Knowledge and Life: What does it mean to be living?

An attractor

A unique area in the state space of the Mandlebrot set

definition

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Access my research papers from Google Citations

Introduction

- **Foundation problems in philosophy and biology**:
    - **Epistemology** is the branch of philosophy concerned with the study of knowledge.
    - **Biology** is the branch of science concerned with the study of life
    - Both disciplines have been around for centuries
    - **Neither discipline has formulated a generally acceptable definition of what it is concerned with**

- I will argue that knowledge and life are inextricably intertwined, and that neither can exist without the other
    - *Life cannot exist without knowledge*
    - *Knowledge is a product of living*
    - *These statements are not mutually paradoxical*

- A unification of concepts from both of these disciplines, together with some important principles from physics and complexity theory robustly answers the foundation questions: **What is knowledge?** and **What is life?**

This talk is one of the outcomes of researching and writing a fugue on the theory of knowledge

- **Application Holy Wars or a new Reformation – A Fugue on the Theory of Knowledge**
  - Combines threads from my two major careers
    - Evolutionary biology
    - Documentation and knowledge management systems analysis and management
  - Started part time in late 2000 to survey the co-evolution of and revolutions in human cognition and the cognitive tools humans used
  - Because the story is complex, crossing many diverse disciplinary paradigms, I adopted a cyclically fugal structure of subject, counter-subject, several episodes with an interlude, and a cadenza and coda.
- The historical part of the story was easy
- Understanding life and knowledge at the organizational level was not!
  - My constructions are at odds with published dogmas of organization studies and most knowledge management practitioners
  - In trying to answer the foundation questions, as will be presented here, I have ended up unifying some quite disparate ideas into a common answer to most of them
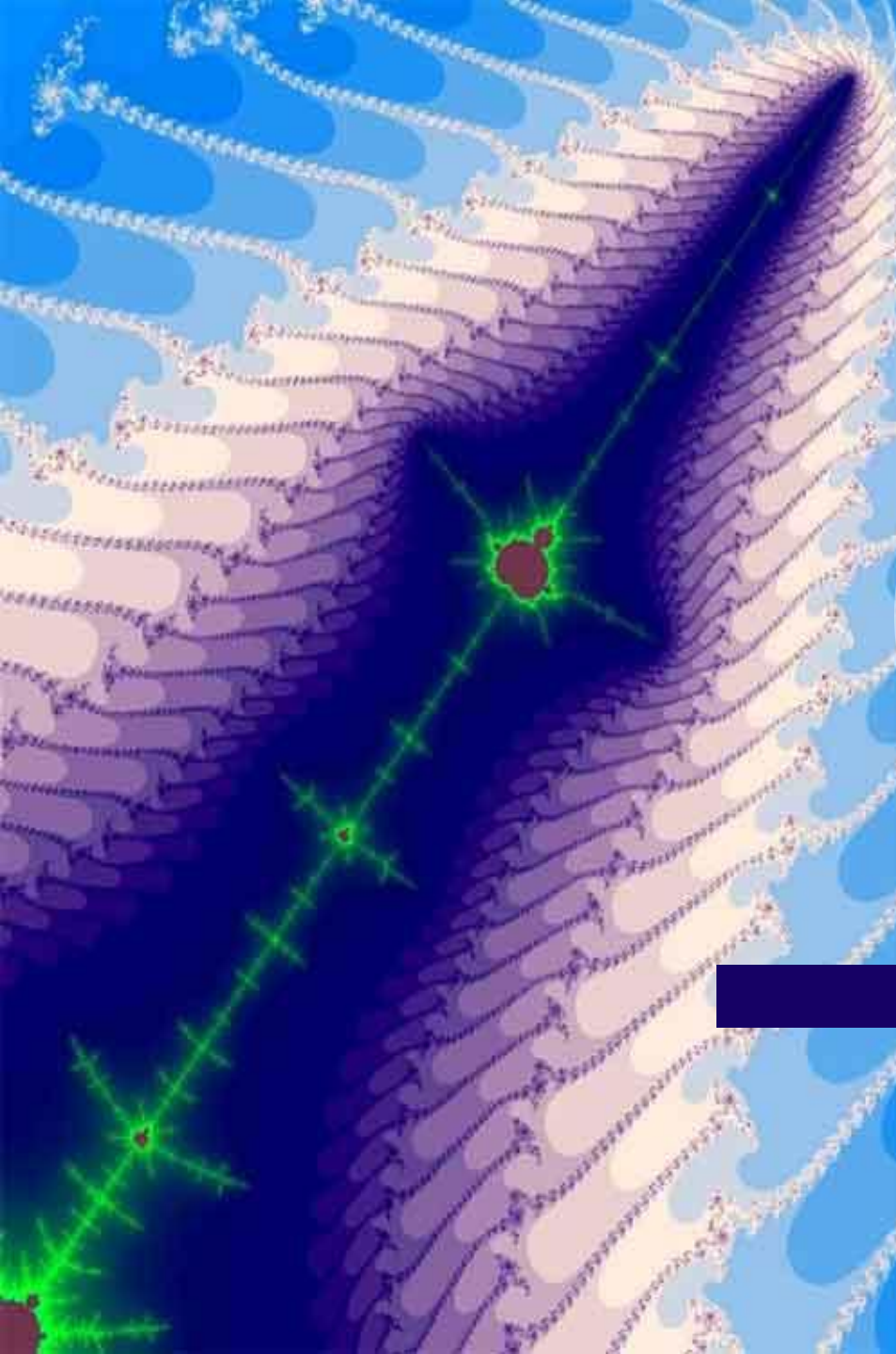
Existentialism, "knowledge", and "truth"

- Caveat: I am not a student of the philosophy of existentialism and am not familiar with its literature
  - I think my approach here leads to an existential and materialistic understanding of the world
    - There is a "real world" with law-like behaviours
    - The operations of reality constrain our individual existences
    - What/who we are and how we perceive reality is conditioned by our existences and individual choices along our trajectories of life
    - There are no essences beyond the reality of our existences
- Knowledge is constructed
  - All our knowledge and beliefs about the real world are cognitively constructed by biological processes working within the constraints of the real world
- Truth is unknowable
  - Knowledge of the world is not identical to the real world
  - Cognition is in the world - it does not mirror it

Questions about life arise from my career in physics and biology

- My early life in Southern California living on a boat
  - Immersed in the ocean, equipped with microscope and aquaria
  - Prior to university I spent hours almost every day day observing life's diversity down to microscopic levels
  - Planned to be an engineer and build space ships
- Started university as a physics major in 1957
  - Studied physics for 3 years until flunked out due to dyslexia with numbers (before hand calculators)
  - Graduated with BS Zool after $7\frac{1}{2}$ years
- Became an evolutionary biologist
  - I taught general biology and invertebrate zoology as a master's degree student around the questions: *What is life? How does life survive?*
  - Completed my PhD in 1973 at Harvard University's Museum of Comparative Zoology studying comparative population cytogenetics, evolution and speciation in a large genus of North Americal Lizards

Questions about knowledge arise from my career in theoretical and applied epistemology

- Came to Australia from 1977 to 79 as a University of Melbourne Research Fellow in Genetics
  - Reviewers of my PhD work forced me to ask whether my approach to comparative biology was "scientific"
  - Spent two years studying history and philosophy of science on my own (no one in Philosophy was then interested in my questions)
  - Returned to the States for a year & concluded there was no career path (complex transcript, Affirmative Action, etc.)
- Immigrated to Australia in 1980
  - Personal computers were evolving much faster than lizards!
  - Technical writer and documentation manager for software house and the original Bank of Melbourne.
  - From 1990 until retirement mid 2007 was documentation and knowledge management systems analyst for Tenix Defence.
  - Practical questions: *What is knowledge to an organization? Why is it important? How should it be managed?*
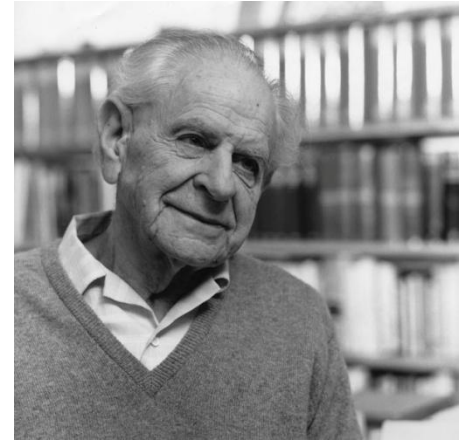
Evolutionary epistemology

