



Introduction

- In physics, there is no mystery behind emergence (Crane 2001). Explanatory bridges between levels of analysis are mostly complete. Emergence is considered as “**weak**” and the a-priori unpredictability of these bridges is considered an *epistemological* problem - not *ontological*. It is noteworthy that the current analytical toolset of physics is based on behaviours and continuous change – a **process metaphysics (PM)**.
- In cognition, there are no accepted bridges between the mental and physical divide and “**strong**” ontological versions of emergence remain viable. Without empirical support, rational thought has produced a proliferating plethora of possible flavours and sources of emergence. It is noteworthy that the analytical tradition of cognition is based on static substances with properties – a **substance metaphysics (SM)**.
- Purpose of the **Emergic Memory Model**
 - Ground debate in simple (yet empirically real) parts, wholes & relations
 - Basis for comparison and discussion among competing hypotheses
 - Generate new insights and hypothesis
 - Emergence is due to epistemological incompleteness and objectification errors
 - Based on change, yet has substance-like properties
 - A substance/process metaphysics hybrid
 - The locus of emergic debate?

What is Emergence?

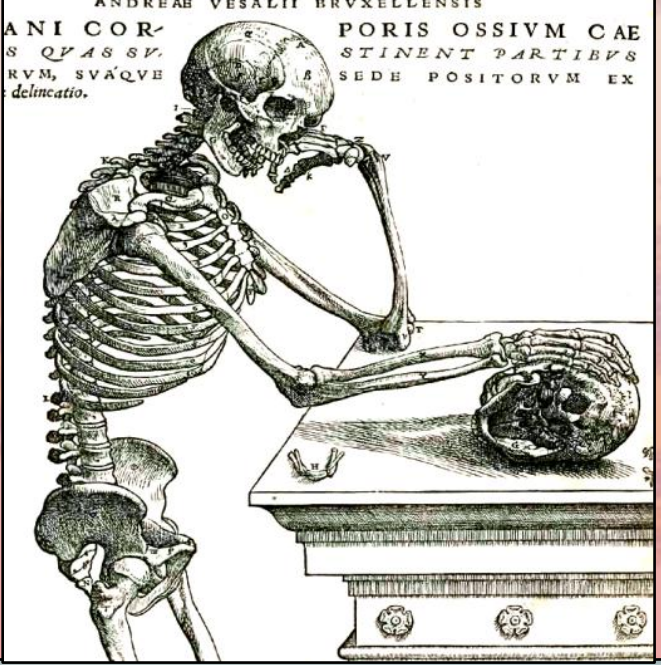
- The whole is more than the sum of its parts – (Aristotle –350BC)



- Obviously, the whole can have **properties** that the parts do not.
- Can these additional properties be attributed to
 - Arrangement of parts? (relations cannot have properties in SM)
 - Interaction of parts? (change not handled in SM)
- Nevertheless, we do know how to causally design a car out of unchanging parts
 - The only true source of causality/change is the burning of gasoline
 - Each part harnesses/directs this change in a different manner
- In substance metaphysics, the behaviour of the part under change is its property

Strong Emergence in Cognition

- The mind seems to **supervene** on the body
 - An aura of **downward causation**
- Mental properties may **depend** on physical properties
- Mental properties **distinct** from physical ones
 - Multiple realizability** (token identity)
 - Additional (**inexplicable**) causal properties
- Note: mental properties have not been operationalized
 - What agreement is there for consciousness, qualia or intentionality?
 - Problem of **subjective** vs. **objective** knowledge (Crutchfield 1994)



Flavours of Cognitive Emergence

- Interactive Illusion
 - Epistemic (non-metaphysical)
 - Language Problem
- Autonomous/Property Dualism
- Anomalous
- Epiphenomenal
- Physically Non-reductive
- Supervenient (Global/Local)

Closure of Physics


(David Chalmers)

(Donald Davidson)

(Thomas Huxley)

(Jaegwon Kim)

(John Haugeland)

