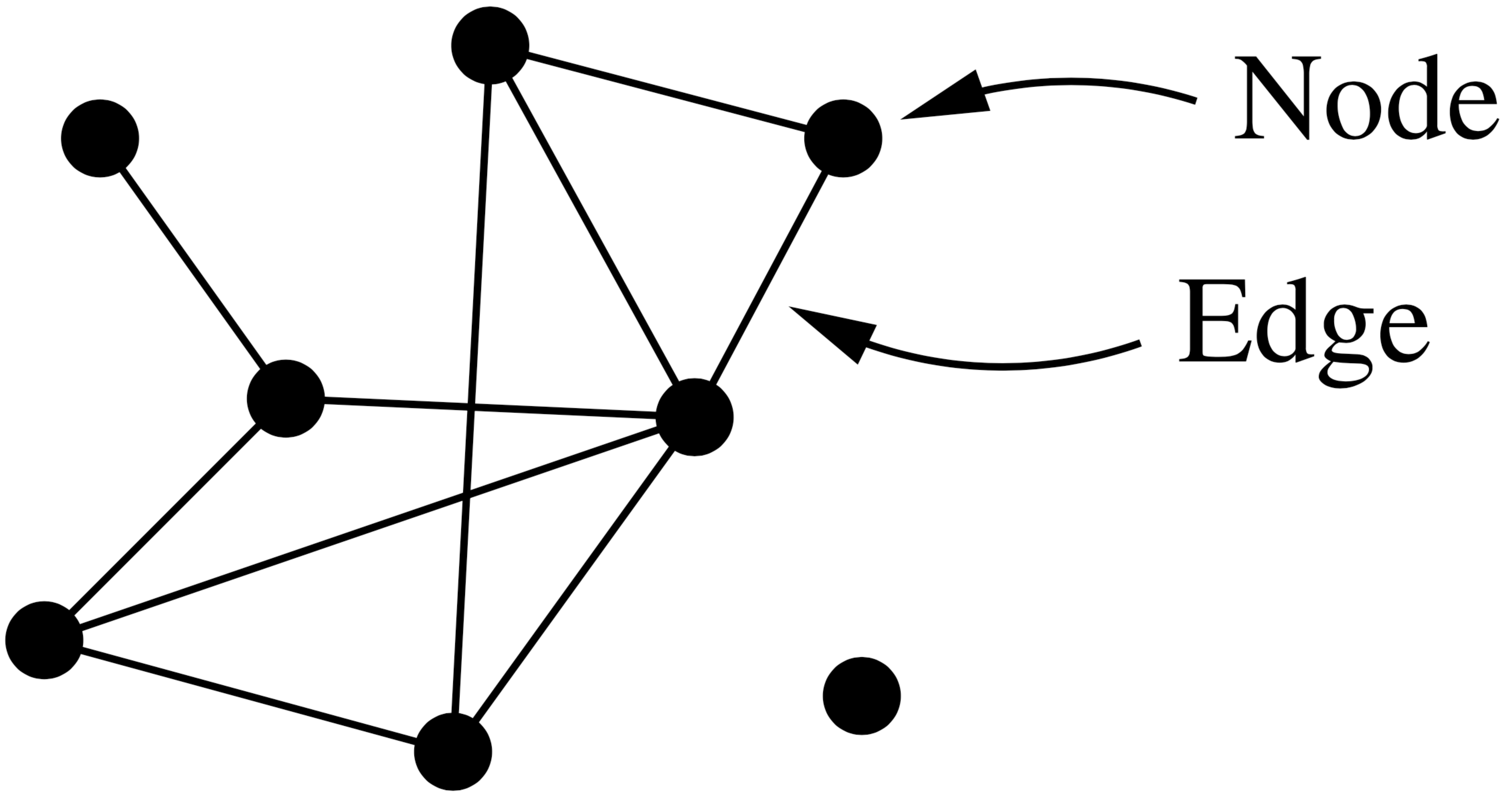