—

A biologically-based theory of knowledge

Sources for biological approach to epistemology

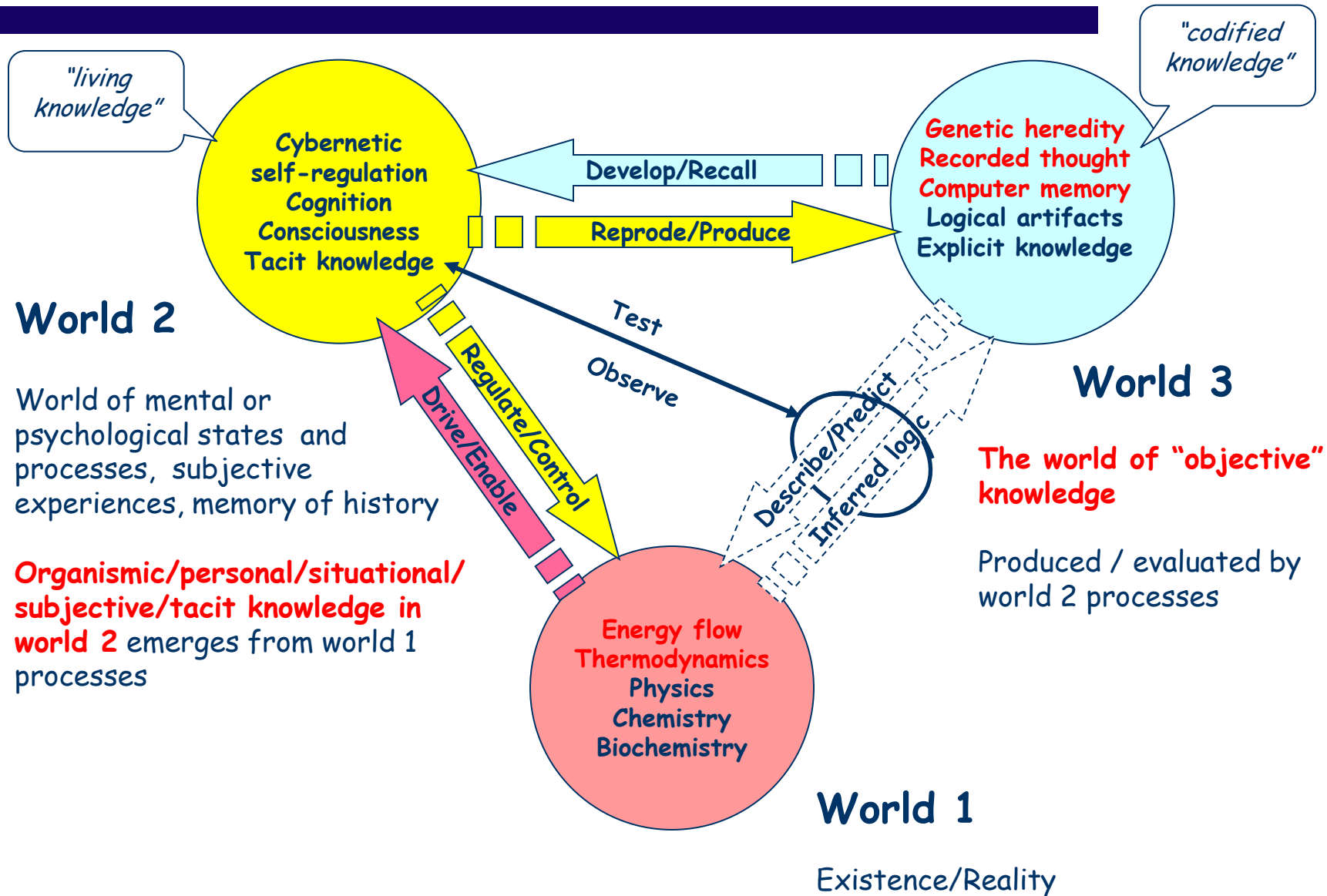- Charles Darwin (1859) On the Origin of Species
- Konrad Lorenz – 1973 Nobel Prize (animal cognition and knowledge)
- Donald T. Campbell (1960, 1974)
  - Psychologist concerned with cognitive processes generating knowledge
  - (1960) Blind Variation and Selective Retention…. (paper)
  - (1974) Evolutionary Epistemology (chapter)
- Sir Karl R. Popper (≥ 1972 – knowledge is solutions to problems)
  - **(1972) Objective Knowledge – An Evolutionary Approach**
  - (1974) "The main task of the theory of knowledge is to understand it as continuous with animal knowledge; and … its discontinuity – if any – from animal knowledge" p 1161, "Replies to my Critics"
  - (1994) Knowledge and the Body-Mind Problem
- Knowledge revolutions
  - Thomas Kuhn (1960) The Structure of Scientific Revolutions
  - Stephen J. Gould (and Eldridge) - Punctuated equilibria

The early Popper / the mature Popper on epistemology

- Popper 1959 – "The Logic of Scientific Discovery"; 1963 – Conjectures and Refutions):
  - There is no such thing as induction
  - We can't prove if we know the truth
  - Deductive falsification is deterministic
  - Make bold hypotheses and try to falsify them – what is left is better than what has been falsified
  - Demarcation between science and pseudoscience based on falsifiability
- **Popper (1972 – "Objective Knowledge") biological approach**
  - All knowledge is constructed
  - Claims can be protected against falsification by infinite regress of auxiliary hypotheses
  - Knowledge as solutions to problems
  - Three worlds ontology
  - "Tetradic schema" to eliminate errors and build knowledge
- Misunderstanding puts off many contemporary philosophers
  - "**Objective knowledge**" = knowledge inertly codified into/onto a physical object (DNA, print on paper, pits on a CD, domains on a magnetic surface)

Karl Popper's first big idea from Objective Knowledge: "three worlds" ontology

"living knowledge"

"codified knowledge"

Cybernetic self-regulation Cognition Consciousness Tacit knowledge

Develop/Recall

Reprode/Produce

Genetic heredity Recorded thought Computer memory Logical artifacts Explicit knowledge

World 2

World of mental or psychological states and processes, subjective experiences, memory of history

Organismic/personal/situational/ subjective/tacit knowledge in world 2 emerges from world 1 processes

Test

Observe

Regulate/Control

Drive/Enable

Describe/Predict

Inferred logic

World 3

The world of "objective" knowledge

Produced / evaluated by world 2 processes

Energy flow Thermodynamics Physics Chemistry Biochemistry

World 1

Existence/Reality

"Epistemic cut" concept clarifies validity and relationships of Popper's three worlds

- Popper did not physically justify his ontological proposal

- **Howard Pattee** 1995 "Artificial life needs a real epistemology"
  - An "**epistemic cut**" refers to strict ontological separation in both physical and philosophical senses between:

    Knowledge of reality from *reality itself*, e.g., description from construction, simulation from realization, mind from brain [*or cognition from physical system*]. Selective evolution began with a description-construction cut…. The highly evolved cognitive epistemology of physics requires an epistemic cut between reversible dynamic laws and the irreversible process of measuring [or describing]….

  - Also known as "Heisenberg cut"

  - Different concept from "*epistemic gap*" separating "phenomenological knowledge" from "physical knowledge"

  - No evidence Pattee or Popper ever cited the other

- One epistemic cut separates the blind physics of world 1 from the cybernetic self-regulation, cognition, and living memory of world 2

- A second epistemic cut separates the self-regulating dynamics of living entities from the encoded knowledge of books, computer memories and DNAs and RNAs

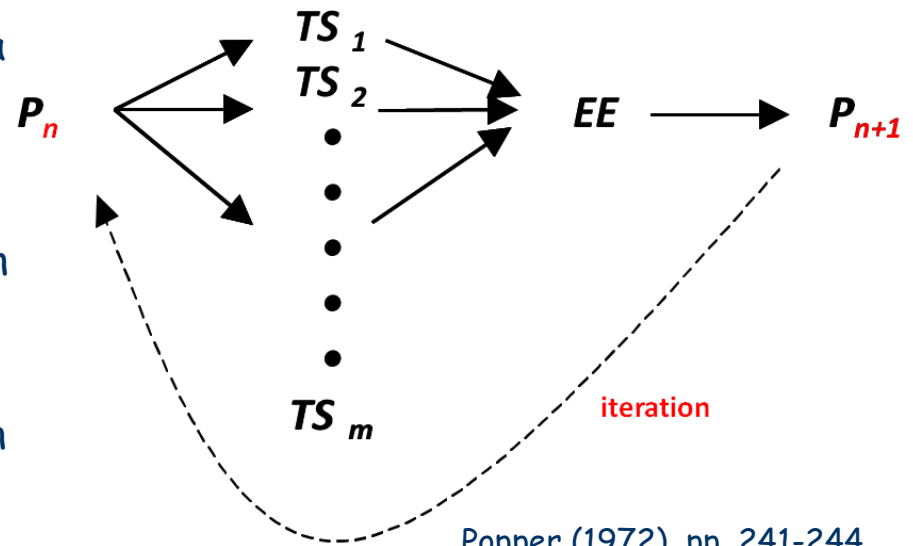- See Pattee (2012) *Laws, Language and Life*. Biosemiotics vol. 7

Popper's second big idea: "tetradic schema" / "evolutionary theory of knowledge" / **general theory of evolution**

P_n a real-world problem faced by a living entity

TS a tentative solution/theory. Tentative solutions are varied through serial/parallel iteration

