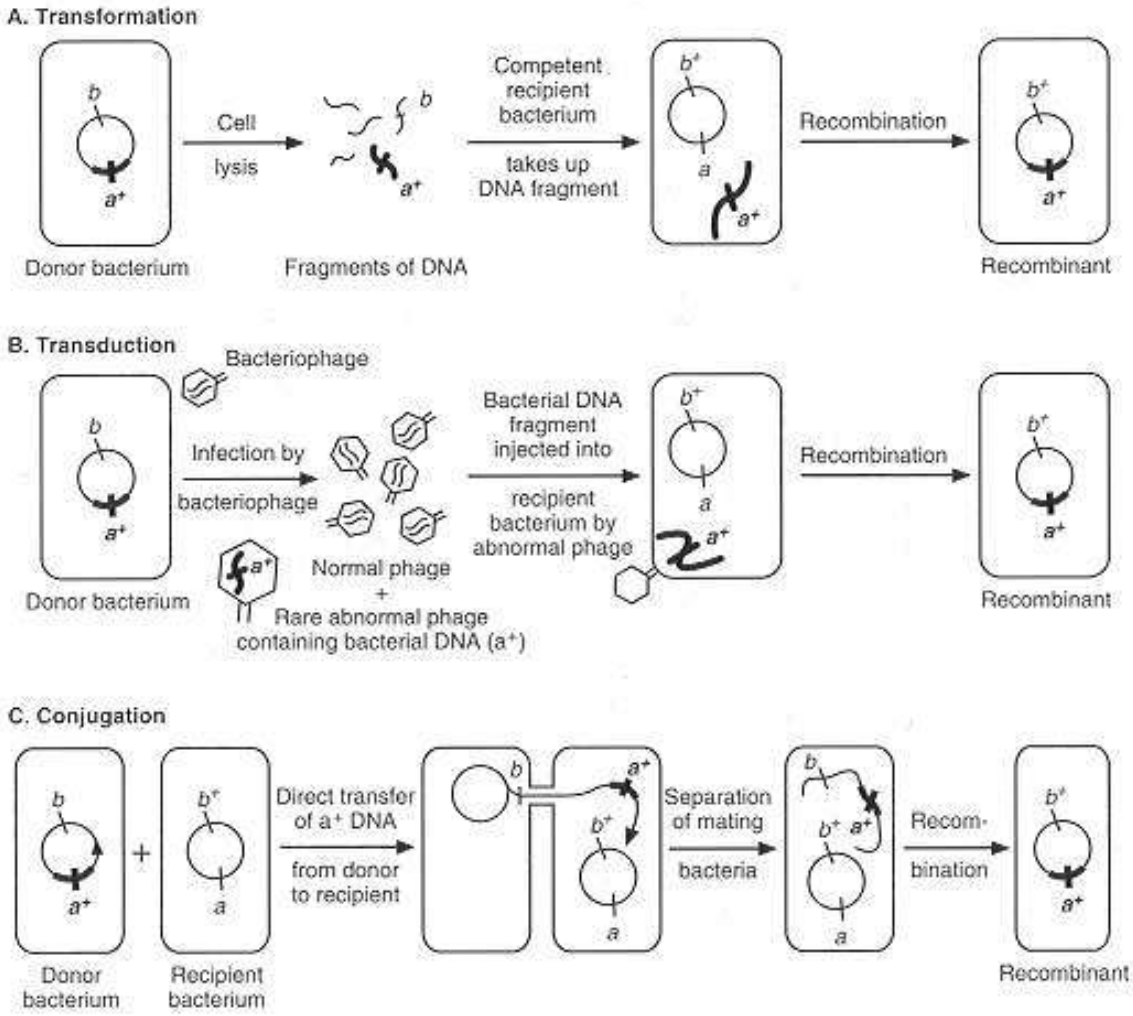
- Panmixia
  - *A panmictic population* is one where all individuals are potential partners
  - Molecular panmixia is where there is a near equilibrium between autopoietic coalescence and disintegration
  - Autopoietic systems increase the frequency of components able to coalesce into autopoietic systems and return these to the environment upon disintegration
- Selection favors the production of molecular components that favor or stabilize autopoietic functions when they coalesce
  - Molecules with enzymatic functions able to couple energy transport to polymerization/synthesis
  - Molecules "encoding" useful regulatory or synthetic functions
- Contradictory attractors for autopoietic systems: protecting what works vs experimenting to find something better

