Imperial College London

Transport and Networks in Biology

Michael Stumpf

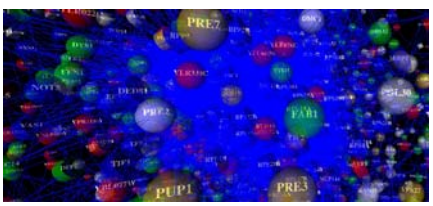
Division of Molecular Biosciences, Imperial College London
Institute of Mathematical Sciences, Imperial College London

Imperial College London

Networks in Biology and Transportation

What we would like to know:

- How do networks grow or evolve?
- How does the network structure affect dynamical processes or the overall behaviour of the system?
- How do we incorporate the network into the statistical analysis of system properties?



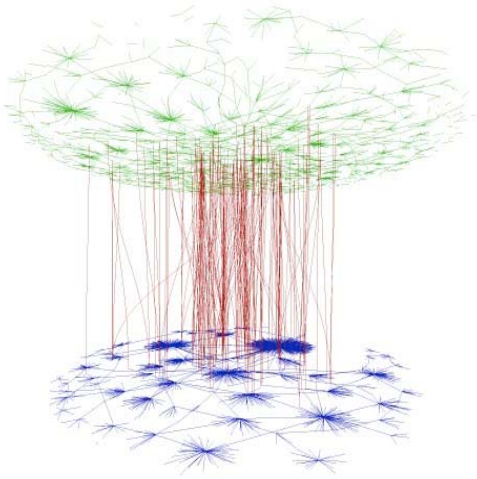
Imperial College London

Analogies between Biological and Freight Transport

Transportation	Biology
Roads, Rail Infrastructure	Biochemical pathways; molecular interactions; nervous/lymphatic system
Ports, Stations, Transport Hubs	Cell/Membrane Receptors
Trucks, Trains, Ships	Molecules, Cells

Imperial College London

Comparative Analysis



Comparing networks in different species will, hopefully, enable us to understand or infer

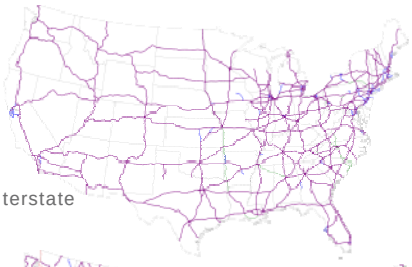
- causes
- mechanisms
- constraints

that are important in shaping biological systems/networks.

Evolution is not an optimization process, and biological networks and systems are not optimal at some global level.

Imperial College London

Comparing Transport Networks



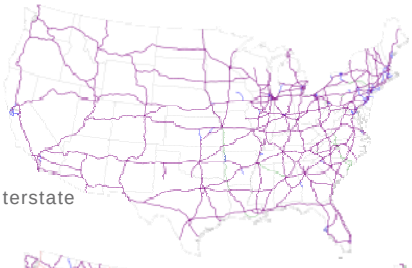
US Interstate

Major Australian Roads

US Highway

Imperial College London

Comparing Transport Networks



US Interstate

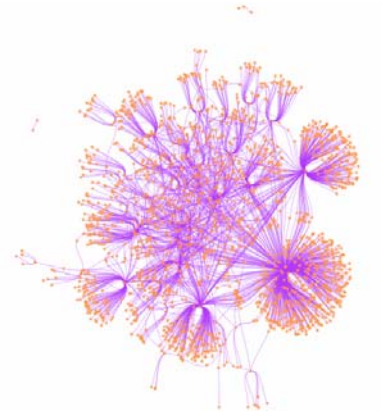
Major Australian Roads

US Highway

US Highway plans from 1926

Imperial College London

Robustness of Evolved Systems



Biologically evolved systems tend to be robust in the sense that they are largely unaffected by random removal of nodes.

Technological systems have similar robustness properties (even when these were not necessarily designed to be robust).

Targeted removal of nodes can lead to quick collapse of biological systems.

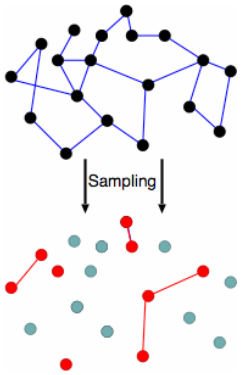
The same is true for technological and transport networks.

Imperial College London

Network Tolerance

Imperial College London

Network Observations



Properties of incomplete network data may be very different from those of the "true" network.

This is different from unstructured data where population samples may provide a good representation of the whole population (such as in electoral forecasting).