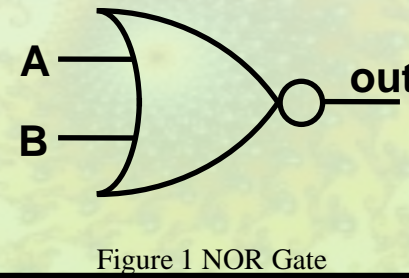
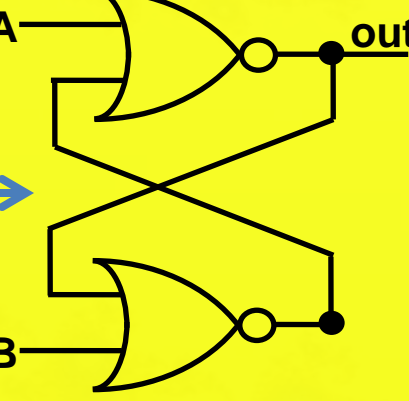


Sources of Cognitive Emergence

- Complexity, Interactivity (Bikhard 2009)
- Scope (Ryan 2007)
- Epistemic Levels, Language (Crane 2001)
- Brain (Searle 1980)



Emergic Memory Model


NOR Gate Circuit (neural analogy)	Effective State Transition Table				Properties
	A(t)	B(t)	out(t) Past	out(t+Δt) Future	
	0	0	Q	1	• No memory of past stimuli or response • Pure (yet real) reactive system
	0	1	Q	0	
	1	0	Q	0	
	1	1	Q	0 ¹	
	0	0	Q	Q (memory)	• Feedforward • Non-continuous • Causally analyzable as a computation (function or operator) • Memory of past stimuli or response • Intentional : about last stimuli even after stimuli removed
	0	1	Q	1	
	1	0	Q	0	
	1	1	Q	Restricted ¹	

¹Design or additional gates typically ensure that an A and B pulse never happen simultaneously. Otherwise, oscillations result.

Comparisons...

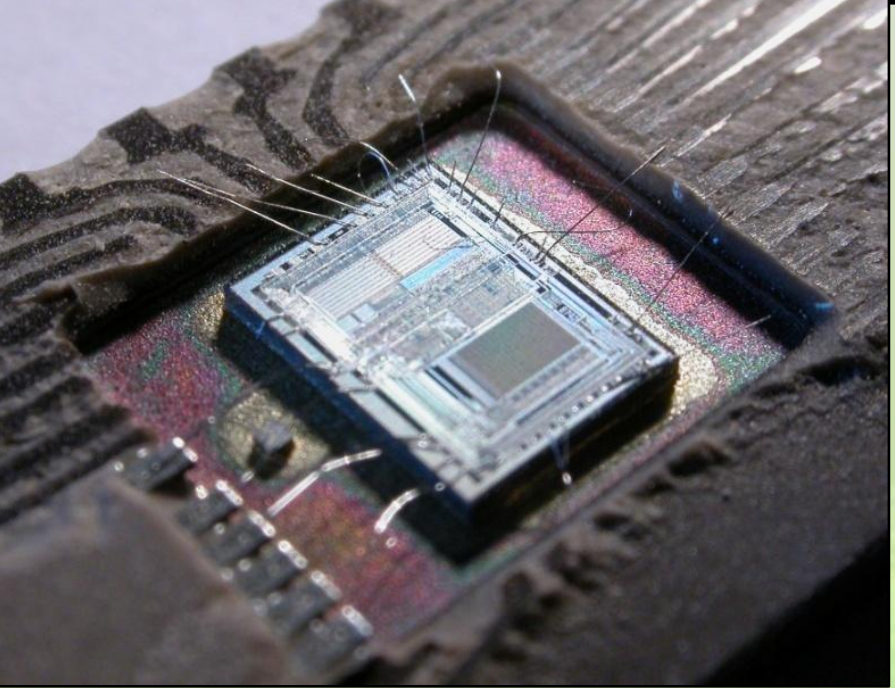
Emergence due to scope? (Ryan 2007)