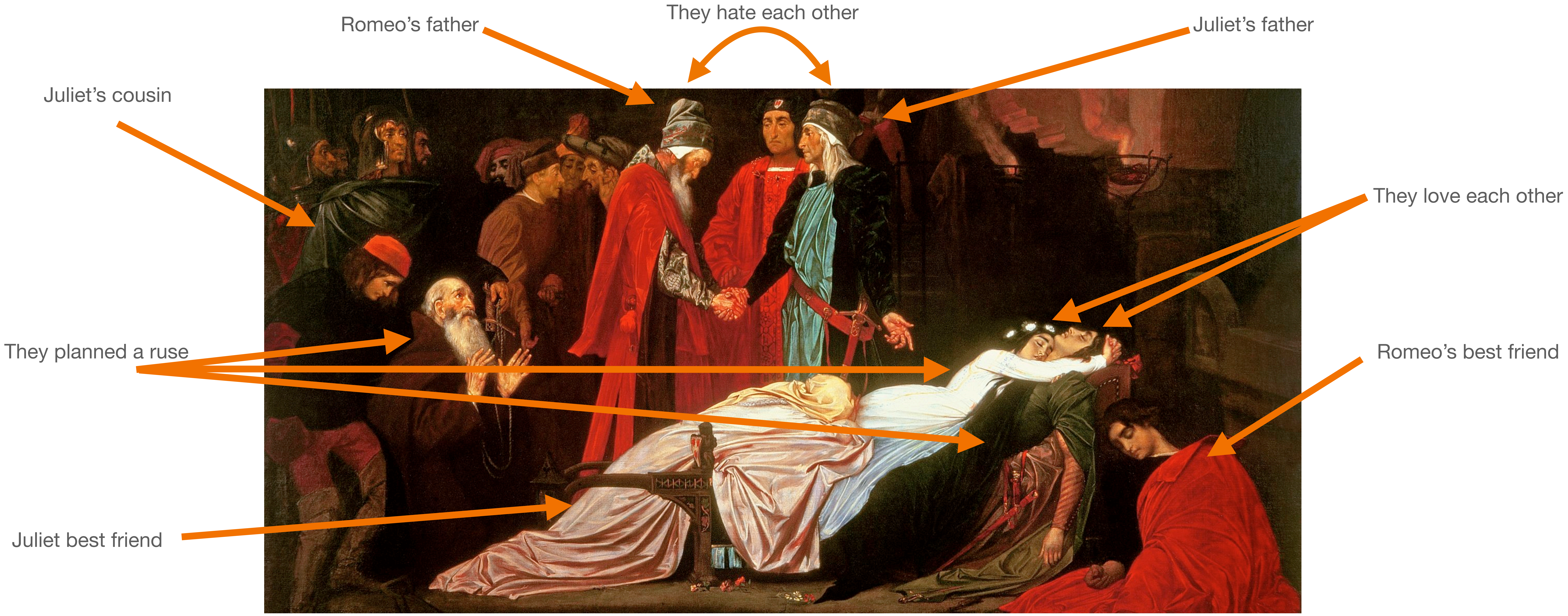
Introduction to Network Analysis