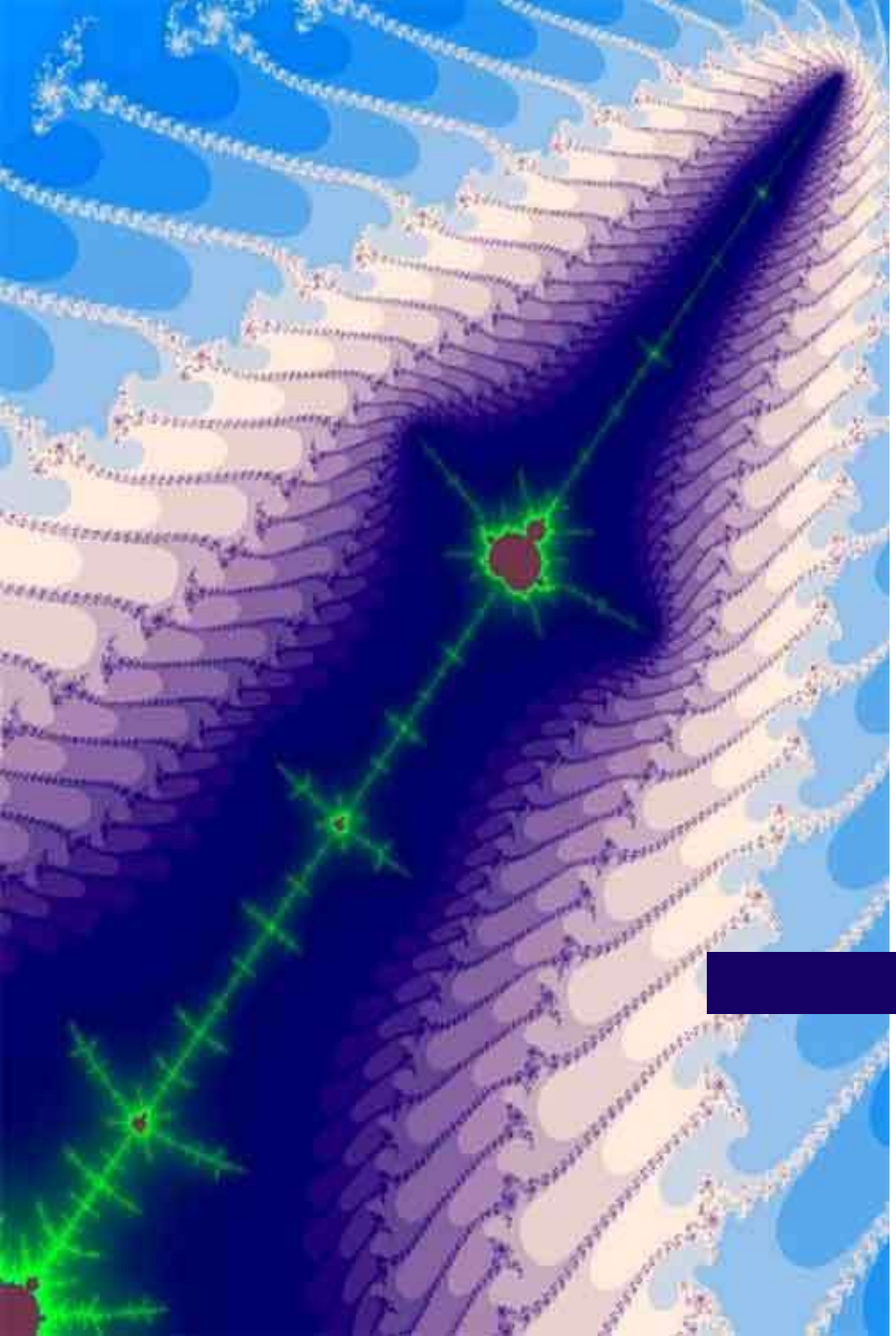
Protecting tested knowledge from changes