- No: Property of memory/intentionality is attributed to the **local** out, or out, signals and does not depend on **global** topology
- There is a process difference
 - Reactive** locally, **autonomous** globally
- Like a Möbius strip, recursive architecture is a causal factor
 - Directs change so that behaviour can be objectified
- Micro or macro states are different analytic observables so topological emergence is epistemic – due to language




Emergence due to complexity? (Bikhard 2009)

- What is complexity?
 - Numbers of parts & interconnections?
 - Then no: just two parts and one feedback loop
 - Even a computer chip with billions of interconnected gates is not considered as demonstrating strong emergence
- However, feedback (recursion)
 - Converts a computational system
 - Into an automaton (process)
 - The mathematics can be more complex, e.g., a 3-body problem is unsolvable, yet CPUs engineerable



Emergence due to brain? (Searle 1980)

- Well, what is special about brain, or neurons, or cells in general, or chemistry, or quantum events?
- Any of these could be a locus.
- Perhaps symbiotic plants and bacteria have intentionality?
- There is no warrant for localizing brain.
- However, a brain is an automaton, and not a computation.
- An epistemological problem in objectifying behaviour via properties?



Emergence due to Epistemology? (Crane 2001)


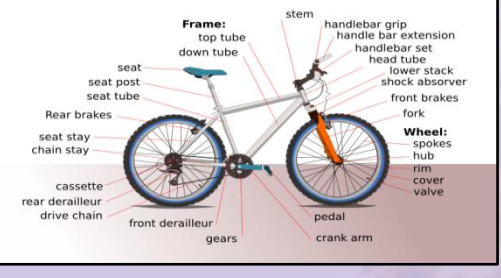
	Process Metaphysics (PM)	Substance Metaphysics (SM)
What a system	Does	Is
Properties	Epistemic Observable Process	Ontological (Objectified?)
Language	Imperative changes	Declarative properties
Causal	Yes	No; (Yes with interpreter)
Control	Reactive Bottom-Up	Top-Down Interpreted (Illusion?)
Meaning	Relative Causal Predictability	Absolute Truths
Semantically Complete	Yes	Gödel Incomplete (1931) for each
Lowest Level (body)	Ontological Physics Empirically Reduced from Top	Ontological (yet no change!) Not Physics; Rational Deduction Unique Epistemic Language Level
Highest Level (mind)	Epistemic Causal Approximation (Remade bottom-up after top-down reduced)	Ontological (yet no change!) Rational Deduction Unique Epistemic Language Level
Linearity	Behaviour Naturally Non-Linear	Sum of Properties Expected
Emergence	Weak (complete causal story)	Strong (regressed to interpreter or objectification error?) Ontology ↔ Ontology!

Cannot reduce PM to SM; Cannot reduce one Ontology to another Ontology
SM is an epistemic commitment that necessitates irreducibility between levels of analysis

Discussion...

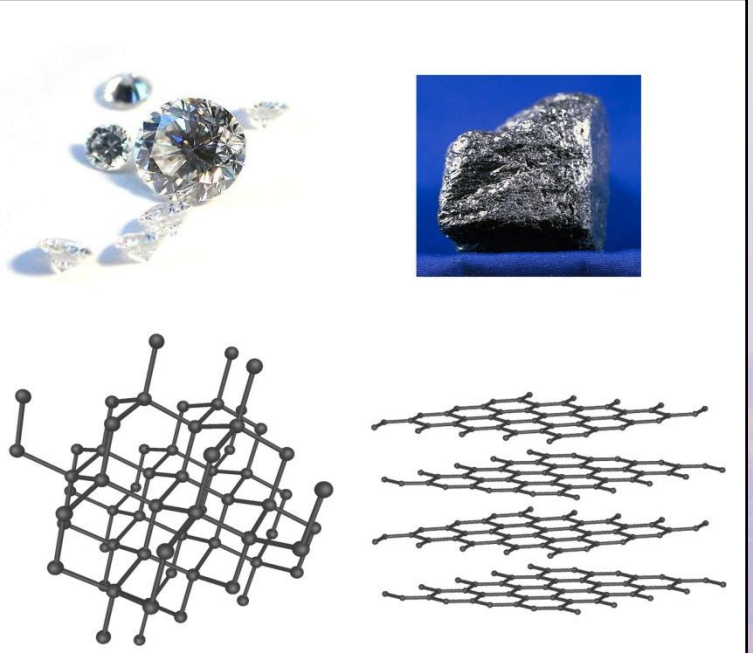
Property or Behaviour?