Networks, examples

Networks



Networks, examples



Networks

A network is a

simplified representation

that

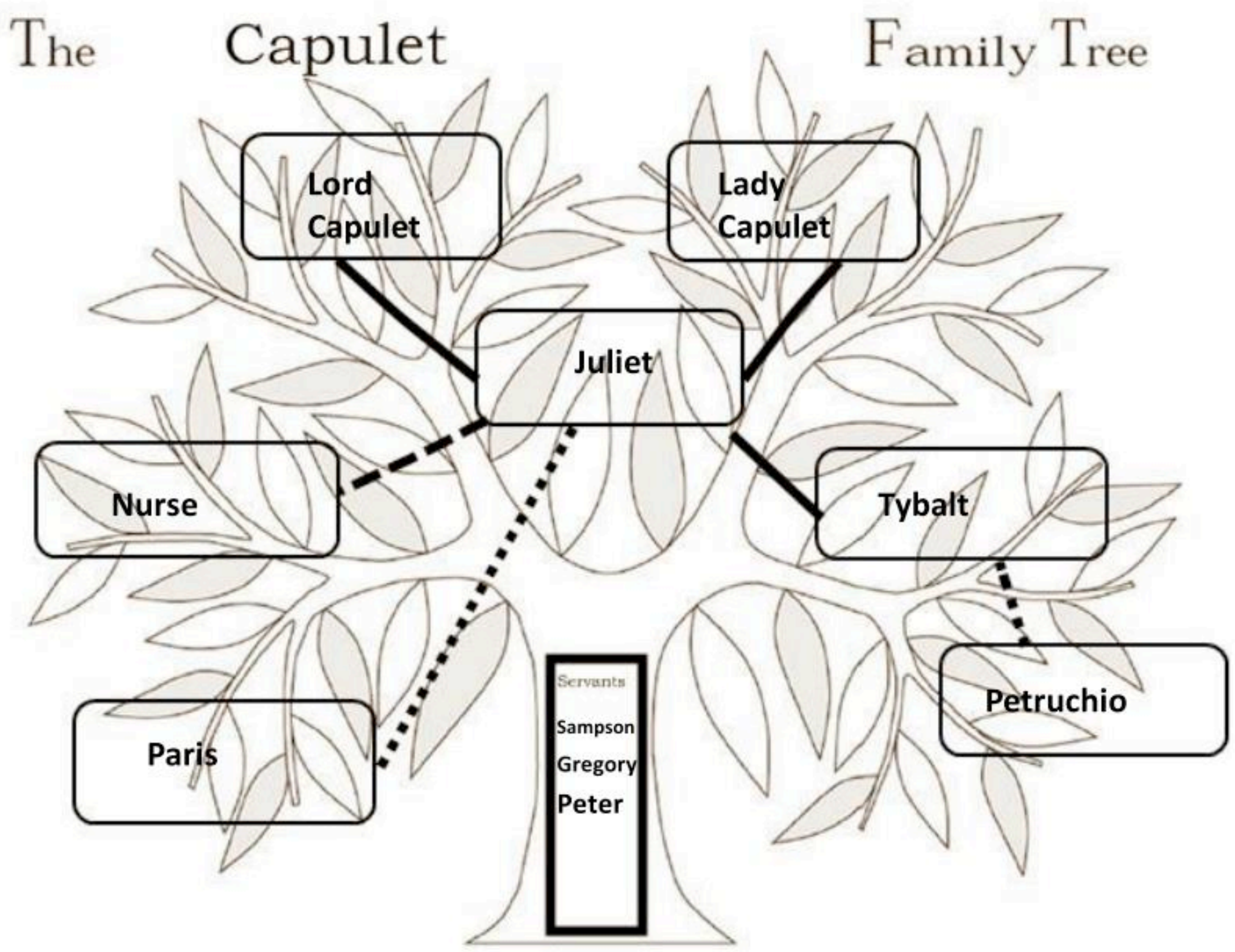
reduces a system to an abstract structure