- Working autopoietic systems need protection from active molecules that are not coadapted for the specific system
  - Boundary controls
- Mutations are more or less random perturbations
  - Most likely deleterious effects on processes
  - May lead to disintegration of autopoiesis
- Managing knowledge at the molecular level
  - Accuracy of replication
  - Linkage into small number of chromosomes
  - Regular separation into daughter cells
- Protection & stasis vs innovation
  - Species living in variable environments with competitors need to cope with environmental change
  - An evolutionary arms race – the Red Queen Hypothesis

Testing, mixing & sharing W3 knowledge from different parents

- Bacterial genetic system
  - Circular DNA attached to cell membrane
  - Replicated & pulled apart as cell grows & divides
- Prokaryotic sex: Encoded DNA from one cell added to another cell
  - Transformation
  - Transduction
  - Conjugation
  - Plasmids (small accessory chromosomes)





Hierarchically complex dynamic systems and higher order autopoietic systems

Theory of Hierarchically Complex Systems

- System:
  - An organized collection of dynamically interacting parts where change in one component causes change in other components
  - Arbitrary vs self-defining assemblies for dynamically propagating causal influences
- Basic theory by Herbert Simon (Nobel laureate)
  - Nearly decomposable systems
    - Architecture of Complexity (1962)
    - The Sciences of the Artificial (1996)
- Organization at multiple levels
  - James Grier Miller 1978 "Living Systems"
  - Stafford Beer 1981 - "Brain of the Firm" (viable system model)
- Holonics
  - Arthur Koestler 1967 "Ghost in the Machine"
  - Arthur Koestler 1978 "Janus"
- Upward and downward causation
  - Stanley Salthe 1985 – "Evolving Hierarchical Systems"
  - Stanley Salthe 1993 – "Development and Evolution"

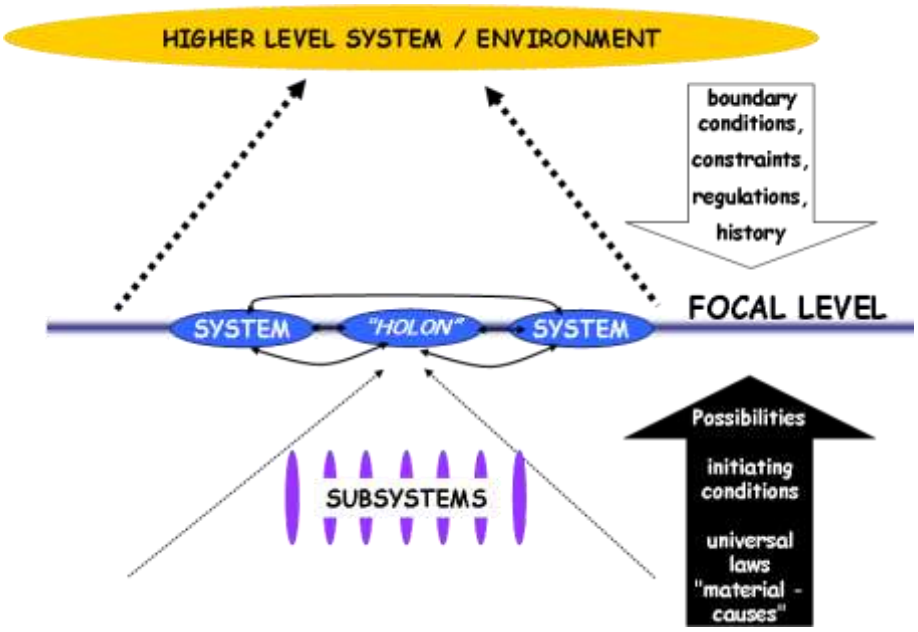
Modular organization and near decomposability

- *Near Decomposability*
  - *Horizontal interactions* – same level of organization
    - Short run behavior of each component subsystem ~ independent of short run behaviors of other components
    - Long run behavior of any component depends only on aggregate behavior of other components
  - *Scalar interactions* – levels of organization of smaller and larger scale components
    - small scale: tiny, close units interact & equilibrate faster
    - large scale: large, more separated units interact & equilibrate much more slowly
    - To larger scale systems, rapidly resolved interactions of small scale components are like laws of nature.
    - To smaller scale systems, slowly resolving interactions of large scale supersystems provide constraints as a relatively constant environment
- *Modularity*: Tempus & Hora (see Architecture of Complexity)
  - Hora's watches were modular – parts forming subsystems, and subsystems forming modules
  - Tempus assembled parts in one sequence
    - With reasonable assumptions about interruptions, Tempus makes 4,000 more watches per unit time
    - As a general phenomenon, modularity is strongly selected for