EE a test or process of error elimination

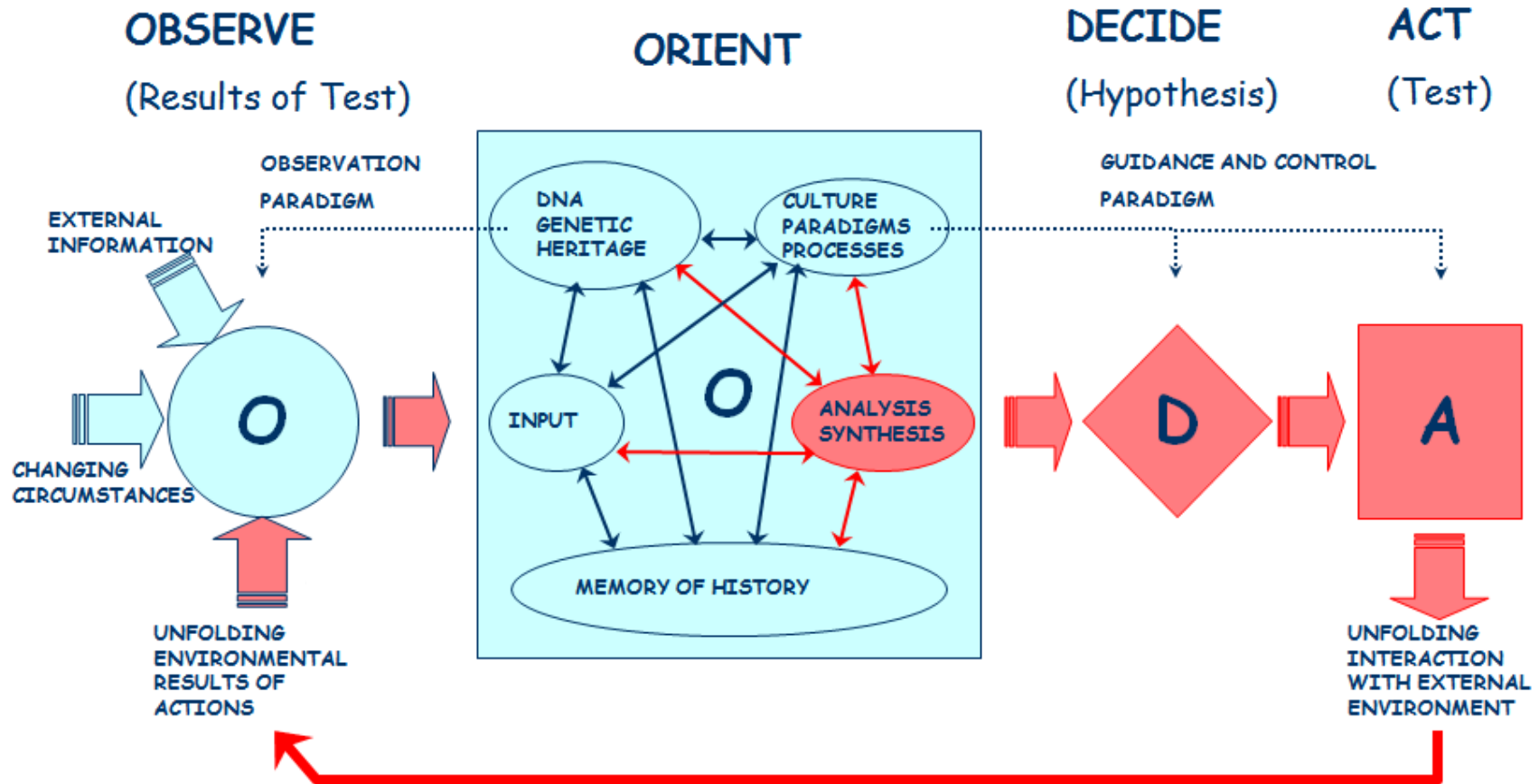P_{n+1} changed problem as faced by an entity incorporating a surviving solution

The whole process is iterated

$$P_n \rightarrow \begin{matrix} TS_1 \\ TS_2 \\ \bullet \\ \bullet \\ \bullet \\ \bullet \\ TS_m \end{matrix} \rightarrow EE \rightarrow P_{n+1}$$

iteration

Popper (1972), pp. 241-244

- **TS**s may be embodied in W2 "structure" in the individual entity, or
- **TS**s may be expressed in words as hypotheses in W3, subject to objective criticism; or as genetic codes in DNA, subject to natural selection
- **Objective expression and *criticism* lets our theories die in our stead**
- Through cyclic iteration, sources of errors are found and eliminated
- Tested solutions/theories become more reliable, i.e., approach reality
- Surviving TSs are the source of all knowledge!

USAF Col. John Boyd's OODA Loop process wins dogfights and military conflicts

OBSERVE (Results of Test)

ORIENT

DECIDE (Hypothesis)

ACT (Test)

EXTERNAL INFORMATION

OBSERVATION PARADIGM

GUIDANCE AND CONTROL PARADIGM

CHANGING CIRCUMSTANCES

DNA GENETIC HERITAGE

CULTURE PARADIGMS PROCESSES

INPUT

ANALYSIS SYNTHESIS

O

O

D

A

MEMORY OF HISTORY

UNFOLDING ENVIRONMENTAL RESULTS OF ACTIONS
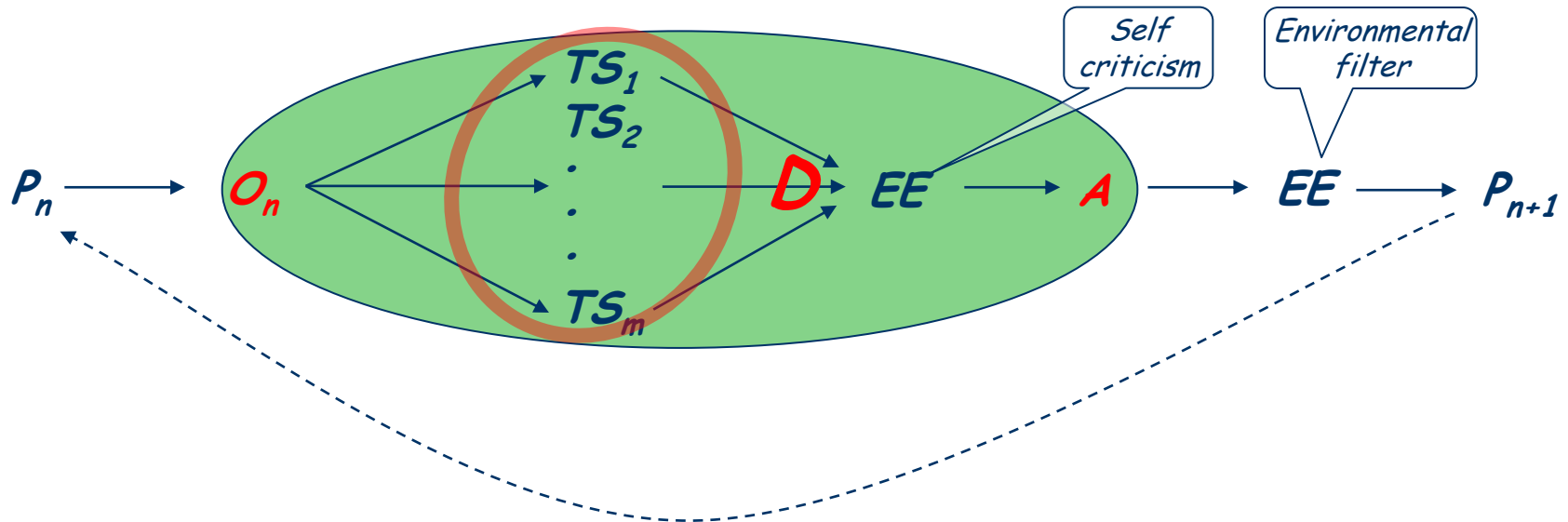
UNFOLDING INTERACTION WITH EXTERNAL ENVIRONMENT

- Achieving strategic power depends critically on learning more, better and faster, and reducing decision cycle times compared to competitors.