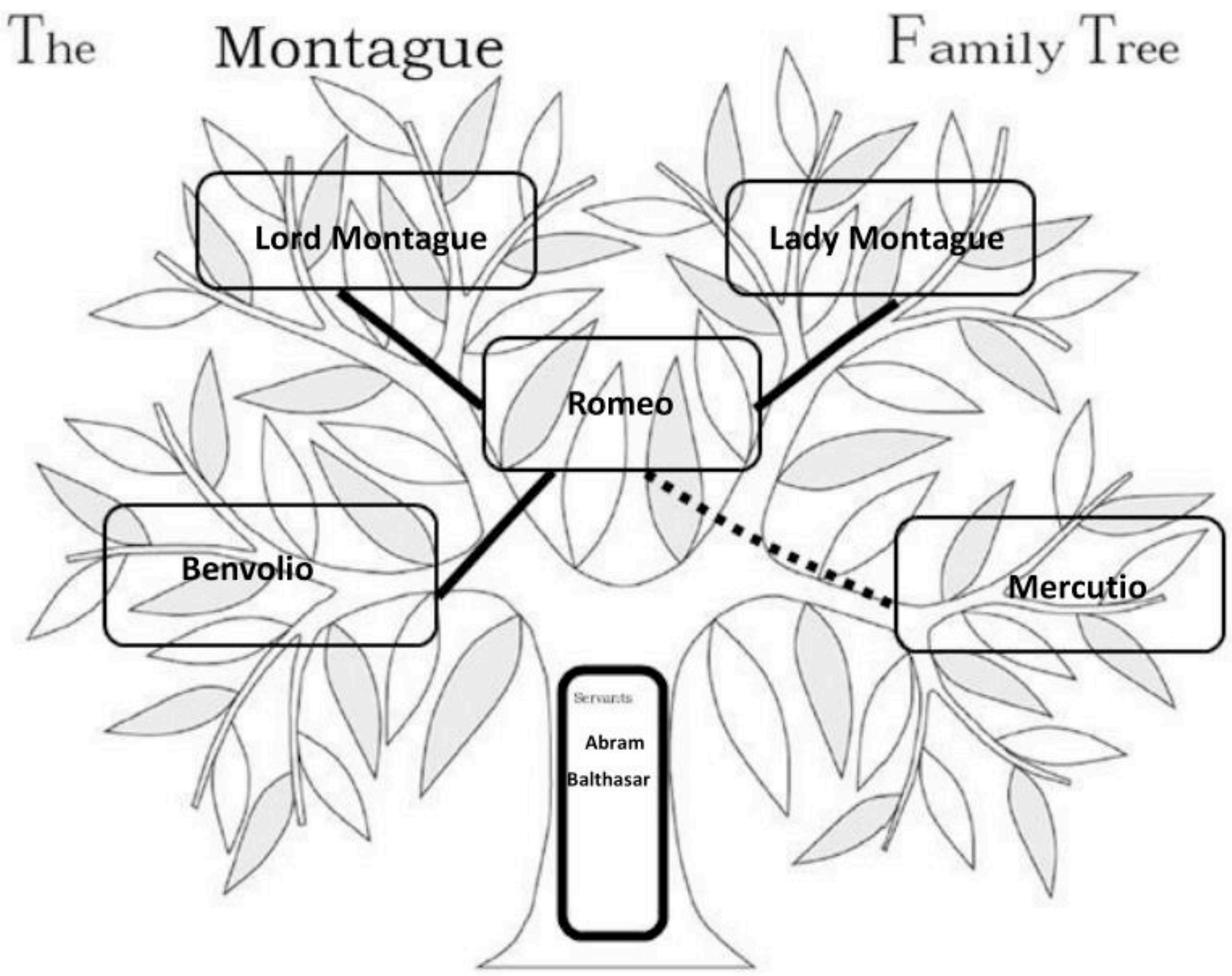
or **topology**, capturing only the basics of the connection patterns and little else.

Networks

- Networks capture the pattern of interactions between the parts of a system. In turn, the pattern of interactions have a sensible effect on the behaviour of a system.
- Examples:
  - the pattern of connections between computers on the Internet affects the routes that data take over the network and hence the efficiency with which the network transports those data.
  - the connections in a friendship network affect how people learn, form opinions, and gather news, as well as other less obvious phenomena, such as the spread of disease.
- Knowing the structure of a network is essential to fully understand how its corresponding system works.