- Is memory/intentionality a property or behaviour across time (an operationalized process)?
- If it is a property, the flip-flop example exhibits strong emergence
 - The flip-flop cannot compute a memory/intention nor any basic property
 - Nevertheless, it is also completely explicable on causal/process grounds (physics)
 - Identity/correspondence by integration over time
 - Thus cognitive intentionality is non-problematic
- If it is a behaviour, then intentionality is weak and non-problematic
- In either case, emergence is causally explicable.
- Suggests that **properties are an objectification fallacy**
 - Converting a process (e.g., kissing) to a substance (a kiss)
 - They are an observable – a process

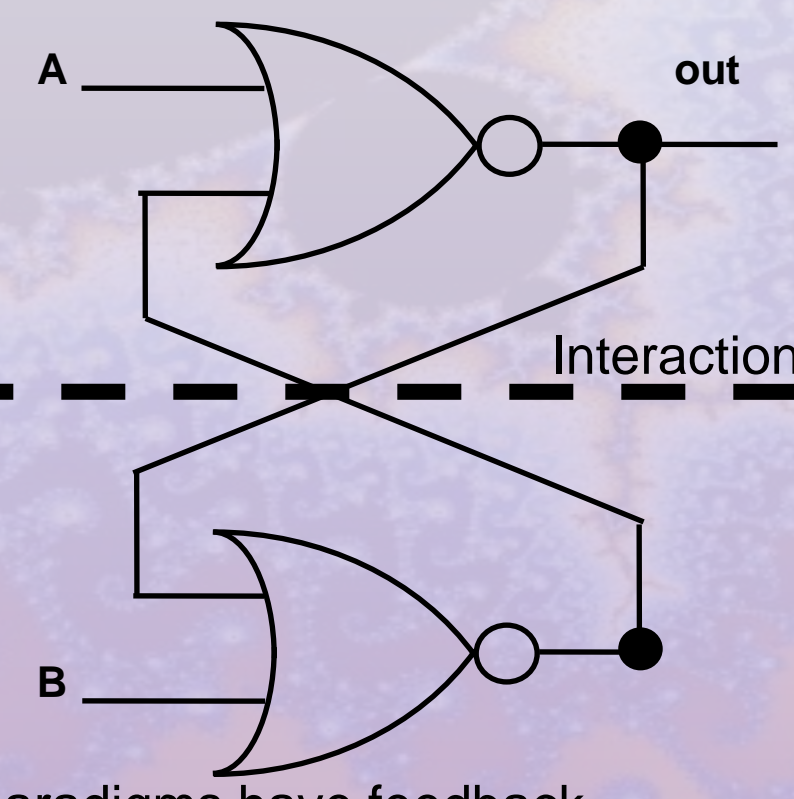




Process or Substance Metaphysics?

- In *substance* metaphysics,
 - Relations are not *substantial* and cannot have *properties*
 - Change* is ignored, and behaviour cannot *create* properties
- In *process* metaphysics (and Physics)
 - Relations, such as chemical bonds, or force fields are substantial and do have properties such as strength and associated energy
 - Observables are realised via an observation process, e.g., the hardness of diamond or graphite measured by scratching one object against another
 - Parts cannot be considered alone (and include the observer)
- In a process oriented worldview
 - Recursive behaviours are naturally non-linear and when objectified lead to weakly emergent properties



Warning: Situated Cognition





Agent


Environment

Interaction

- Many experimental paradigms have feedback
 - Often implicit via epistemic structures (screen location, previous trials/questions)
- Care must be taken so that states
 - e.g., memory Q, mental mapare not misattributed to a reactive agent (Brooks 1986) instead of the interactive system
 - i.e., do not confuse behaviour with mental properties

