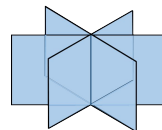


Hard-to-Define Events in Biological Networks



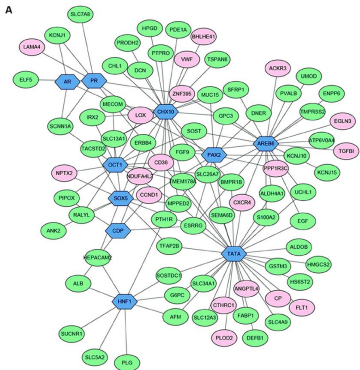
@ NetSci 2022: Shanghai and Virtual



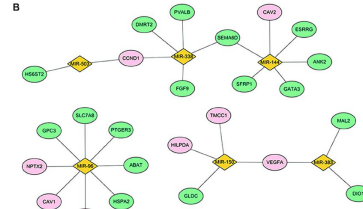
Bradly Alicea

OpenWorm Foundation
Orthogonal Research and Education Lab

bradly-alicea.weebly.com



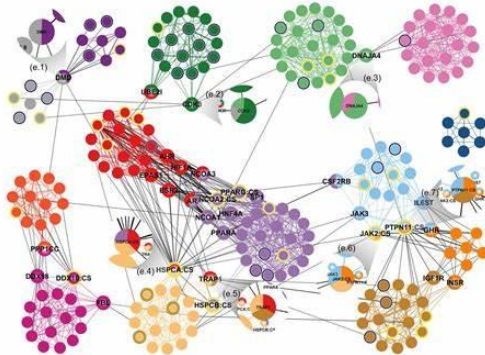
Regulatory Networks



Animal Social Networks

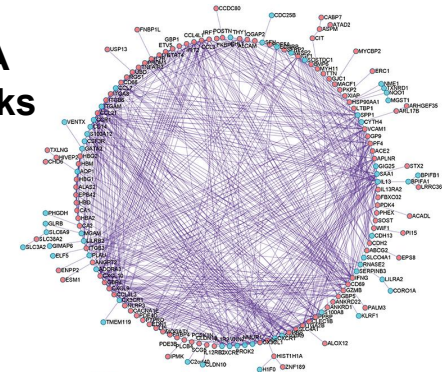


Network modeling has been quite successful at the level of genes, proteins, cell population, and even individual organisms

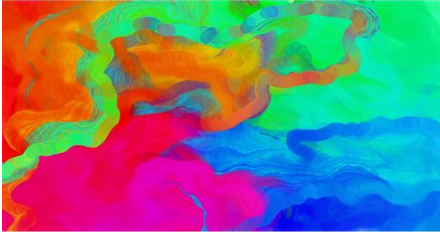


Protein-Protein Interaction Networks

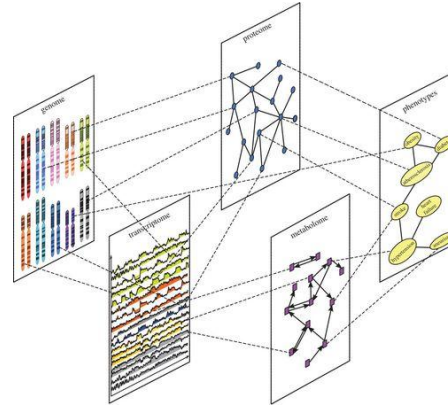
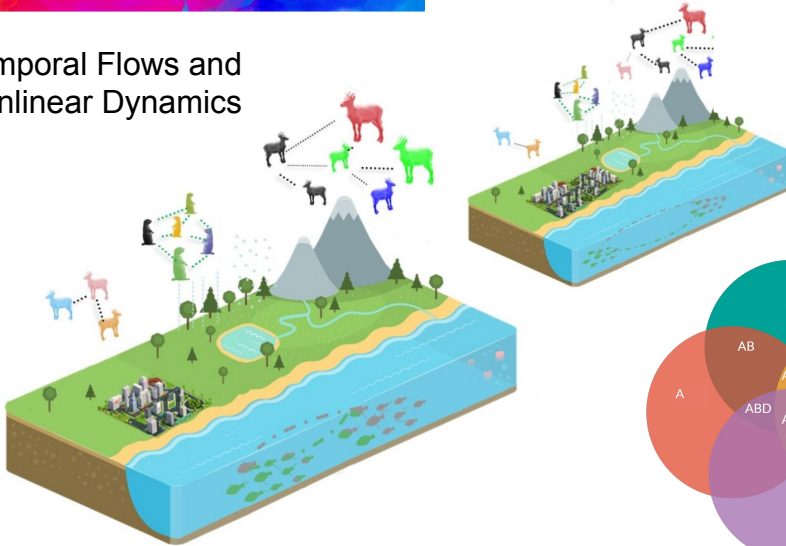
mRNA Networks