Networks, examples

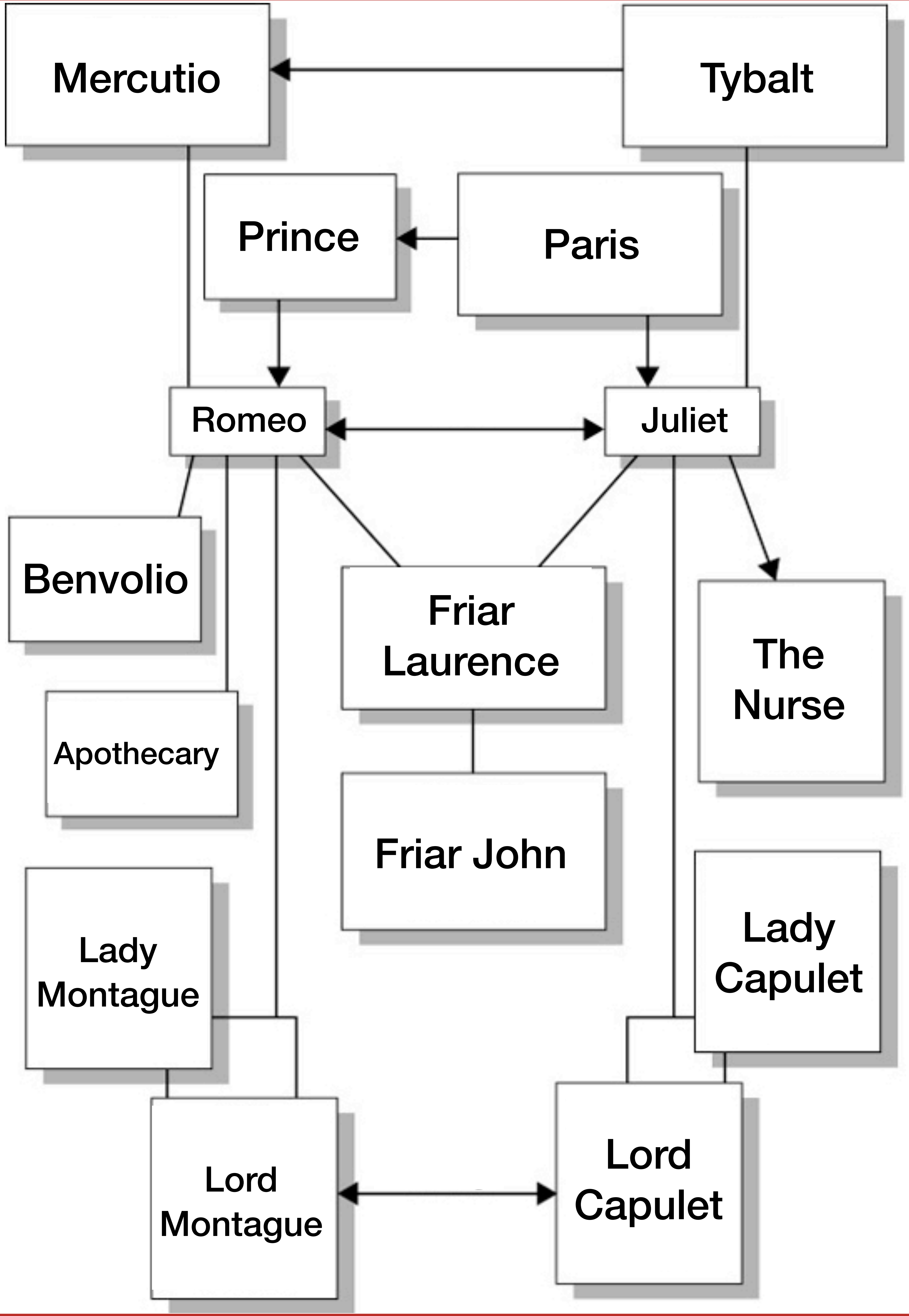




Networks

The systems studied can have interesting features not represented by the network—e.g., the detailed behaviours of individual nodes, such as people and the precise nature of the interactions between them.