- See Osinga (2005) Science, strategy and war: the strategic theory of John Boyd - http://tinyurl.com/26eqduv

Some OODA definitions after John Boyd

- Generic process for any complex adaptive entity
  - **Observation** assembles **data** about the world (including the entity's own prior effects and those of its competitors on that world). *Data* is given context relating to interactions with the world.
    Orientation processes **information** from those observations into semantically linked **knowledge** to form a world view comprised of
    - recent observations
    - memories of prior experience (which may be explicit, implicit or even tacit)
    - genetic heritage (i.e., "natural talent")
    - cultural traditions (i.e., paradigms)
    - sense making (i.e., inferring meaning)
    - analysis (destruction) of the existing world view
    - synthesis (creation) of a revised world view including possibilities for action.
    This generates **intelligence** (in a military sense).
  - **Decision** selects amongst possible actions generated by the orientation, action(s) to try. Choice is governed and informed by
    - **wisdom** based on experience gained from previous OODA cycles
  - **Action** puts tests decisions against the world. The loop begins to repeat as the entity observes the results of its action.
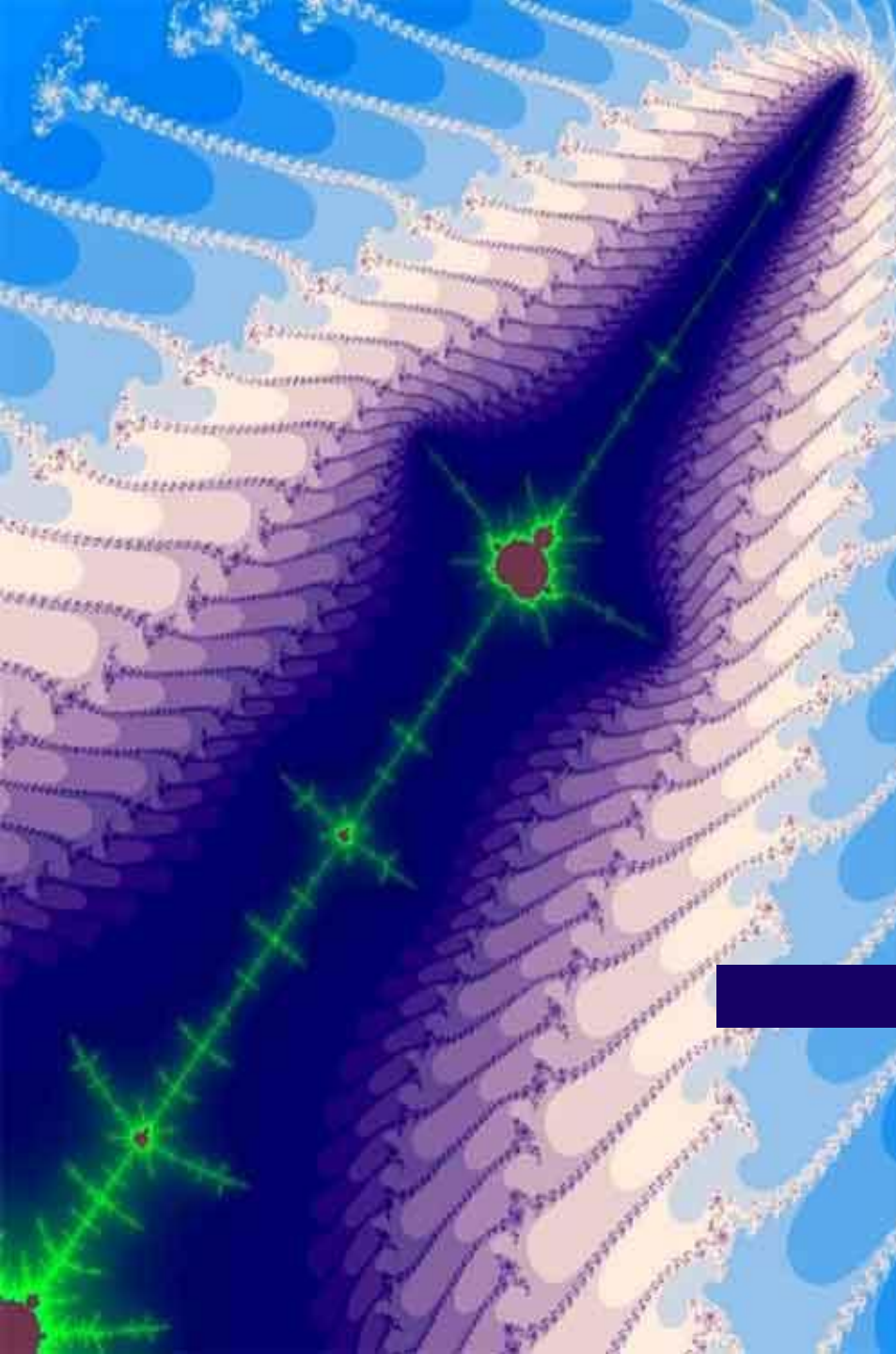
Popper's General Theory of Evolution + John Boyd

O = Observation of reality; O = Making sense and orienting to observations with solutions to be tested; D = Selection of a solution or "decision"

A = Application of decision or "Action" on reality

The real world is a filter that penalizes/eliminates entities that act on decisions that prove to be errors (i.e., Darwinian selection operates)

- Self-criticism eliminates bad ideas
- If errors remain, the environment penalizes or eliminates entities acting on the errors
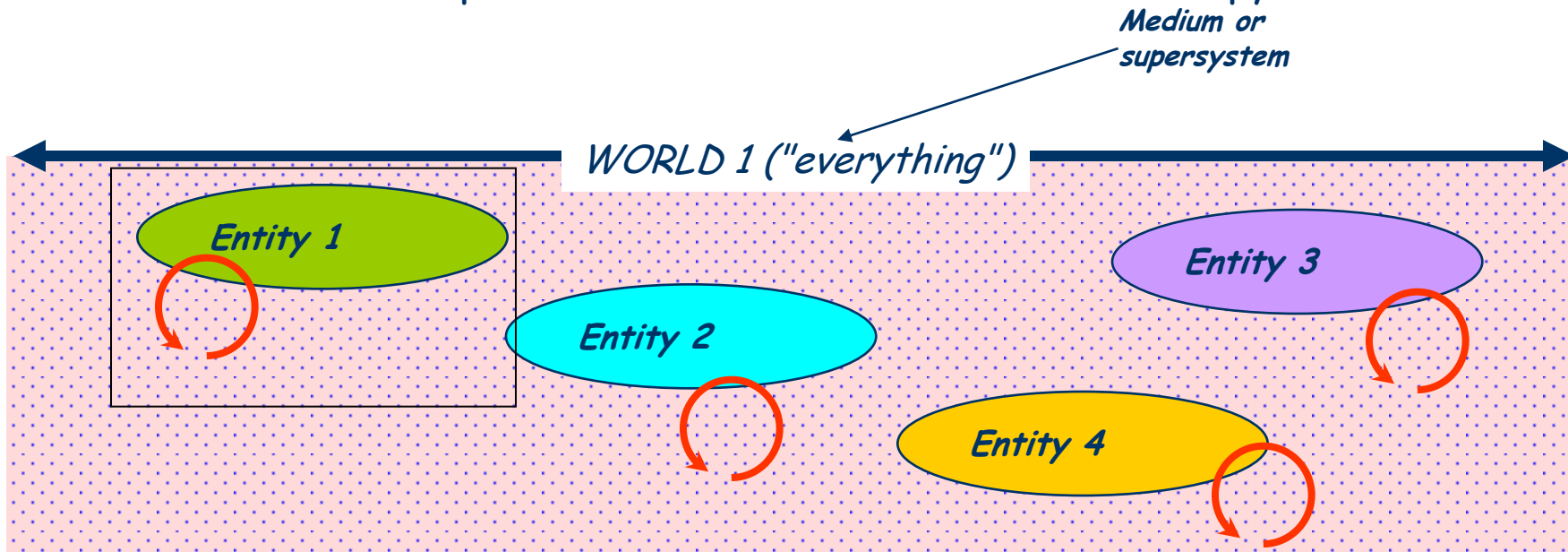
Autopoiesis
—
A systems-based theory of life and cognition

