# Underlying Logic of Interdisciplinary Systems Emergence

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# Outline

Interdisciplinary Science

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Reaction Networks and Organizations

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The Underlying Logic

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- It is right there where the foundational problems are!
- Shortcut example: Resilience has more than 150 definitions!

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*We assess the scientific and policy literature and show that this disconnect is one consequence of an inconsistent and one-dimensional approach that ecologists have taken to both disturbances and stability. This has led to confused communication of the nature of stability and the level of our insight into it. Disturbances and stability are multidimensional. Our understanding of them is not. Donohue et. al., Ecology Letters (2016)*

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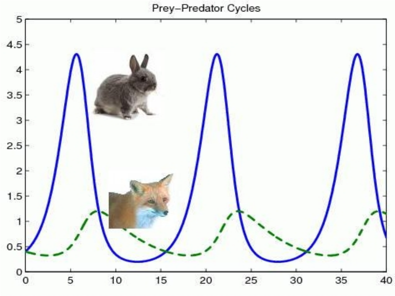
- In the end combining these concepts only lead to more confusion!...Not too scientific right?

# How to study the CS problem? Dynamical Models

- Provide an analytic description of the interactions and dynamics by means of *equations*

$$\frac{dx}{dt} = \alpha x - \beta xy$$
$$\frac{dy}{dt} = \delta xy - \gamma y$$



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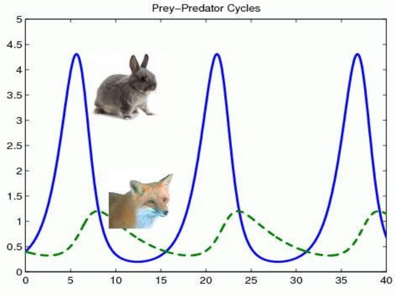
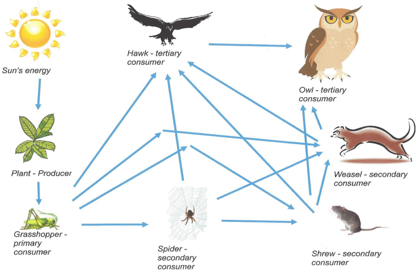



- But can be solved only for small ecosystems

# How to study the CS problem? Network Models

- Provide an analytic description of the interactions and can be developed for ecosystems with many species by means of *links*



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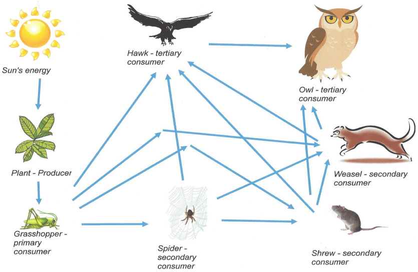


- But can encompass only one type of interaction at a time

# How to study the CS problem? Agent Based Models

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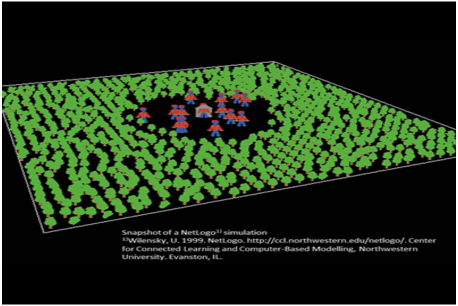

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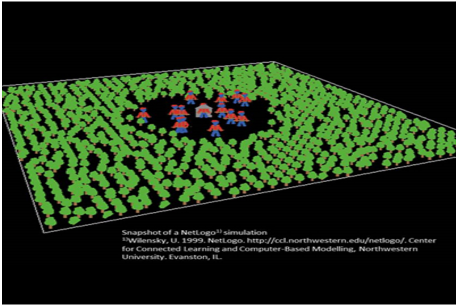


- But lack of analytic methods of study

# Summary of the problem

The following table summarizes the methodological problem of the study of the CS debate

| **CS reps.** | Specs. | Interacts. | Dyn. Evo. | Mechanisms | Analytic Tools |
|---|---|---|---|---|---|
| Dyn. Eqs. | Few | Few | Yes | Yes | Rich |
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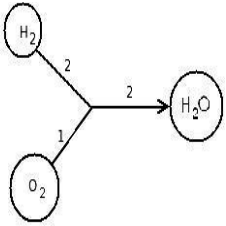
We provide a shift in perspective towards a solution

# Reaction Networks: Intro




Represents the reaction

$$2H_2 + O_2 \rightarrow 2H_2O$$

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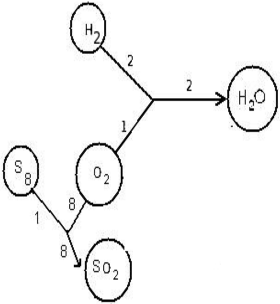


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$$S_8 + 8O_2 \rightarrow 8SO_2$$

- We have in mind large reaction networks (many species/interactions)

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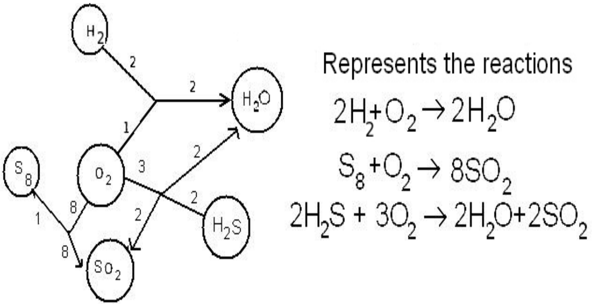