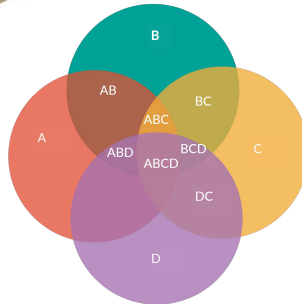
In cases where the relationship between nodes, arcs, and temporal events are not clearly identifiable, network analysis can be less effective



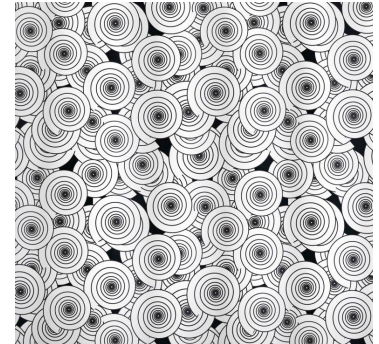
Temporal Flows and Nonlinear Dynamics



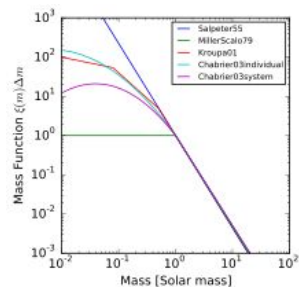
Cryptic Temporal and Emergent Processes



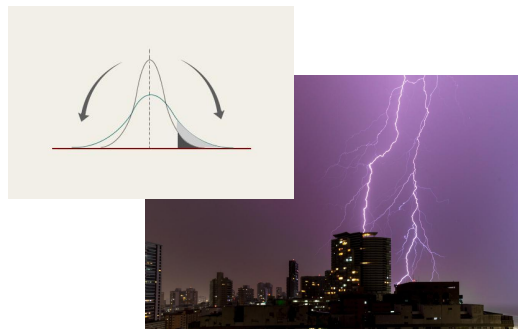
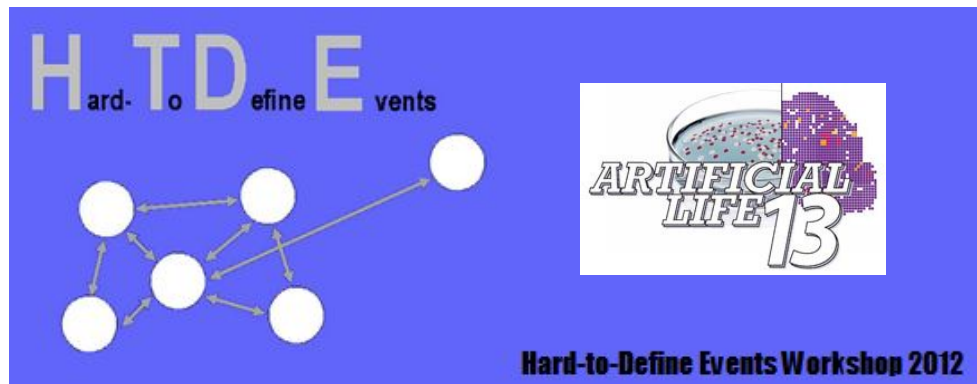
Overlapping and Intersecting Information