Maturana and Varela (1980). "Autopoiesis and Cognition – The Realization of the Living"
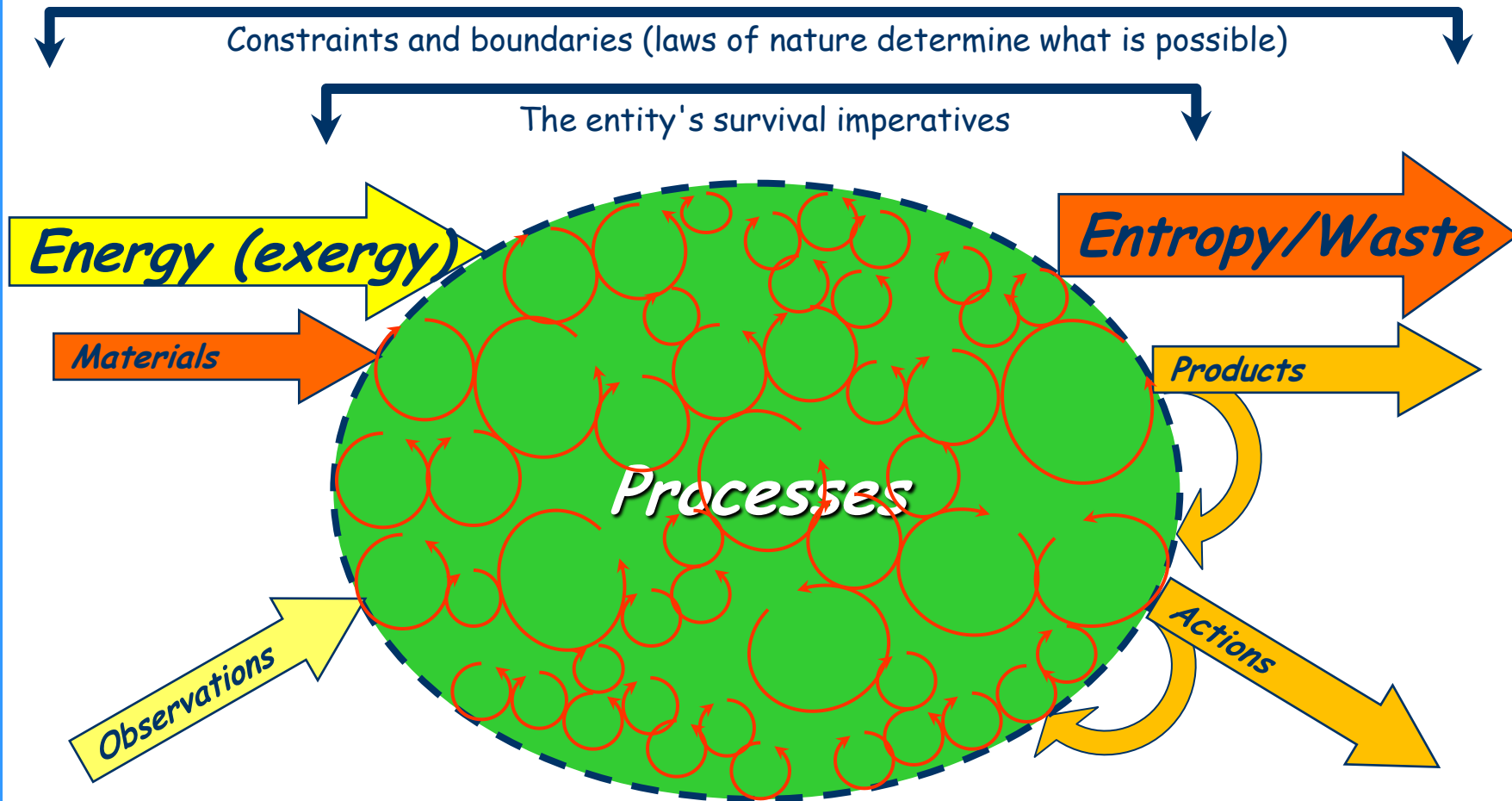
- *Autopoiesis* ("self" + "production": Maturana and Varela 1980) defines when a complex dynamic system is alive
  - An autopoietic system is a thermodynamically driven network of processes of production (transformation and destruction) of material components that produces the components that:
    - through their interactions and transformations continuously regenerate and realize the network of processes (as an organised entity) that produced the network; and
    - constitute the resulting entity in the space in which the components exist by specifying the topological domain of the entity's realization as such a network.
  - Recognition criteria (Varela et al. 1974)
    - Identifiably bounded (membranes, tags)
    - Identifiable components within the boundary (complex)
    - Mechanistic (i.e., metabolism/cybernetic processes)
    - System boundaries internally determined (self-reference)
    - System intrinsically produces own components (self-production)
    - Self-produced components are necessary and sufficient to produce the system (autonomy)

Autopoiesis, energy, and entropy

- Autopoietic entities are complex dissipative systems that have *emerged* from the medium some time in the past
- Processes depend on increasing entropy through dissipating potential differences between high energy sources and low energy sinks
- Energy flow enables work to be done to regulate processes or assemble higher entropy resources into lower entropy products (e.g., self-production of new components for system)
- Net result of dissipation minus work still increases entropy

Medium or supersystem

WORLD 1 ("everything")

Entity 1

Entity 2

Entity 3

Entity 4

An autopoietic system in detail

Constraints and boundaries (laws of nature determine what is possible)

The entity's survival imperatives

Energy (exergy)

Entropy/Waste

Materials

Processes

Products

Observations

Actions

- Cyclic processes driven by dissipation of energy flowing from high potential sources to low potential sinks drives coupled processes against entropy

Knowledge is embodied in the living structure of the autopoietic system

- Continued survival of the quasi cyclical entity depends on the *physical* and *dynamic* configuration of its state in the previous instant *acting* to produce its autopoiesis in the next instant
  - i.e., the "state space" of an instant, comprising
    - spatial location of each particle
    - motion vectors and other dynamic properties of each particle that determine how they will interact in the next instant
  - produces the state space of the next instant
- The system remains autopoietic only so long as an autopoietic configuration is realized from each instant to the next
  - If the next configuration fails to remain within an autopoietic domain its integration as a system is lost (i.e., it has dis-integrated; ref "attractor basins" in complex system theory)
- A quasi-cyclical sequence of states that continues to generate autopoietic states is a form of "structural knowledge"

Key points on autopoiesis

- Autopoiesis continues only as long as the entity's dynamic structure follows a trajectory of change from one instant to the next that produces autopoiesis in the next instant
  - Fundamentally cyclical
  - Continuation depends on the structure of the state in the previous instant to produce autopoiesis in the next instant
  - Feedback regulation is critical
- Loss of control = *dis-integration*, *death*
  - Survival builds knowledge into living systems one problem solution at a time
  - (Popper 1994 "Alles Leben ist Problemlösen", p 48) "the adaptation of life to its environment is a kind of knowledge"
- Niklas Luhmann & his European school argue the logic of self-production is viciously cyclical
  - Requires autopoiesis to exist in an imaginary realm (i.e., orthoganal to the material world likened to imaginary numbers in mathematics)
  - Nature of time in evolutionary processes – to be discussed – demonstrates that autopoietic cycles are "virtuous" not vicious

Cognition in autopoietic systems
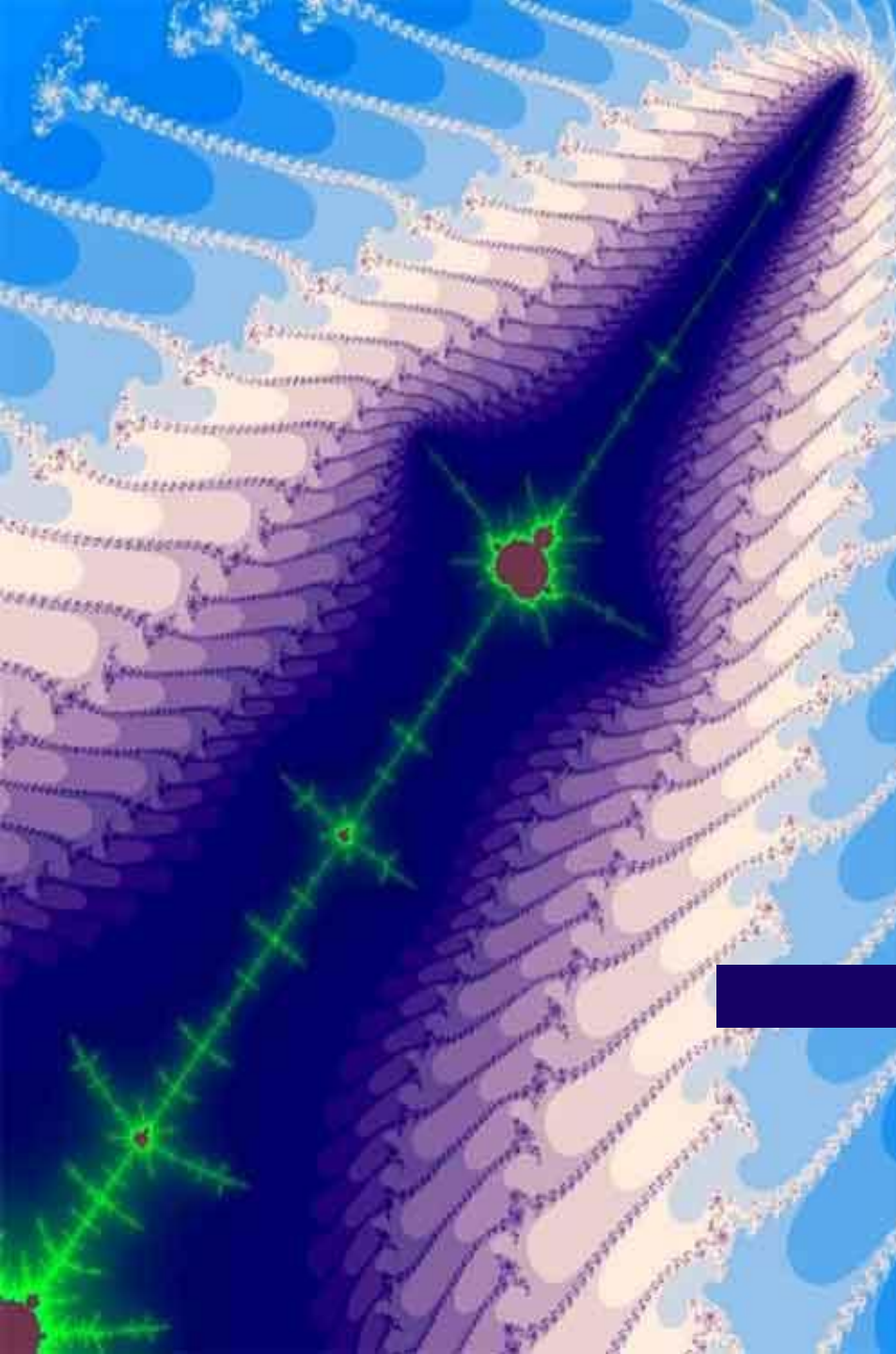## Maturana & Varela 1980

- Cognition is the collection of processes by which the autopoietic system maintains itself
  - For any autopoietic system its cognitive domain relates to the particular way in which its autopoiesis is realized.
- Knowledge is a product of autopoiesis
  - Knowledge is descriptive conduct, relative to the cognitive domain of the knower.
  - If the way in which the autopoiesis of an organism is realized changes during its ontogenic history, the actual knowledge of the organism (its conduct repertoire) also changes;
  - Thus knowledge necessarily reflects the ontogeny of the knower
    - Ontogeny as a process of continuous structural change without loss of autopoiesis
    - This is a process of continuous specification of the behavioral capacity of the organism, and, hence, of its actual domain of interactions.
  - Intrinsically, then, no absolute knowledge is possible, and the validation of all possible relative knowledge is attained through successful autopoiesis.