Imperial College London

Analysis of Network Data

Prerequisites:

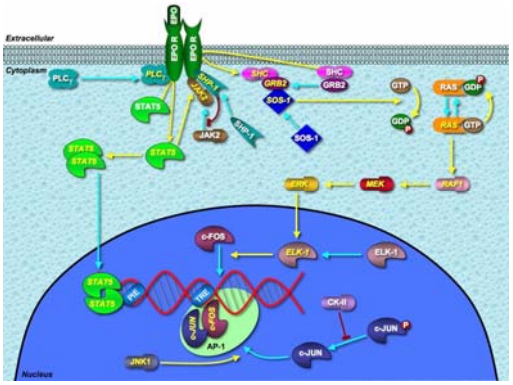
•A model for the network.

•Statistical routines to analyze network data.

Caveats:

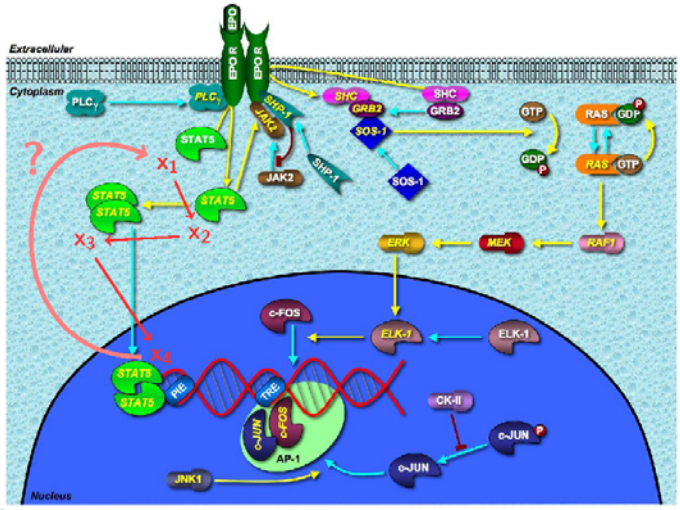
•Biological network models are by design simplistic and incorrect.

•There is a trade-off between the predictive and the explanatory power of mathematical models.



Imperial College London

Analysis of Network Data

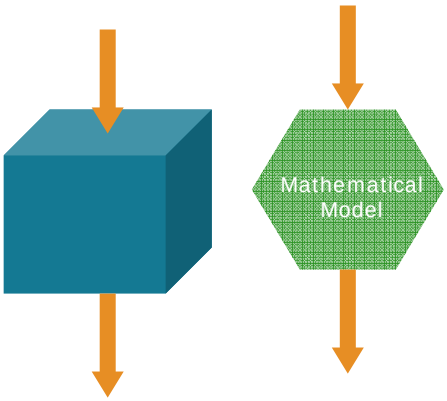


Imperial College London

A Framework for Dealing with our Ignorance

We know that we cannot be certain about

- the quality of the data.
- the accuracy of the model.



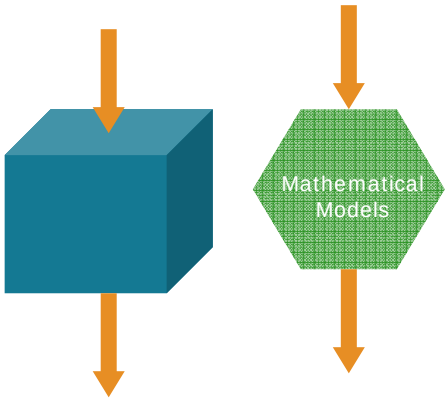
Imperial College London

A Framework for Dealing with our Ignorance

We know that we cannot be certain about

- the quality of the data.
- the accuracy of the model.

Rather than investigating a single model of some biological network we study an ensemble of models.



Imperial College London

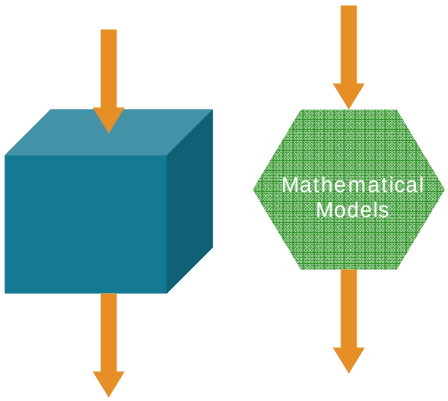
A Framework for Dealing with our Ignorance

We know that we cannot be certain about

- the quality of the data.
- the accuracy of the model.

Rather than investigating a single model of some biological network we study an ensemble of models.

This can be used to make predictions about the behaviour/preformance of the network.



Imperial College London

Similarities between Transport and Biological Networks

•The statistical and mathematical problems are often identical.

• Mathematical concepts can be applied across disciplines.

•The processes of learning about transport phenomena - such as flow through a road or metabolic network - are similar.

•Despite the similarities, there are significant differences and in any rigorous analysis details will matter.