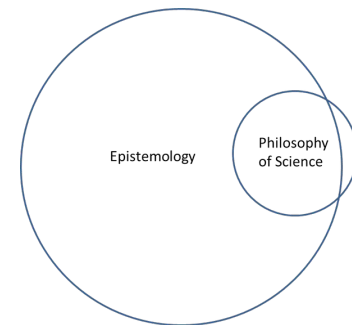
Hard-to-Define Events (HTDE): 10 years out



Modeling power laws
and long-tailed
phenomena



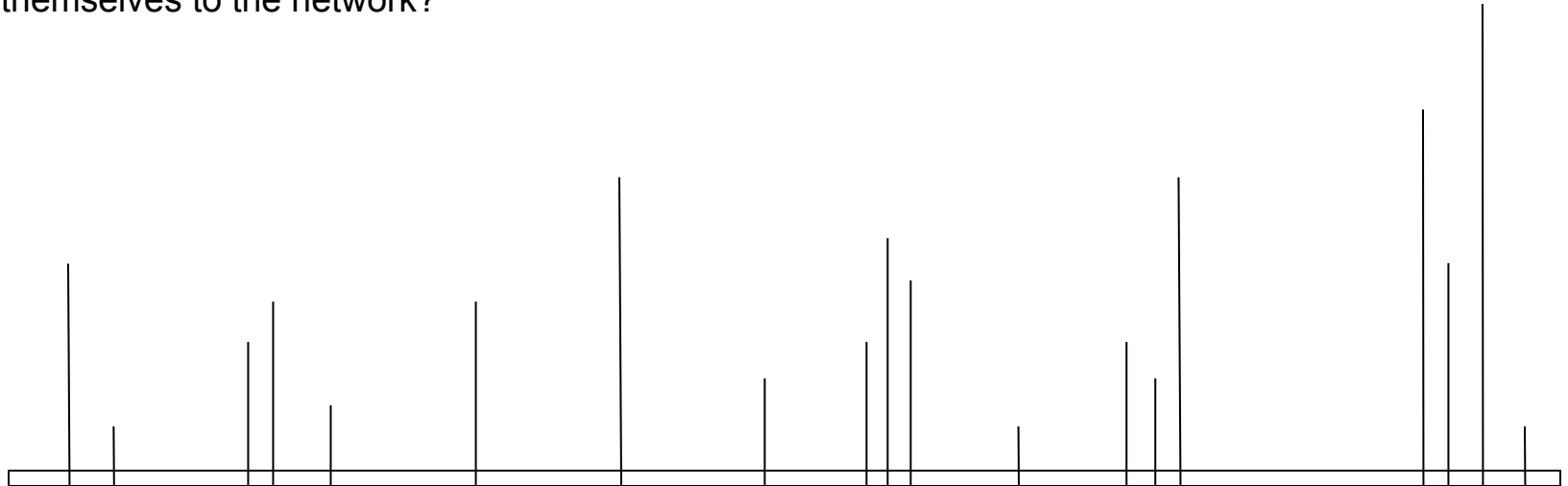
Rare and out-of-distribution
empirical observation



Epistemology of
Science

Systems with rare events, or out-of-distribution events (occur extremely rarely in a given spatiotemporal context)

How do new nodes attach
themselves to the network?