Some Hierarchy Theory Terms

- *Hierarchy* – an ordered ranking of things by some measure
  - *Scalar hierarchy* – hierarchy based on size or extent; systems and subsystems or parts nested in supersystems or wholes. These can be seen in the objective structure of the world.
  - *Specification hierarchy* – hierarchy based on descriptive complexity
  - *Command hierarchy* – hierarchy based on control. The command and control hierarchy of an organization is important in terms of determining how autonomous an entity may be.
- *Level of organization* – level in a scalar hierarchy where discriminable entities of comparable extent can be seen to interact
  - *Focal level / level of observation* – the level of organization in a scalar hierarchy that is of primary interest
- *Complicated* vs *complex*
  - *Complicated* - system parts maintain some independence from one another. Adding or removing a part does not alter the system's behavior beyond what is directly caused the particular part.
  - *Complex*: dependencies among elements are important: adding or removing one such element disturbs system behavior beyond that which is directly caused by the particular part. Most complex systems exhibit non-linear behavior that may appear to be chaotic

Causation in hierarchical structure



- Holon – a "two faced" system that looks upward to the supersystem that constrains its behavior, and downward to the subsystems that determine what it is possible for it to do.

- *Downward causation* - Every organizational entity ("holon") is a component within a higher-level *supersystem* (e.g., "the economy", "the system of government") forming an environment that constrains what the holon can or must do to survive
- Every holon interacts with other holons at its own *focal level* of organization to form that higher level supersystem
- *Upward causation* - Every holon is comprised of lower-level subsystems (e.g., people, machines) whose capabilities and law-like behavioral interactions determine what is possible for the entity to do

Architecture of complexity – levels of organization

	PLANET EARTH	gaia	economy
		5th? ecosystem	5th? nation state
		ecological community	city, industry cluster
multiverse universe super clusters galaxy clusters galaxies solar systems planets, stars	[fourth order autopoiesis]		
	colonial organisations e.g., siphonophores, ectoprocta	evolutionary species	Social/economic organizations, insect colonies
	[third order autopoiesis – emergence of "social" knowledge and structure]		
	organism (organ systems) (organs) (tissues)		
	[second order autopoietic systems (multicellular)]		
	eukaryotic cells - meiotic recombination and random assortment (organelles - endosymbionts – Hall 1966 membranes, filaments, microtubules) prokaryotic cells - "genetic knowledge"		
	[first order autopoietic systems – emergence of "structural" knowledge]		
	polymers/macromolecules – tertiary and quaternary molecular structure		
	[condensed matter: molecules, crystals, compounds]		
atoms bosons and leptons quarks			

Planck units 10^{-33} cm: "spin networks" (Smolin 2004, 2008, see also Tony Smith's toy universes

Carriers of knowledge at different levels of cellular autopoietic organization

- Single cell (prokaryotic organization)
  - Single nucleic acid polymer chromosome
  - Knowledge sharing via nucleic acid fragments (naked or viral)
  - Social interactions via chemical communication & contact
- Eukaryotic cells
  - Multiple nucleoprotein chromosomes (haploid/diploid)
  - Symbiogenetic mergers of different cellular lineages
    - Environment facing host cell (archaeal origin?)
      - Cytoplasmic motility
      - Knowledge replication & management within nuclear membrane
      - Other membrane bound machinery in the cytoplasm
    - Specialized metabolic originally derived from prokaryote symbionts
      - Mitochondrial power generators (oxidative metabolism) of bacterial origin
      - Photonically driven electron pumps (chloroplasts) of blue-green algal origin
  - Knowledge sharing via recombination (meiosis), assortment, and fertilization
  - Social interactions via chemical communication & contact

Emergence of autopoiesis and knowledge at the mullticellular level

- As eukaryotic cells are replicated by binary fissioning they may remain adjacent to one another
  - Preadaptation to form colonies of cooperating cells (colonial flagellates)
  - May lead to cellular specialization, e.g., somatic and reproductive cells (Volvox)
- With increasing complexity
  - Tissues (boundary, motility, support, neurosensory network)
  - Organs (muscles, brains, digestive, etc.)
  - Organ systems (neuro muscular, support, alimentary, circulatory, etc)
- W2 knowledge embodied in facultative connections and settings of nerve cells in the neurosensory network.