My interpretation of terms relating to cognition re autopoietic or artificially intelligent systems

- **Observation**: Initial change induced within the autopoietic system by a perturbation
- **Classification** (/ **decision**): Process by which an induced change results in the system settling into one of several alternative attractor basins on a landscape of potential gradients
- **Meaning**: The net change in the system due to the initial propagation and classification of an observation
- Ian Coombe's Hierarchy (ref. Aust. Army Information Manual)
    - **Data**: The atomic level of meaning
    - **Information** (first level of synthesis): Classified observations assembled into relationship structures
    - **Knowledge** (second level of synthesis): Semantically identified and linked information
    - **Intelligence** (third level of synthesis): Tentative theory(ies) about the world based on knowledge
    - **Wisdom** (fourth level of synthesis): Solutions after the elimination of errors through testing theories against the world
    - **Strategic power** (the result): Wisdom applied to control the world

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First take on what knowledge is

- Popper's **World 1** encompasses everything - it is the dynamic reality that exists independently of observation, knowing and knowledge
- **Observation**, **meaning** and **knowledge** dynamically emerge in **W2** as consequences of universal laws governing physical processes in **W1** as these processes impact living (i.e., autopoietic) entities with an autonomous history able to distinguish themselves from the rest of the world
  - **Observation** is a *dynamic change propagated within the autopoietic system* resulting from an interaction with the world
  - **Meaning** is a *consequence of the observation induced change* in the constitution of the autopoietic system
  - **Knowledge** (in one sense) is *the persistent effect of a history observation and meaning* as represented in successfully surviving autopoietic systems, i.e., those embodying solutions to problems
- There is an **epistemic cut** between phenomena of W1 and the knowledge of the phenomena as represented in the living system (Howard Pattee, 1995)

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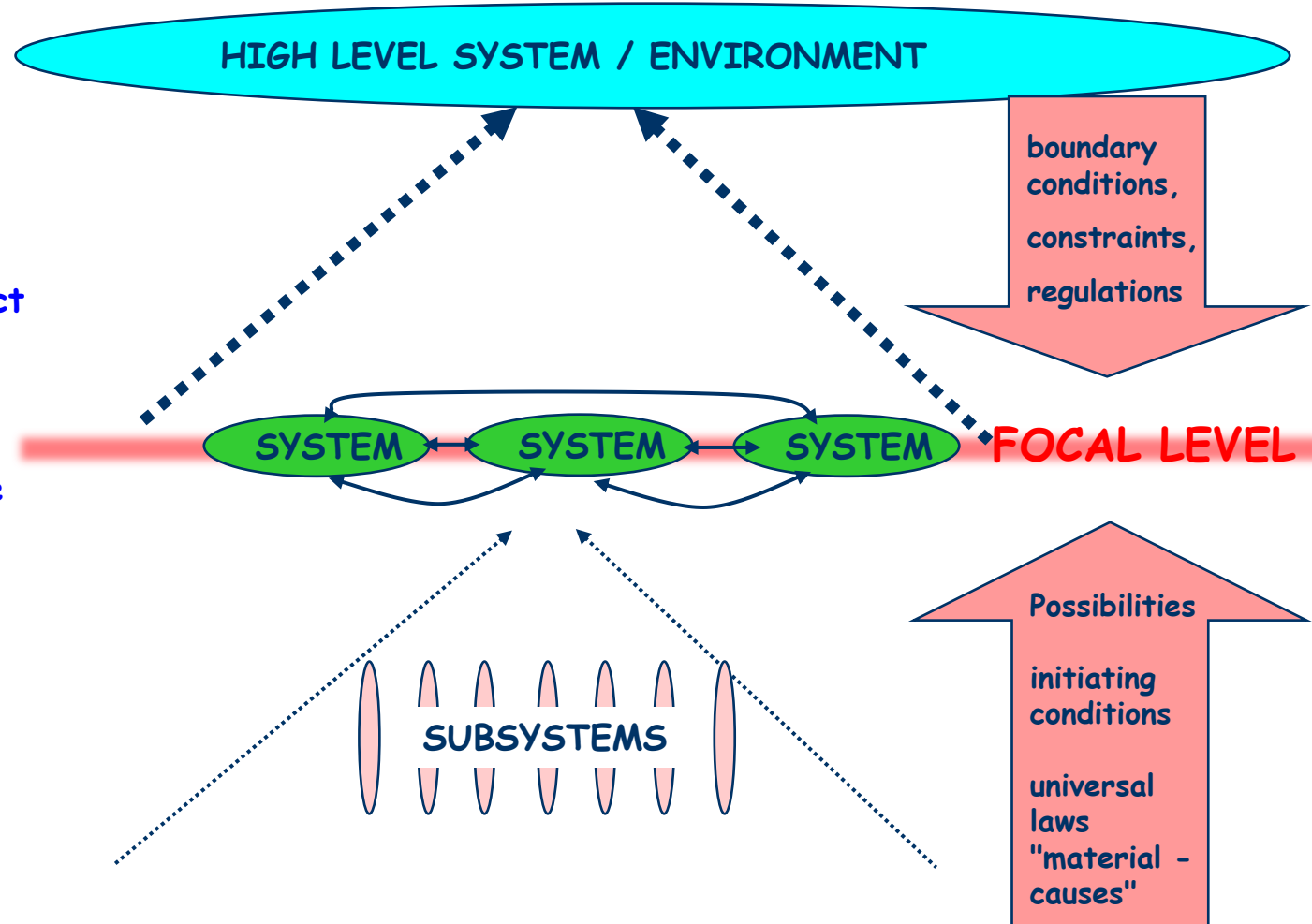
Emergence of autopoiesis and knowledge in a hierarchical world —

Origins of life and knowledge

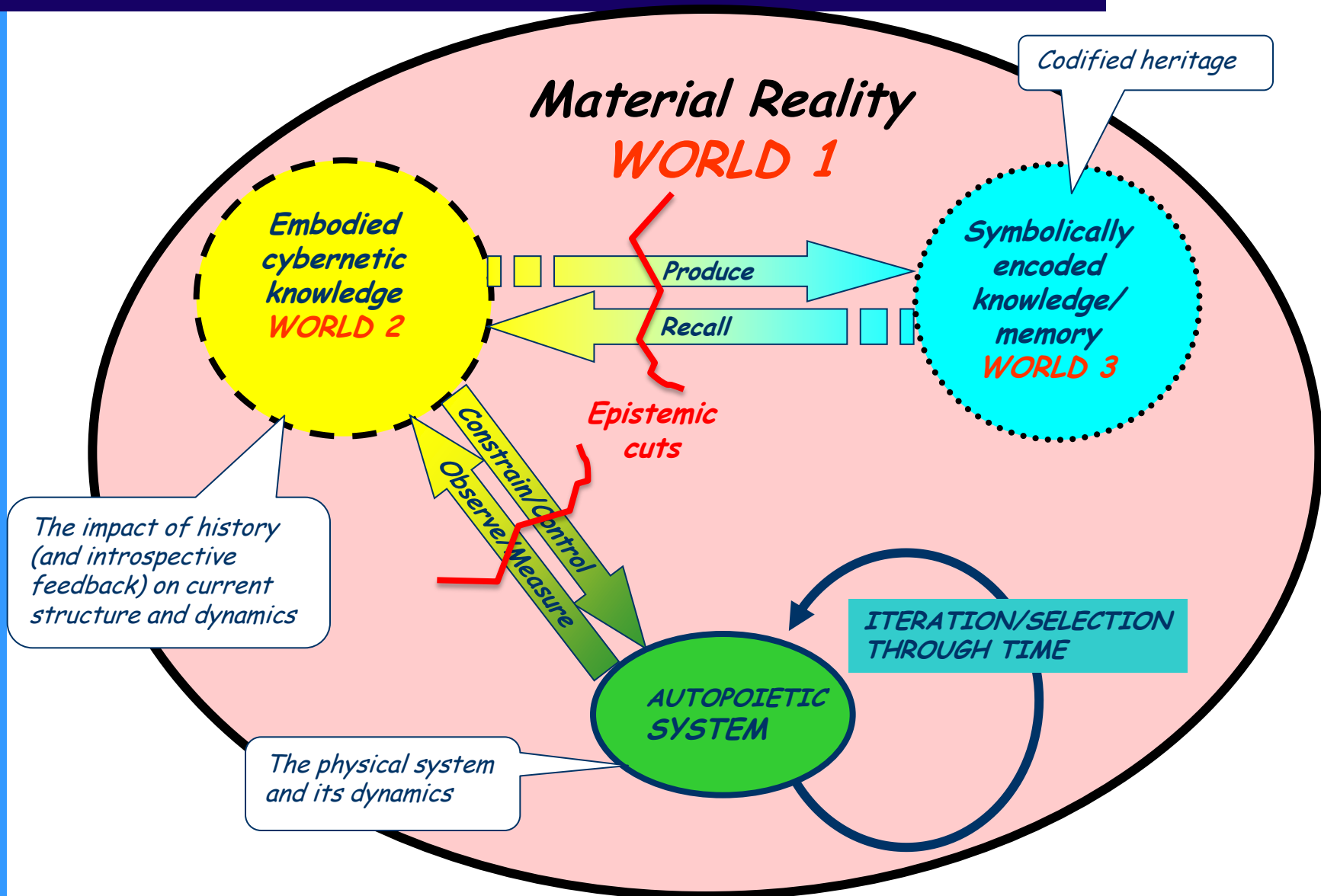# Complexity theory: Hierarchically complex dissipative systems and the focal level