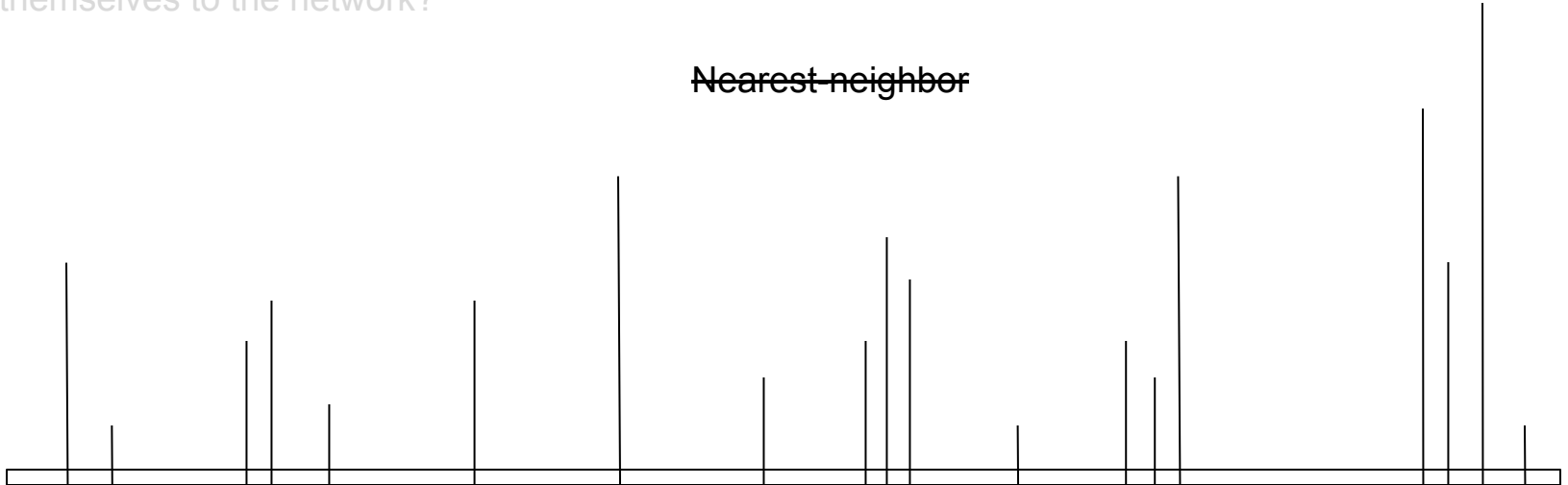


Systems with rare events, or out-of-distribution events (occur extremely rarely in a given spatiotemporal context)

~~Preferential attachment~~

How do new nodes attach
themselves to the network?

~~Nearest neighbor~~



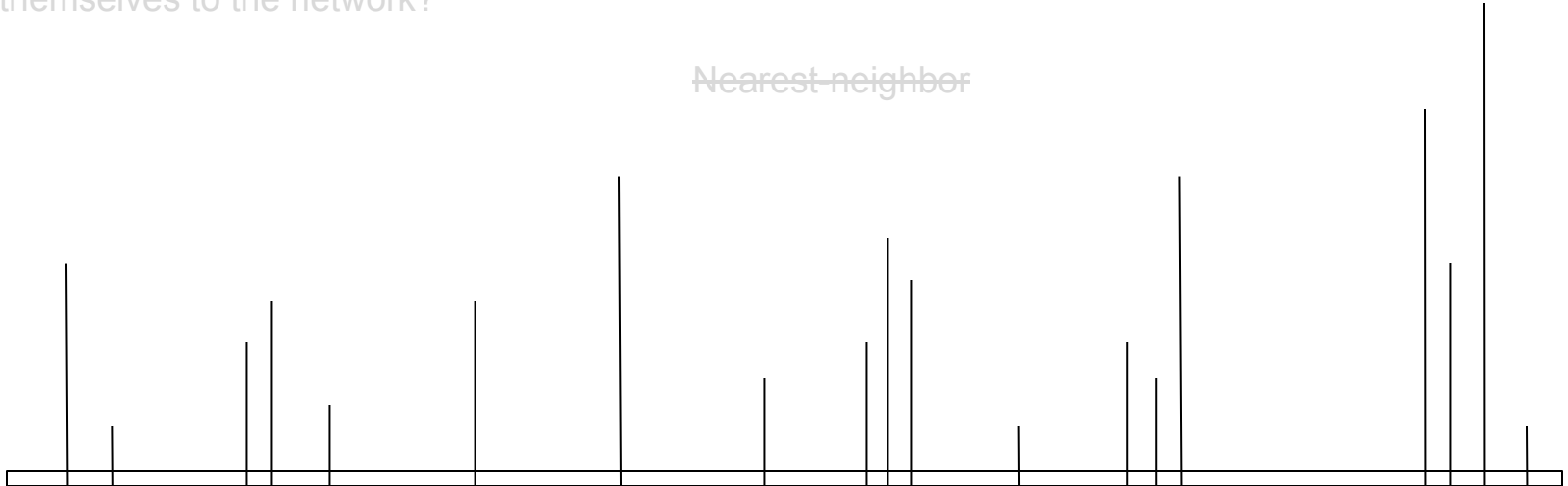
Systems with rare events, or out-of-distribution events (occur extremely rarely in a given spatiotemporal context)