Socially sharing knowledge at a higher levels of organization

- Second order autopoiesis
  - Multicellular organization
    - Social cells, e.g., Choanoflagellates
    - Cellular differentiation, e.g., colonial peritrich – coordinated response to chemical & tactile communication
    - Formation of tissues & functional organs following programmed development
  - Development of neurosensory system
    - Coordinated responsiveness
    - Learning and anticipation
  - Self-regulation & self-consciousness
  - Inter-individual social interactions via chemical trails, tactual, visual, and sonic signals
- Third order autopoiesis (societies of multicellular organisms)
  - Colonial organisms (corals, siphonophores, tunicates – chemical & tactile organization
  - Social insects (pheromonally & tactually coordinated)

Third order (social) autopoiesis in humans

- **Bounded**
  - People know what organizations they belong to. Members are variously tagged with ID badges, bear membership cards, wear uniforms displaying the company logo, etc. Many organizations are physically bounded by "semi-permeable" walls and gates, etc.
- **Complex**
  - Organization members are unique, recognize one another as members, and are identified as such within the organization; also machines, property, bank accounts, etc. are identified with tags, catalogued in property registers, etc.
- **Mechanistic**
  - Individuals receive rewards and benefits to belong, and are involved in processes, routines, procedures etc. that the organization conducts to ensure its survival.
- **Self-referential or self-differentiated**
  - Rules of association, voluntary allegiance to organizational goals, etc. determined within the organization itself determine what people and property, etc. belong to the organization.
- **Self-producing**
  - Members are recruited from the environment, inducted, trained, monitored, and managed, etc. Other property and assets are procured and variously integrated into the overall functioning of the organization.
- **Autonomous**
  - Most organizations outlive the association of particular individuals, and are readily able to replace individual people as they retire or leave and plant and equipment as it wears out.