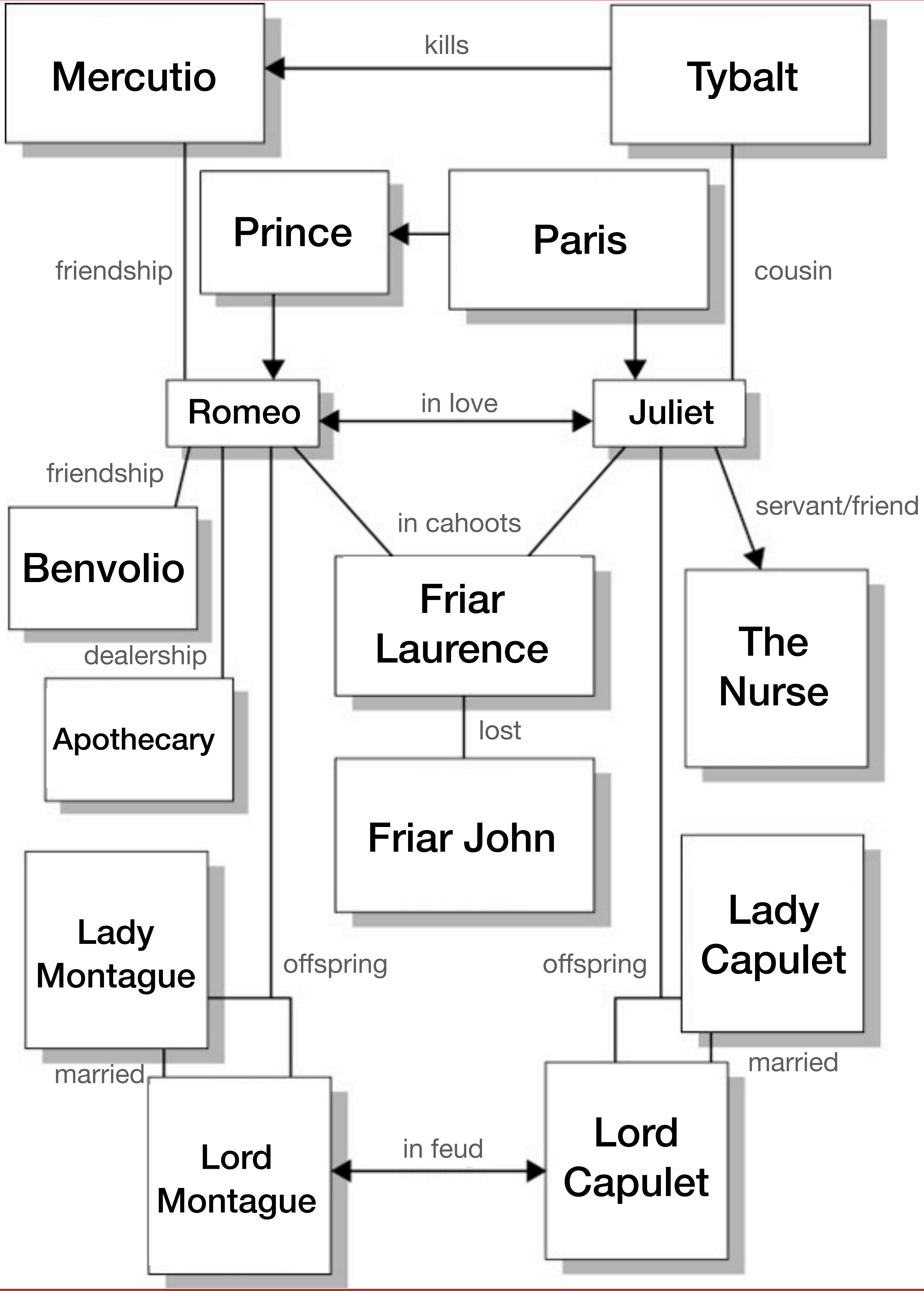
Networks, examples



Networks

We can capture additional information by labelling the nodes and/or edges of the network, such as with names or strengths of interactions.