Preferential attachment

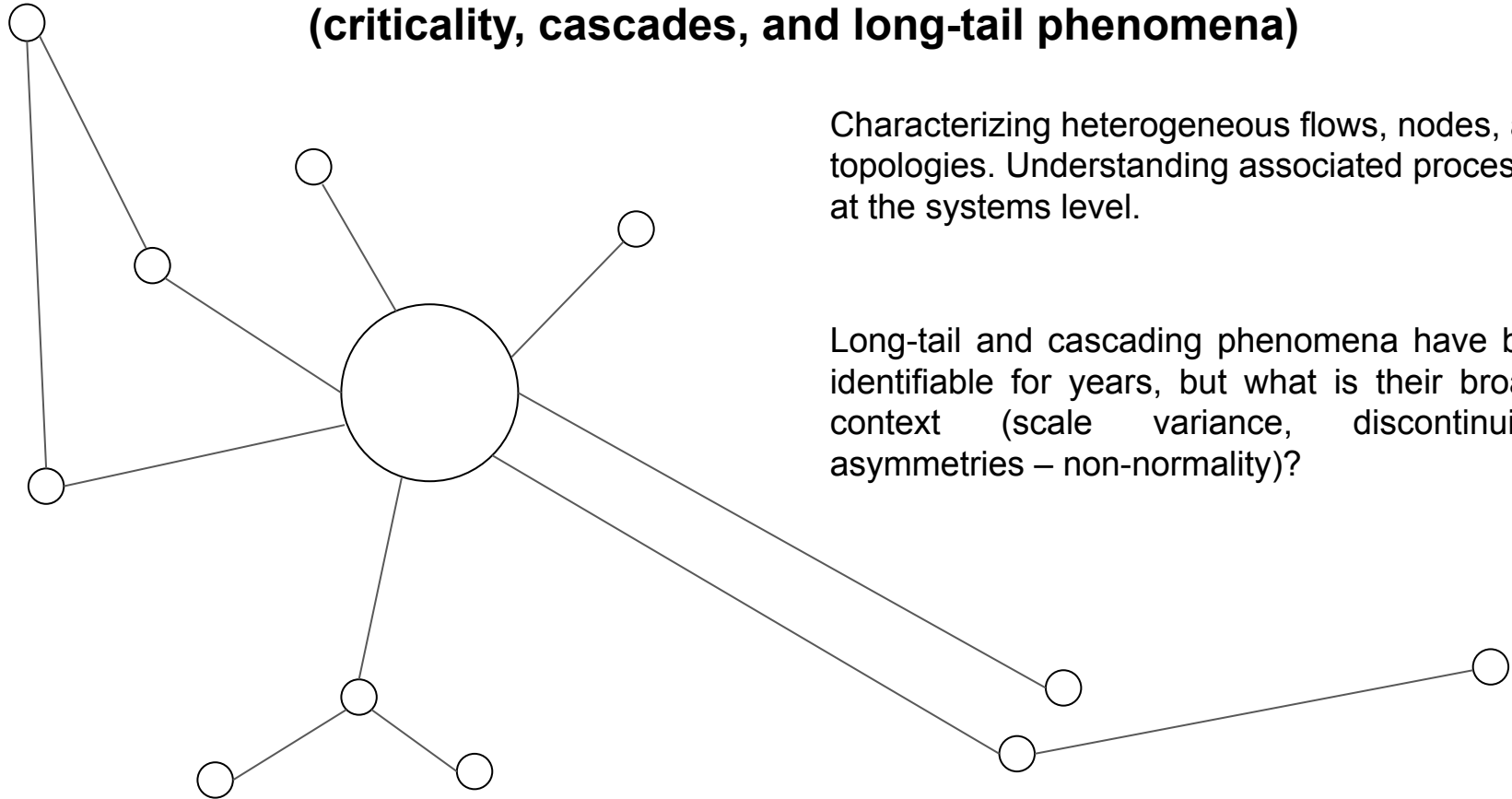
How do you incorporate nodes that have abnormal behaviors?