Warning: Memories Invert Control

- Top-down design/reduction (computer software, electronic circuits, levels of analysis) should not be confused with bottom-up reactive operation.
 - Reactivity realizes automata, e.g., the Flip-Flop
 - Operation realizes design
 - Process metaphysics realizes substance metaphysics (properties are observables)
 - Process ontology realizes epistemic analysis?
- Memories imply some intentional symbol placed therein
 - Symbols imply a top-down interpreter that reads, understands, plans & acts
 - An interpreter leads to a homunculus fallacy (infinite regress)
 - Regress avoided by ultimately terminating analysis in bottom-up reactivity
- In process metaphysics, memories & intentionality are epistemic behavioural characterizations
 - Substances reduced top-down to ontological processes, then
 - Epistemically (and approximately) rebuilt via bridges
- In substance metaphysics, memories & intentionality are ontological properties
 - PM considers this an objectification fallacy and that these are epistemic illusions



Conclusion

- Emergic memories (flip-flops) make a good model of emergent properties**
 - Simple: 2 parts, 1 feedback (recursive) loop
 - Grounded
 - Real** operational NOR gates lead to emergence
 - Abstract** logical NOR operators do not (recursion illegal)
 - An excellent vehicle to contrast various flavours and sources of emergentism
 - Explains source of emergence
- Recursion & epistemology is source of emergence
 - With no recursion, a simplified substance metaphysics suffices
 - Properties are a sum of their parts
 - A part can react to a discrete stimuli
 - With recursion, reaction becomes a continuous process of change**
 - Naturally handled by process metaphysics
 - Behaviour has never been a “sum” of micro-behaviours
 - E.g., computer programs, digital circuits, swarm intelligence
 - Substance metaphysics no longer applicable
 - Properties become an objectification fallacy (product of an arbitrary observable process)
 - Emergence is due to objectification errors in substance metaphysics**
 - Substance metaphysics conflates ontology and epistemology
 - Emergence also due to incompleteness of epistemology** (when based on truth semantics)
- Be aware of
 - objectified substances and properties
 - importance of feedback architecture as a source of weak emergence
 - An interpreter, along with symbolism
 - Are ontological illusions
 - Are epistemic useful approximations
 - Substance metaphysics should never be the basis for any metaphysical or philosophical argumentation**
- Whenever emergence is encountered, adopt process metaphysics**
 - Change your language of analytical thought
 - After all, Physics did so with great success!

Terminology

Epistemology	Theory of Knowledge. An arbitrary and approximate analytical language to share useful information. Could be based on truth, predictability, beliefs, justifications...
Objectification	(& Reification) Fallacy. Treating (epistemic) abstractions as ontological.
Ontology	Reality based on being (substance) or becoming (process) metaphysics.
Recursion	Feedback or repetition loops
Topology	Mathematical connectivity/relational architecture

References

Aristotle (~350BC) *Metaphysics*, Book 8.6.1045a.8-10

Bickhard (2009) The interactivist model. *Synthese*, 166:547-591

Brooks, RA (1986) A Robust Layered Control System for a Mobile Robot. *IEEE Journal of Robotics and Automation*, 2(1):14-23.

Crane, T (2001) The significance of emergence. In Barry Lowder and Grant Gillett (eds.), *Physicalism and its Discontents* (Cambridge University Press 2001)

Crutchfield, JP (1994) The Calculi of Emergence: Computation, Dynamics, and Induction. Special issue on the Proceedings of the Oj International Seminar: Complex Systems — from Complex Dynamics to Artificial Reality”, *Physica D*

Davidson, D (1970) Mental Events in *Experience and Theory*, Foster and Swanson (eds.), London, Duckworth.

Gödel (1931) Über formal unentscheidbare Sätze der Principia Mathematica und verwandter Systeme, I. *Monatshette für Mathematik und Physik*. 38: 173-98

Ryan, AJ (2007) Emergence is Coupled to Scope, Not Level. *Complexity*, 13(2): 66-77

Searle, JR (1980) Minds, Brain & Programs. *Behavioral and Brain Sciences*, 3(3): 417-457.