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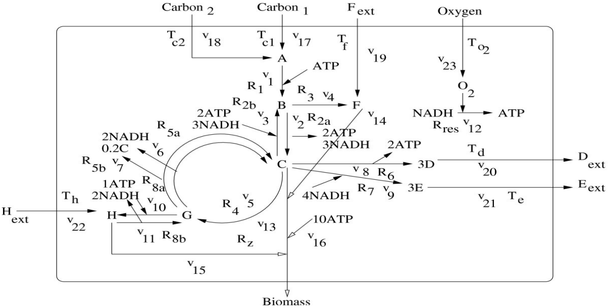


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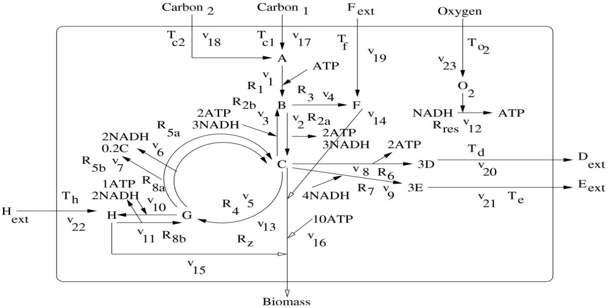


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- **Goal:** The relation between structure and dynamical stability

# Reaction Networks: Basics

- A reaction network is composed by
  - A set of species $\mathcal{M} = \{s_1, ..., s_n\}$
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A set of species $C \subseteq \mathcal{M}$ is:

1. *Closed* iff all the produced species in $\mathcal{R}_C$ are in $C$.
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Can we use the notion of self-maintaining process to understand the dynamics of large reaction networks?

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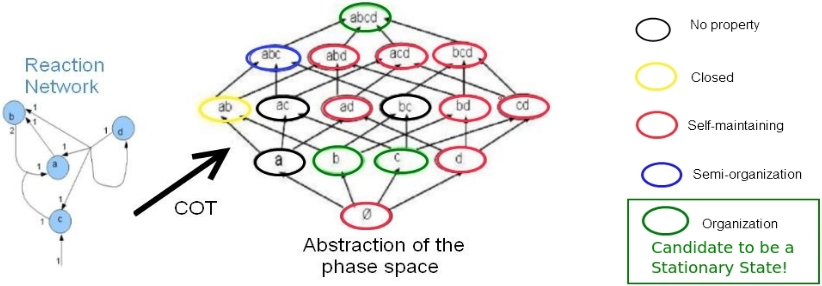
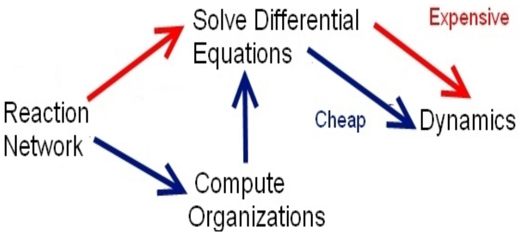
- **Corollary:** Organizations of a reaction network contain all **stationary states**



# What do we have? - Abstract Reflexion



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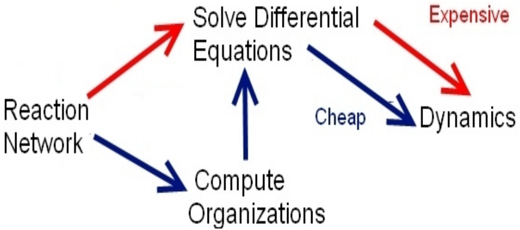


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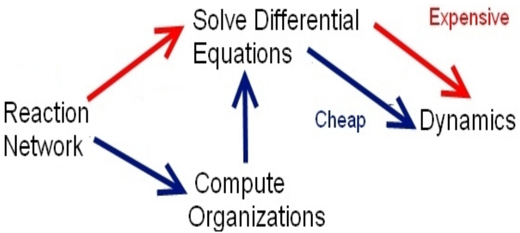


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- Many species & many interactions - Stable meta-structures emerge

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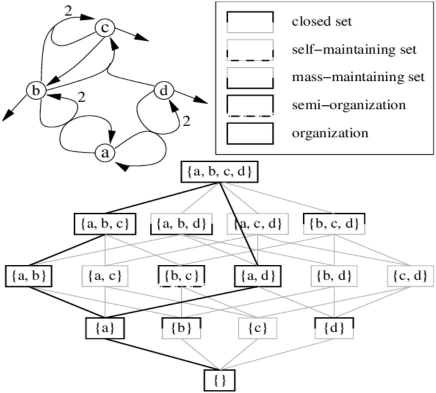
## The organizational (propositional) structure

- If we consider sub-networks of a reaction network as propositions we see that COT could represent logical structures



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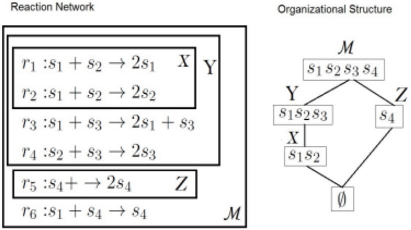
- This is an example of an ecological system with non-boolean structure




$$X \vee (Y \wedge Z) = X \vee G_{\mathcal{O}}(Y \cap Z) = X \vee \emptyset = X, \text{ and}$$
$$(X \vee Y) \wedge (X \vee Z) = G_{\mathcal{O}}(X \cup Y) \wedge G_{\mathcal{O}}(X \cup Z) = Y \wedge Z = \emptyset.$$

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- COT allows to mofify the lattice of organizations under these types of change
- This permits an operationalization of changes of structure and behaviour (operation) of systems, compatible with notions such as resilience, agency, etc.

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- Organizations cover the set of structures that can possibly emerge
- Organizations can subjected to perturbations and be combined, they can be seen as a logic where propositions are structures persistent enought to be observable (objects)
- We are currently working on the formalization of the taxonomy of systemic concepts (resilience, diversity, robustness) in this setting