How do new nodes attach themselves to the network?

Nearest-neighbor



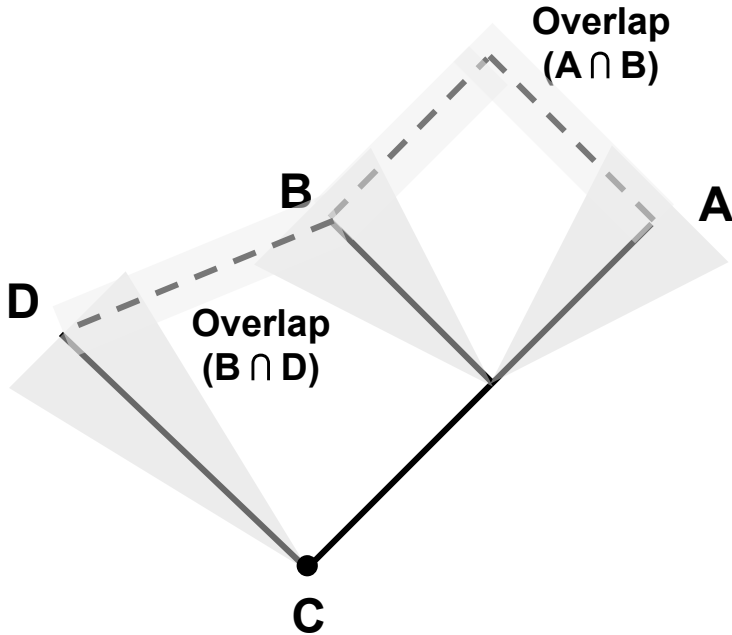
Systems with non-normally distributed processes (criticality, cascades, and long-tail phenomena)



Characterizing heterogeneous flows, nodes, and topologies. Understanding associated processes at the systems level.

Long-tail and cascading phenomena have been identifiable for years, but what is their broader context (scale variance, discontinuities, asymmetries – non-normality)?

Cases in which nodes are poorly defined in terms of their compartmentalization and/or epistemology



Edges can belong to different categories simultaneously.

Nodes can be intersections $\{A, B, D\}$ or defined elements of a set $\{C\}$.

Nodes can also overlap $\{A \text{ and } B, B \text{ and } D\}$.

Nodes and edges that do not conform to transitivity $\{A < B \rightarrow B < C \rightarrow A < C\}$.

Sampling of Approaches in the
Network Science Literature
(since 2005)

Lawyer, G. (2015). Understanding the influence of all nodes in a network. *Scientific Reports*, 5, 8665.

Asllani, M., Lambiotte, R., and Carletti, T. (2018). Structure and dynamical behavior of non-normal networks. *Scientific Advances*, 4, eaau9403.

Allen, R.J., Warren, P.B., and ten Wolde, P.R. (2005). Sampling rare switching events in biochemical networks. *Physical Review Letters*, 94, 018104.

Hindes, J. and Schwartz, I.B. (2017). Rare events in networks with internal and external noise. *Europhysics Letters*, 120, 56004.

Sheridan, P. and Onodera, T. (2018). A Preferential Attachment Paradox: how preferential attachment combines with growth to produce networks with log-normal in-degree distributions. *Scientific Reports*, 8, 2811.

Guimera, R., Sales-Pardo, M., and Amaral, L.A.N. (2007). Module identification in bipartite and directed networks. *Physical Review E*, 76, 036102.

Lawyer, G. (2015). Understanding the influence of all nodes in a network. *Scientific Reports*, 5, 8665.