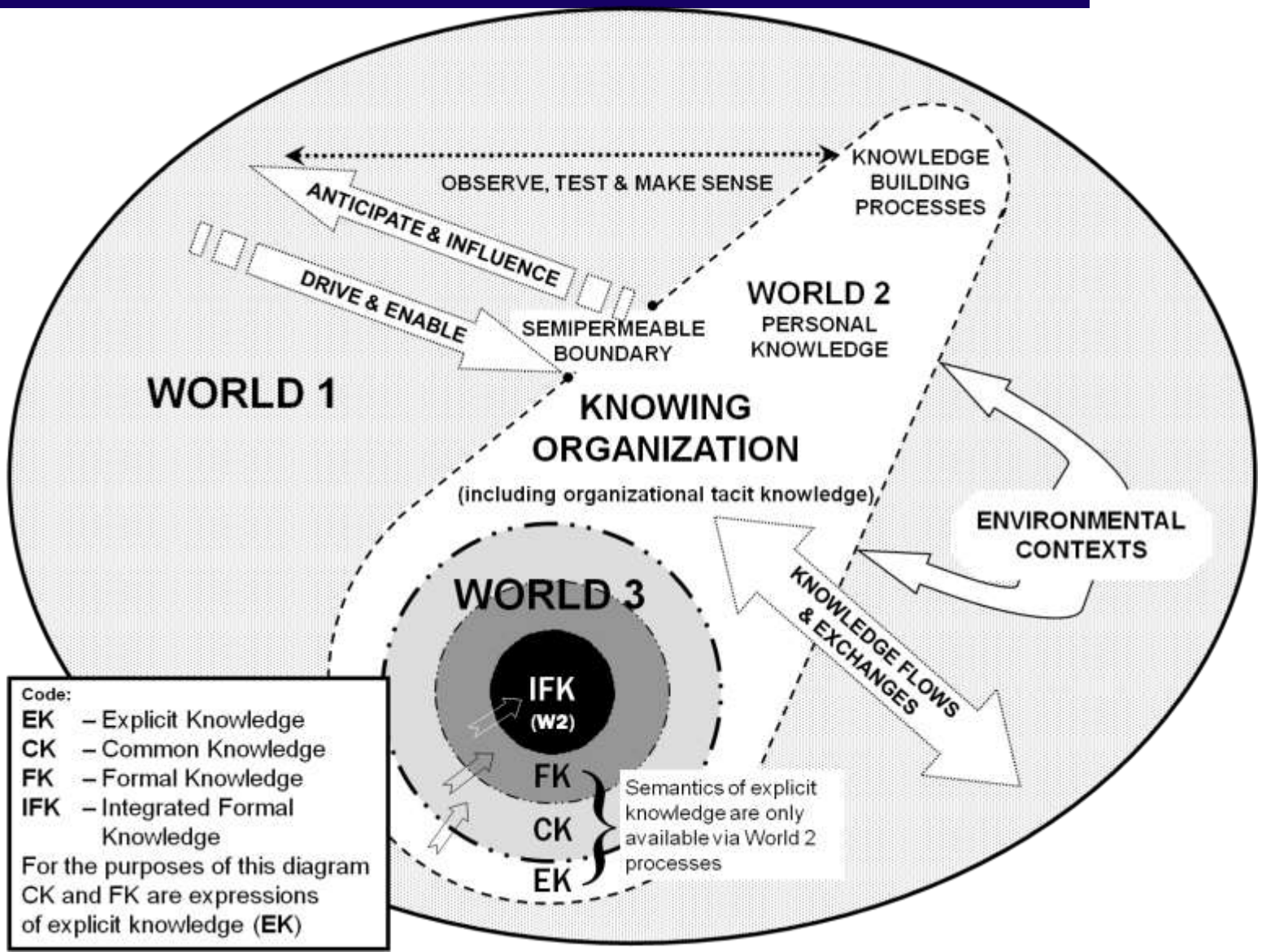
Group knowledge & group coordination

- Selection drives all living entities to seek strategic power over resources necessary for their survival
- Group survival and niche occupation depends on the group's knowledge of technologies and nature
- The group phenotype is determined by
  - The basically similar (i.e., very slowly evolving) genetic heritage that defines individual capabilities
  - The highly plastic cultural heritage that is shared among the group's individuals and passed down from one generation to the next
- For cultural heritage, groups become the living units of natural selection and evolution
  - Shared attention, language, cooperation and collaboration in the creation, use and transmission of cultural knowledge
  - Purely oral groups share knowledge visually or orally within eyesight or earshot
- Writing and intercommunication over distance stabilizes knowledge across guilds, extended companies, city-states, religions
- Individual can belong to more than one group at same time
  - Works best where group niches do not overlap
  - Intersecting or nested

Personal vs organizational knowledge

- Personal knowledge (in any form) is known by an individual
- Organizational knowledge relates to the organization and is available within it and may be personal or explicit
- People know:
  - what knowledge the organization needs,
  - who may know the answer,
  - where in the organization explicit knowledge may be found,
  - why the knowledge is important or why it was created,
  - when the knowledge might be needed, and
  - how to apply the knowledge
- This human knowledge is critical to the organization
- Snowden, D. 2002. Complex acts of knowing: paradox and descriptive self-awareness. J. Knowledge Management 6:100-111
  - *Personal knowledge is volunteered; it cannot be conscripted.*
  - *People always know more than can be told, and will tell more than can be written down.*
  - *People only know what they know when they need to know it.*

Vines, R., Hall, W.P. 2011. Exploring the foundations of organizational knowledge. Kororoit Institute Working Papers No. 3: 1-39



What does higher order autopoiesis mean for the future of humanity?

- Will human individuality become submerged in higher order autopoietic systems?
  - Cells in multicellular organisms?
  - Some historical thoughts
    - Nazi Germany
    - Russian Communism
- Next session: Episode 4 looks at human cyborgs with endosymbiotic technology

Extending Human Cognition and Emergence of Humano-Technical Cyborgs

Moore's Law still at work – clouds, pipes, devices, and apps.

Human Computer Interfaces (HCI) – sensing, processing, augmenting cognition

The next steps in merging human and computer cognition

Intimately wearable interfaces

Implanted/embodied human-machine interfaces

Moore's Law and its implications for embodied interfaces

What does it mean to be human?

Autopoietic boundaries and cognition

Neural basis for self-consciousness

Human evolution in several dimensions