Autopoiesis, Cognition, and Evolution

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Department of Mathematics
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Doug, I hope that the results of this work help to recharge your own energy stores at AFOSR, i.e. that my work is useful to those who make it possible. 1

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I don't claim to know the answers, so let's think together.

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Some conceptual primitives

- Compression and elaboration: *we are compressions being elaborated*
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  - Scientific theories compress natural phenomena in language.
  - Theories are elaborated in laboratories to channel phenomena.
- Prediction and betting: *we are predictions / bets*
  - Your knees are a prediction that gravity will be in some range.
  - Your lungs are a prediction that air pressure will be in some range.
  - Past *lessons*—bets won and lost—encoded as current structure.

Cognition

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- My mind, like DNA, compresses the lessons of my past.
- Present cognition, like living, elaborates the compressed stuff.
- All of this serves as an experiment on the present situation.

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- I use my computer, or just pencil and paper: offloading cognition.
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One answer: dissipating energy; channeling potential differences.

- Earliest life channeled high-energy emissions from geothermal vents

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Complex cognition is required to dissipate energy at scale.

- Team members distribute cognitive load.
  - Scientists, engineers, financial backers, drill operators, etc.
  - Each acts—releases stored energy—in order to make it happen.
  - Communication is required to translate problems and solutions.
- If the total effort is successful, team members are recharged, repaid.

A mathematical ground for autopoiesis?

Autopoiesis means self-production.

- An ant colony, a cell, a football team, capitalism, one's mind.
- These systems repeatedly channel energy through themselves.
- They expend energy now, and are recharged later.
- They adapt to changing environments.
- They act to successfully predict futures in which they exist/flourish.

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- What is it?
- How are autopoietic systems assembled?
- How to conceptualize their evolution / adaptation/ structural drift?
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What mathematical primitives best found this study?

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Category theory

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- Language is what makes (distributed) cognition possible.
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Applied category theory

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Category theory is mathematics, form-fit to any technical subject.

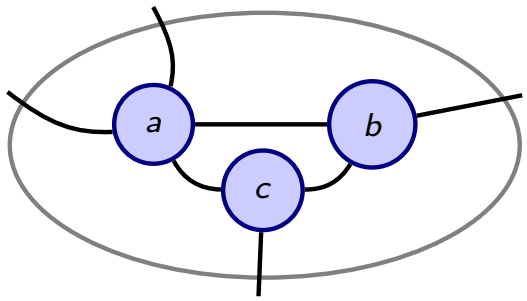
- Consists of conceptual primitives and principles for combining them.
- Data, software, business processes can all be compressed into CT.

Example: wiring diagrams

Wiring diagrams can be interpreted according to a variety of semantics.

- E.g. tensor networks, relational algebra, dynamical systems.
- Each is called an *algebra*; construct new terms from old.

Wiring diagrams can be nested.



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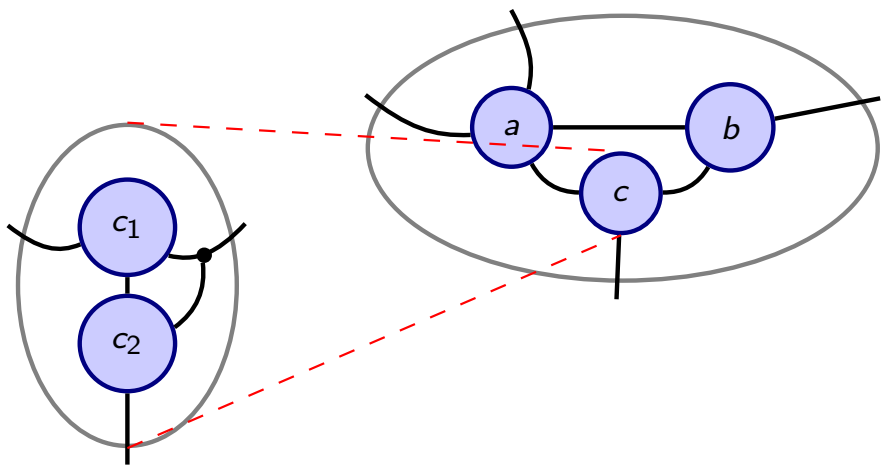