Asllani, M., Lambiotte, R., and Carletti, T. (2018). Structure and dynamical behavior of non-normal networks. *Scientific Advances*, 4, eaau9403.

Allen, R.J., W
networks. *Phy*

State of the Art: identification of HTDE phenomena within
problem domains

biochemical

Hindes, J. and
Letters, 120, 5

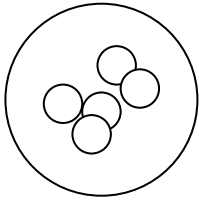
Future Challenge: refining network science techniques
for the HTDE problem class.

. *Europhysics*

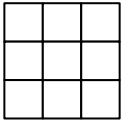
Sheridan, P. and Onodera, T. (2018). A Preferential Attachment Paradox: how preferential attachment combines with growth to produce networks with log-normal in-degree distributions. *Scientific Reports*, 8, 2811.

Guimera, R., Sales-Pardo, M., and Amaral, L.A.N. (2007). Module identification in bipartite and directed networks. *Physical Review E*, 76, 036102.

A future role for theory-building and model epistemology

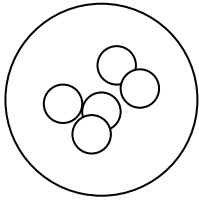


Nodes that represent quantitative constructs, overlapping states (experiments with developmental hypergraphs).

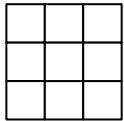


Edges that represent multiple properties simultaneously (experiments with Contextual Geometric Structures).

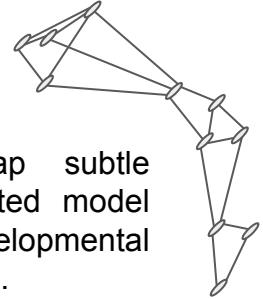
A future role for theory-building and model epistemology



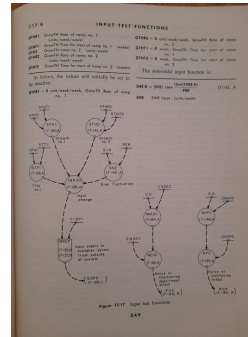
Nodes that represent quantitative constructs, overlapping states (experiments with developmental hypergraphs).



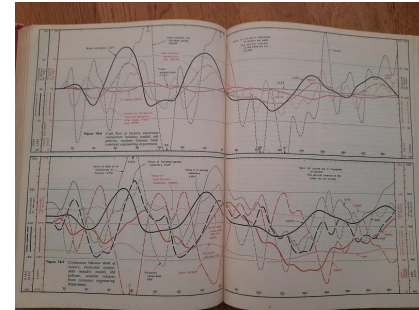
Edges that represent multiple properties simultaneously (experiments with Contextual Geometric Structures).



Embeddings that map subtle concepts to a connected model (experiments with developmental Graph Neural Networks).

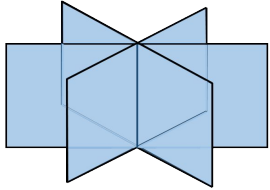


Networked dynamics of systems models.

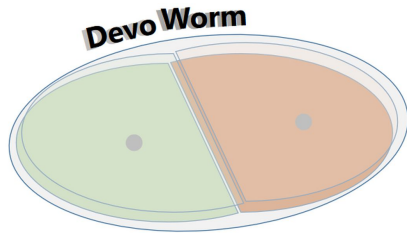


Forrester. Industrial Dynamics (1958).
Images: Trace and Traceability
(trace-and-traceability.org)

Thank You for Your Attention!



Cybernetics and Systems Dynamics,
Contextual Geometric Structures
(CGS)



Developmental Graph Neural
Networks (D-GNNs), Developmental
Hypergraphs

July 27, 1:15 UTC

**Hypergraphs Demonstrate
Anastomoses During Divergent
Integration**



NetSci 2022

Wednesday July 27, 2022 / 12:00 PM - 01:30 PM

“

*Session 10A:
Biological Networks II*

”



Bradley
Alicea

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