Networks, examples

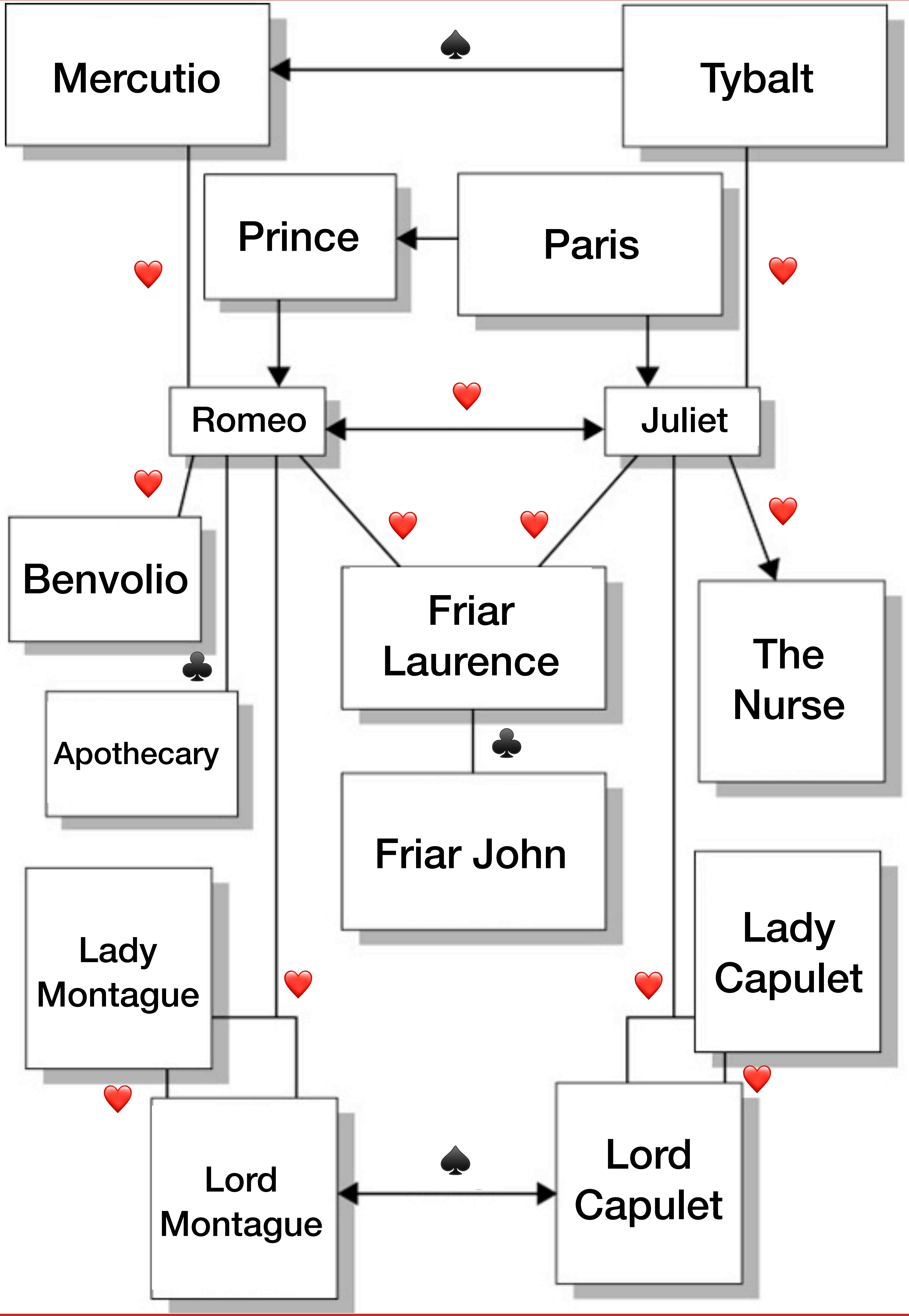


Networks

Finding what is the “right” kind/amount of information to make a system treatable (to reasoning) is a work of craftsmanship and experience.

The invariant here is that, every time we define a representation of a full system, we decide to filter out some information.