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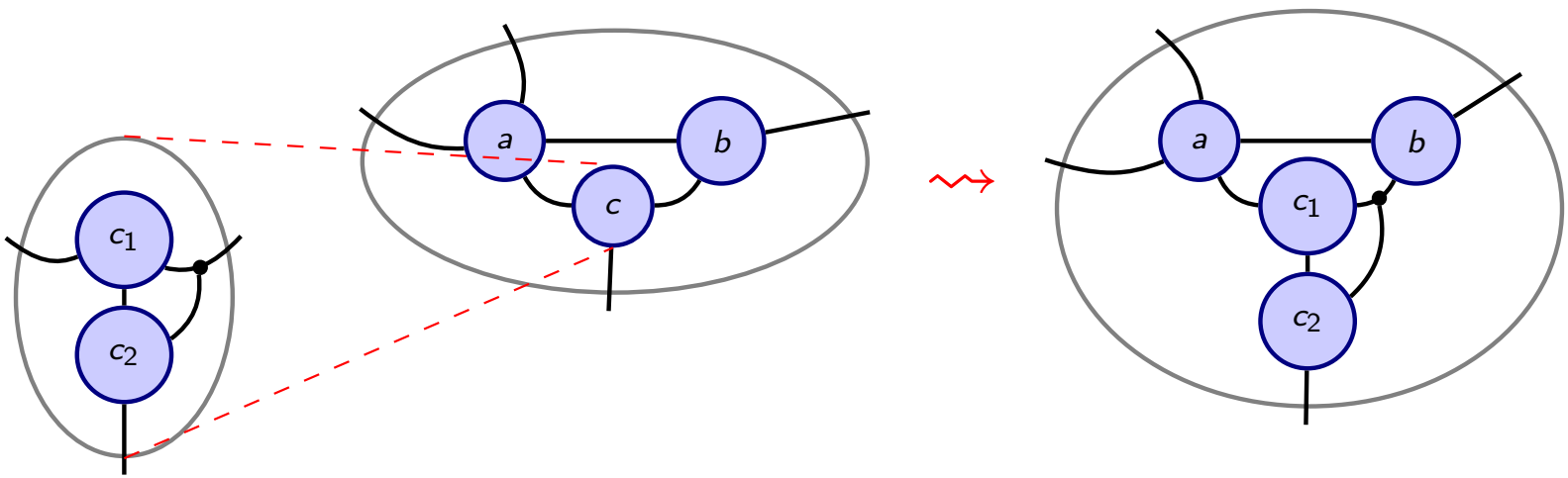
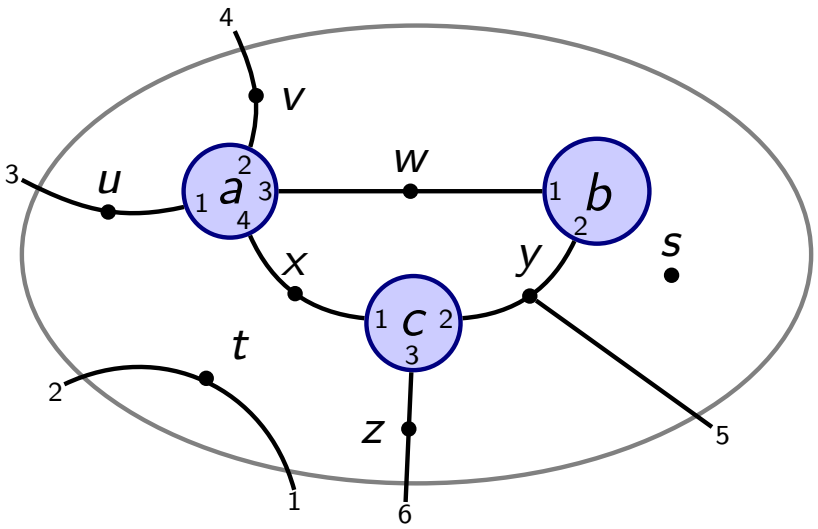


Mathematics of wiring diagrams

The operad of wiring diagrams is a naturally-readable formal system.