HIGH LEVEL SYSTEM / ENVIRONMENT

boundary conditions,

constraints,

regulations

Emergent properties

- **Synthesis cannot predict higher level properties**

- **Behaviour is uncomputable**

- **Boundary conditions & constraints select**

- **Analysis can explain**

SYSTEM ⬌ **SYSTEM** ⬌ **SYSTEM**   **FOCAL LEVEL**

Possibilities

initiating conditions

universal laws "material - causes"

SUBSYSTEMS
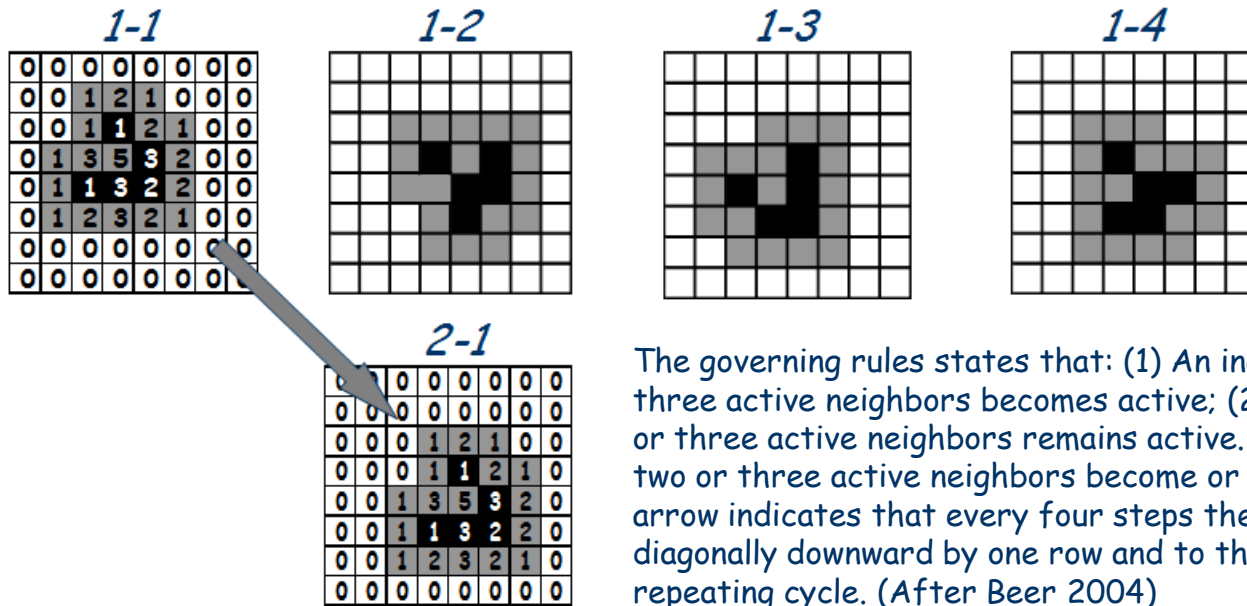
- Herbert Simon (1962) The architecture of complexity
- Stanley Salthe (1993) Development and Evolution: Complexity and Change in Biology

Knowledge in an autopoietic entity

Structural Knowledge in cellular automata
Conway's Game of Life

See Golly cellular automata generator

The governing rules states that: (1) An inactive cell with exactly three active neighbors becomes active; (2) An active cell with two or three active neighbors remains active. (3) Cells with other than two or three active neighbors become or remain inactive. The arrow indicates that every four steps the glider moves on the grid diagonally downward by one row and to the right by one column in a repeating cycle. (After Beer 2004)

- "Governing rules" are the universal laws of a toy universe
  - Rules determine how the state of one instant affects the next instant
  - Any change in a rule establishes a new toy universe
- Many universes close to the border between order and chaos support emergent self-perpetuating dynamic structures
  - Some structures support a sequence of dynamic changes that cyclically repeat the structure
  - Structures can be quite complex and even robust against perturbation in collisions
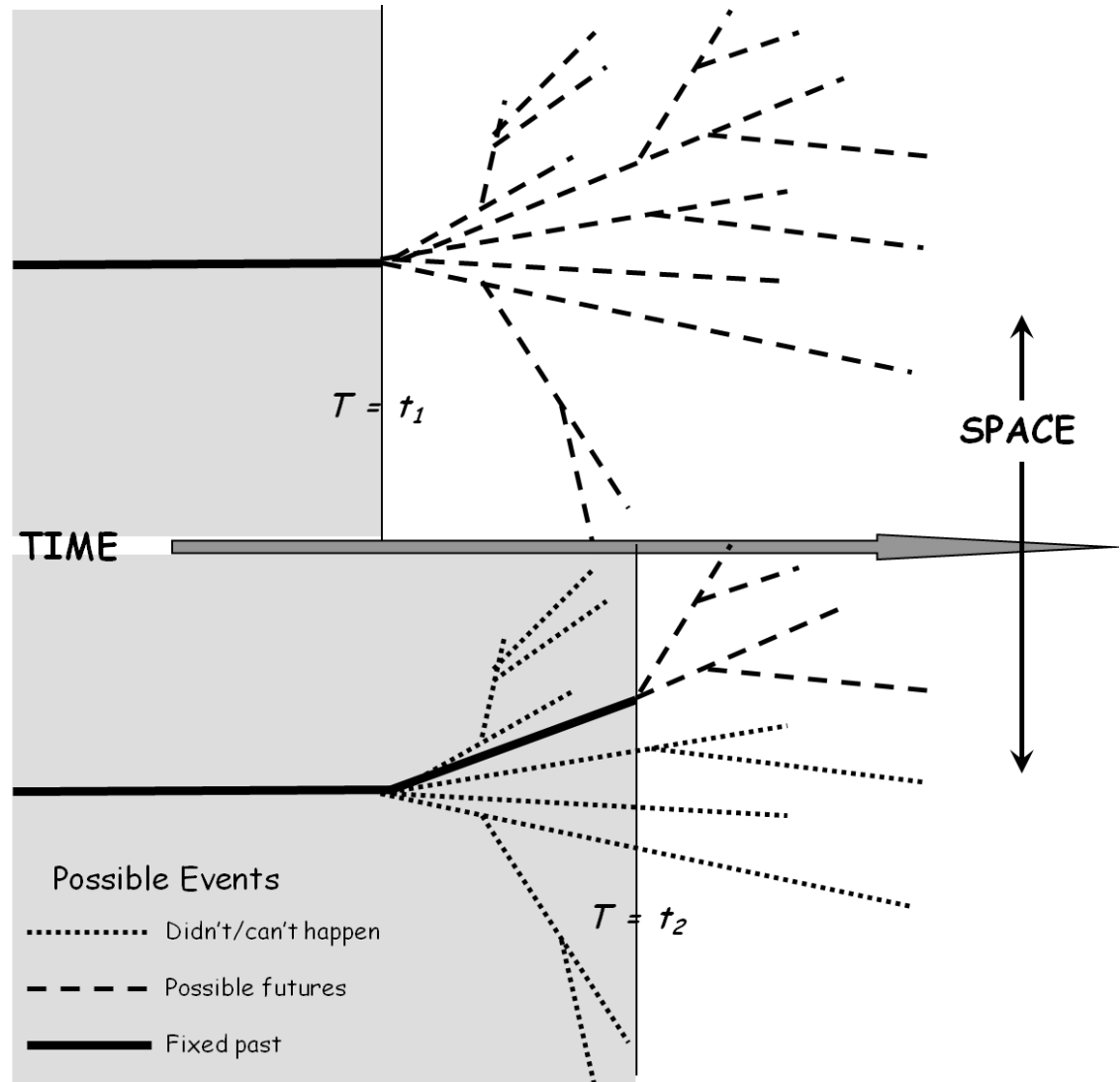 - Metabolism: grid cells consumed – grid cells evacuated