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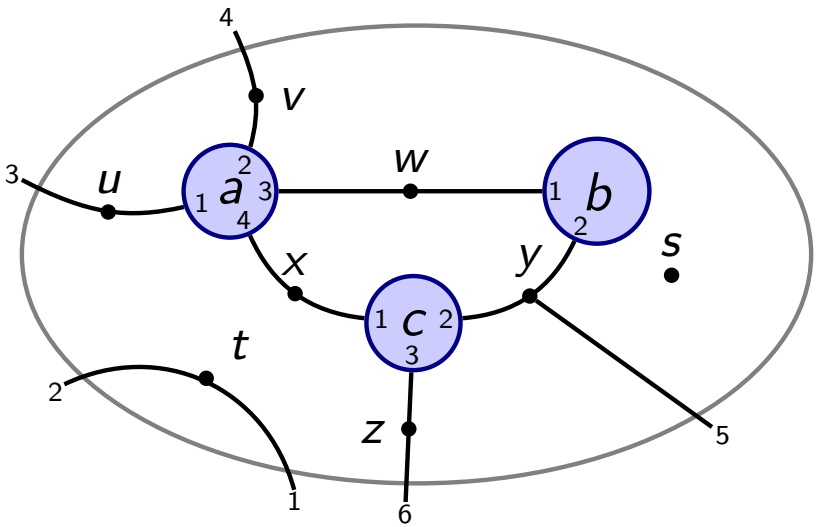
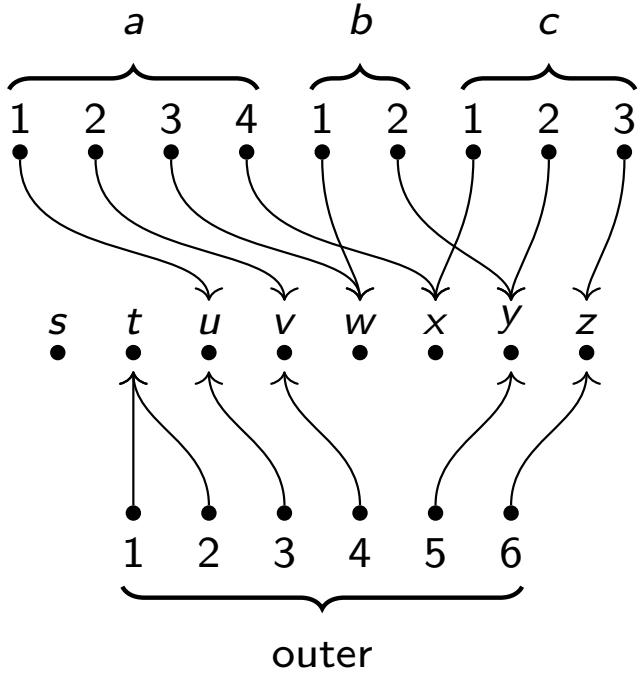
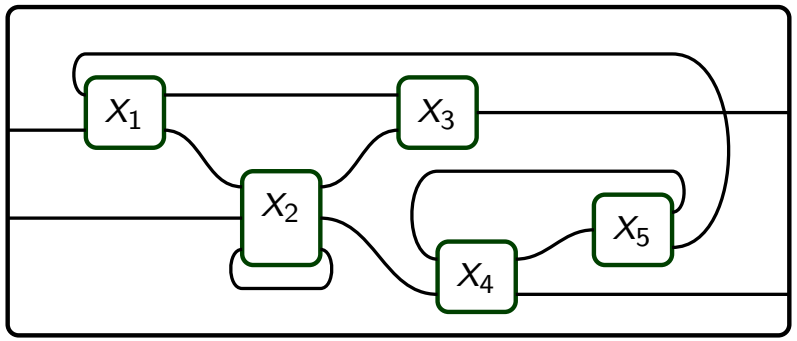




Wiring diagrams are encoded mathematically via sets and functions.

Memoryless tests generate all dynamical systems



Open discrete dynamical system (DDS) = stream processor

- Input streams drive the system through state space.
- The system outputs a stream which is passed to another system.
- Wiring all these together you get a more complex system.

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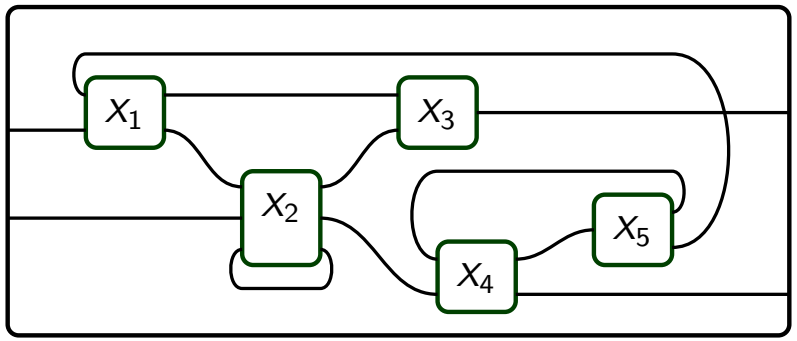

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Thm: Every DDS is equivalent to a wiring together of memoryless tests.

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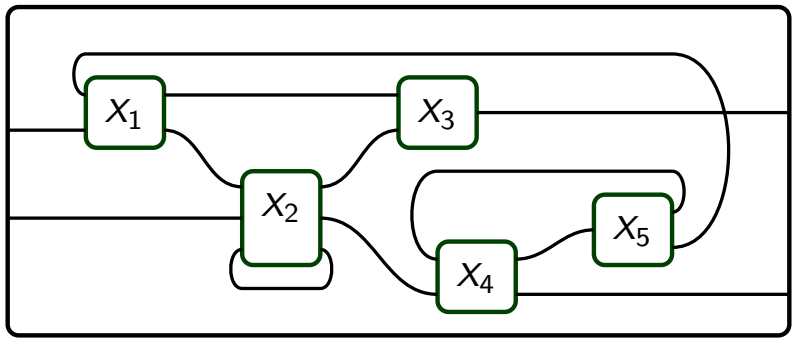

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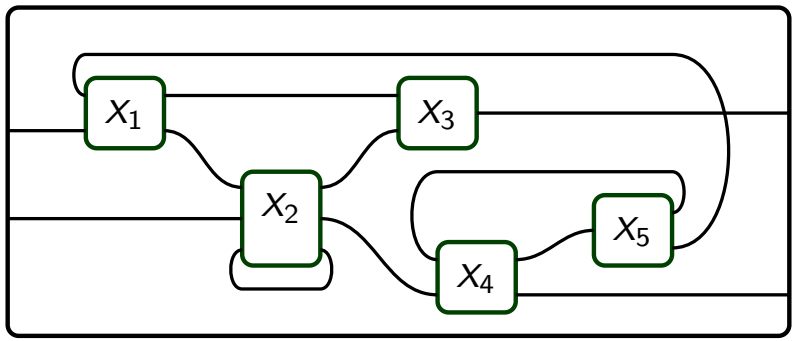
- Upshot: simplist systems, wired together, become arbitrarily complex.

Mode-dependent networks of dynamical systems



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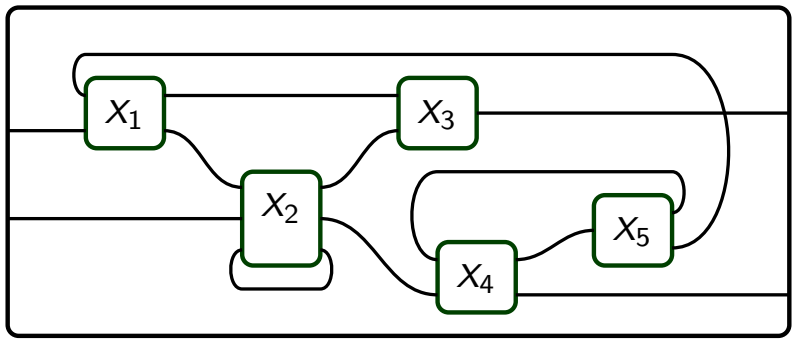

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We can also allow the interface to change shape based on system *modes*.

- Each cell's state determines its "communicative mode."
- This mode determines the input/output shape of the cell's interface.
- The modes of everyone in the network jointly determine the wiring.
- Idea: I can close or open my eyes; we can decide to connect.

Mode-dependent networks in autopoiesis?

Goal: a compositional framework for studying autopoiesis.

- The above is about systems that dynamically change wiring pattern.
- But there's no "why", no goals, no sense of direction.
- Can we somehow encode:
  - Energy dissipation?
  - Selectivity, adaptation, evolution, cognition, autopoiesis?

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I imagine that systems want predictable environments rich in free energy.

- Subsystems agree to remain wired up in exchange for these conditions.
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This is the current status, one way we might look at autopoiesis.

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- ...if it'd lead us to more free energy, more low-hanging fruit.
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