Ellis (2006) Evolving block universe (Newtonian)
Ellis & Rothman (2010) Crystallizing block universe (quantum mechanical)

- Past is fixed
- Present is determined in the instant of becoming
- Future is undetermined
- Solid line – what happened
- Kauffman – adjacent possible
  - t_1 Dashed lines represent all of the possible future states that can be reached in the next instant from the present instant
  - t_2 One state was realized at t_1, Dotted lines lead to states that could have happened at t_1 but didn't/can't happen. Dashed lines represent states that can still be reached from the state at t_2
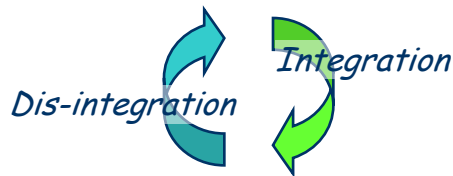- The future is continually and progressively constrained by realization of the present

$T = t_1$

SPACE

TIME

Possible Events

· · · · · · · · · · Didn't/can't happen

– – – – Possible futures

———— Fixed past

$T = t_2$

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Knowledge (memory of history): a phenomenon of emergent and evolving autopoiesis

Evolutionary Stage

Chaotic turbulence

Integration

Dis-integration

Coalescence / Emergence

Tentative solutions

t

Stabilised autopoiesis

Stable solutions

t

Dispositional autopoiesis

Selected solutions

t

Semiotic autopoiesis

t

Criticised solutions   Shared solutions

Knowledge sharing

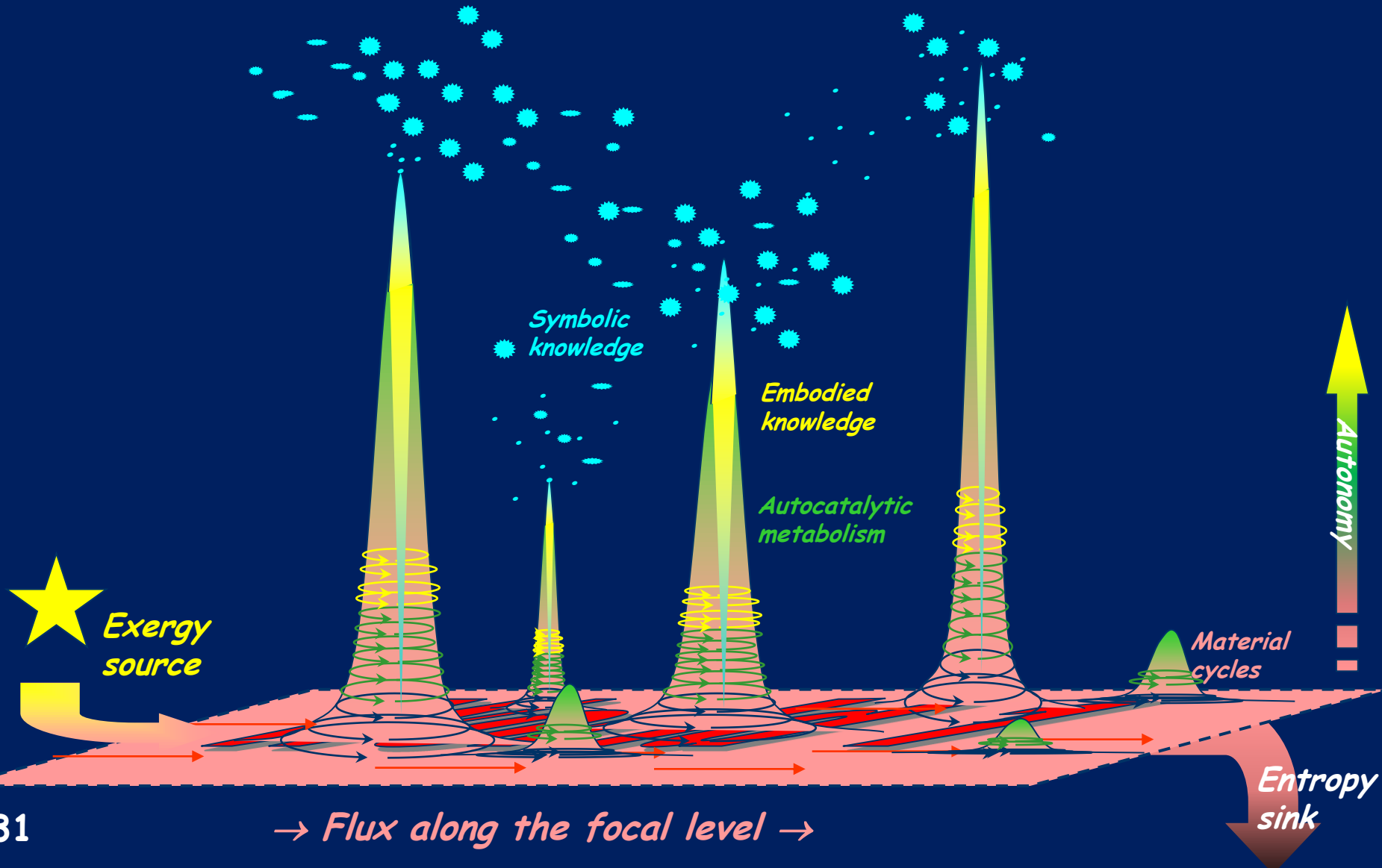**The nature and growth of autopoietic knowledge**

Systems driven to transport energy from sources of high potential to sinks of lower potential become more organized - Prigogine, Morowitz, Kauffman, et al.)

Coalescent systems have no memory. Self-regulatory/self-productive (autocatalytic) activities that persist for a time before disintegrating produce components whose individual histories "precondition" them to form autopoietic systems. **Each emerged autopoietic system represents a tentative solution to problems of life. Those that dis-integrate lose the structural memories (= heredity/knowledge) of their histories**

Stable systems are those whose embodied tentative solutions enable 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 dispositional or tacit knowledge (W2). **Those that fail to solve new problems dis-integrate and lose their histories.**

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. **Objective knowledge may be shared across space and through time.** - Howard Pattee (1965-2008 series of papers; Luis Rocha (1995-) series of papers.

Symbolic knowledge

Embodied knowledge

Autocatalytic metabolism

Exergy source

Autonomy

Material cycles

Entropy sink

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→ *Flux along the focal level* →

OODA Loop in the autopoietic entity

Autopoietic system
Cell
Multicellular organism
Social organisation
State

Environment

Classification

Observations (data)

Memory of history

Semantic processing to form knowledge

Meaning

Related information

Perturbations

Predict, propose

Intelligence

An "attractor basin"

Another view

Conscious OODA Loop in Material Terms

Medium/ Environment

Autopoietic system

Memory

Observation

Classification

World State 1

Perturbation

Transduction

Synthesis

Time

Codified knowledge

Evaluation

Processing Paradigm

Decision

Observed internal changes

Assemble Response

Iterate

Effect

World State 2

Effect action

Internal changes

Conclusions

- Results highlight the importance to understand autopoiesis as first defined by Maturana and Varela
  - Life is a complex physical organization persisting over time
- Autopoiesis and the construction of knowledge are inseparable aspects of physical dynamics and the progression of time in an evolutionary block universe of sufficient complexity
  - Life is impossible without the knowledge to survive problems of existence
  - All knowledge is constructed by living systems through solving their problems of existence
  - Knowledge and life emerge together as a consequence of the constraints of history on the adjacent possible
- The result unifies theories of epistemology, physical dynamics, life, biological evolution, knowledge and social systems.
  - Claims asserted in one discipline may be deeply explained in other disciplines
  - The resulting biological epistemology is far more robust and scientifically grounded than are the claims of any one of these disciplines standing alone
- Implications
  - No Telos, no essences, but choice in the instant of becoming allows us to constrain the future
- Criticisms welcome!

Contributing disciplines

- Physics: mechanics, dynamics, thermodynamics and cybernetics
  - Ilya Prigogine (Nobel laureate) – non equilibrium thermodynamics
  - Harold J. Morowitz 1968 – "Energy Flow in Biology"
  - Eugene Odum 1971 – "Fundamentals of Ecology"
- Biology: Genetics, cytology, natural history, evolutionary biology
  - My own research and teaching background
  - S.J. Gould 2002 – "The Structure of Evolutionary Theory"
- Evolutionary epistemology
  - Popper 1972 - "Objective Knowledge"
  - Thomas Kuhn 1970 - "The Structure of Scientific Revolutions"
  - John Boyd 1996 – OODA Loops
- Autopoiesis
  - Maturana & Varela 1980 - "Autopoiesis and Cognition"
- Theories of emergent and hierarchical complexity
  - Herbert Simon (Nobel laureate in economics)
  - Stanley Salthe 1985 – "Evolving Hierarchical Systems"
  - Stuart Kauffman 1983 – "The Origins of Order"
- Cosmology, time, causation and the "adjacent possible"
  - George F.R. Ellis > 2006 – evolving block and, crystallizing block universes
  - Kauffman > 2000 – adjacent possible