Networks, examples



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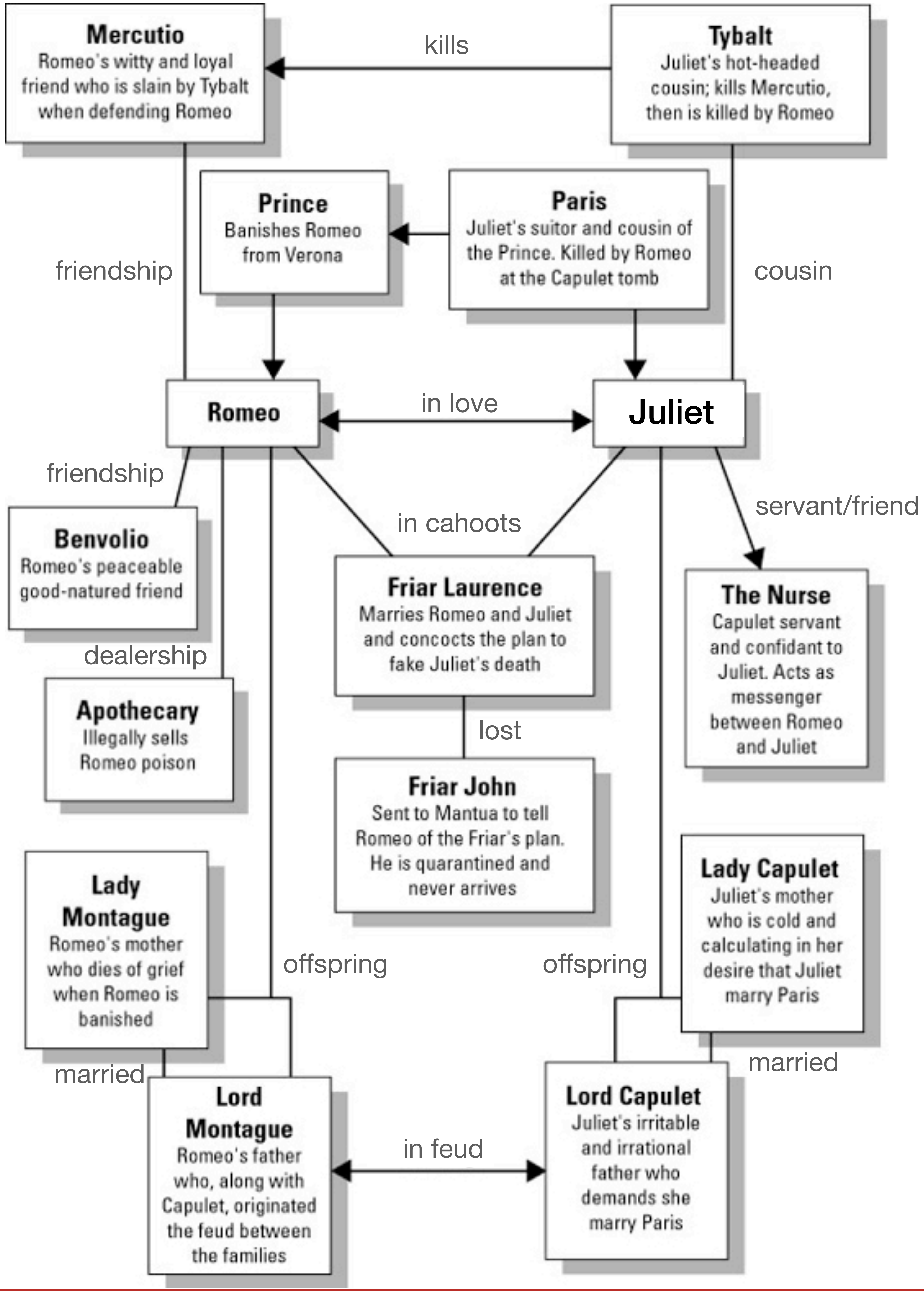

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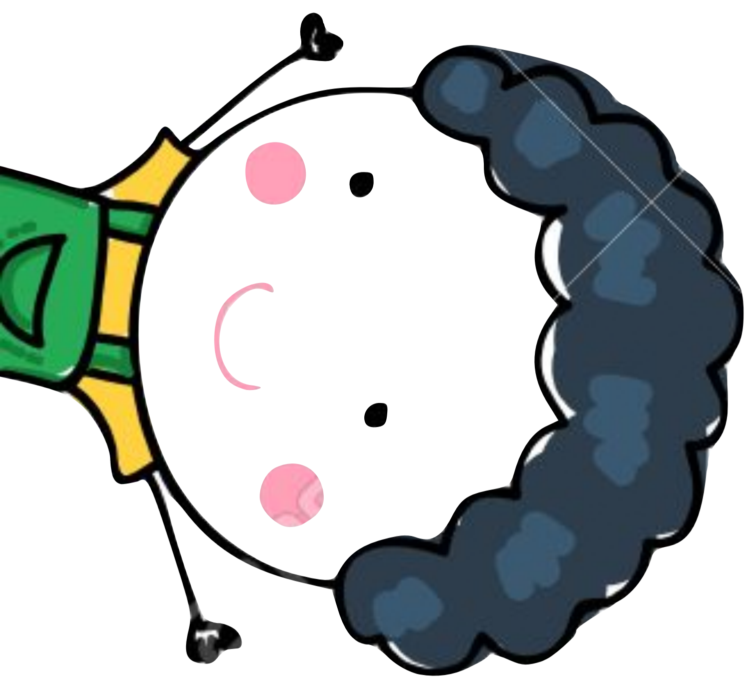
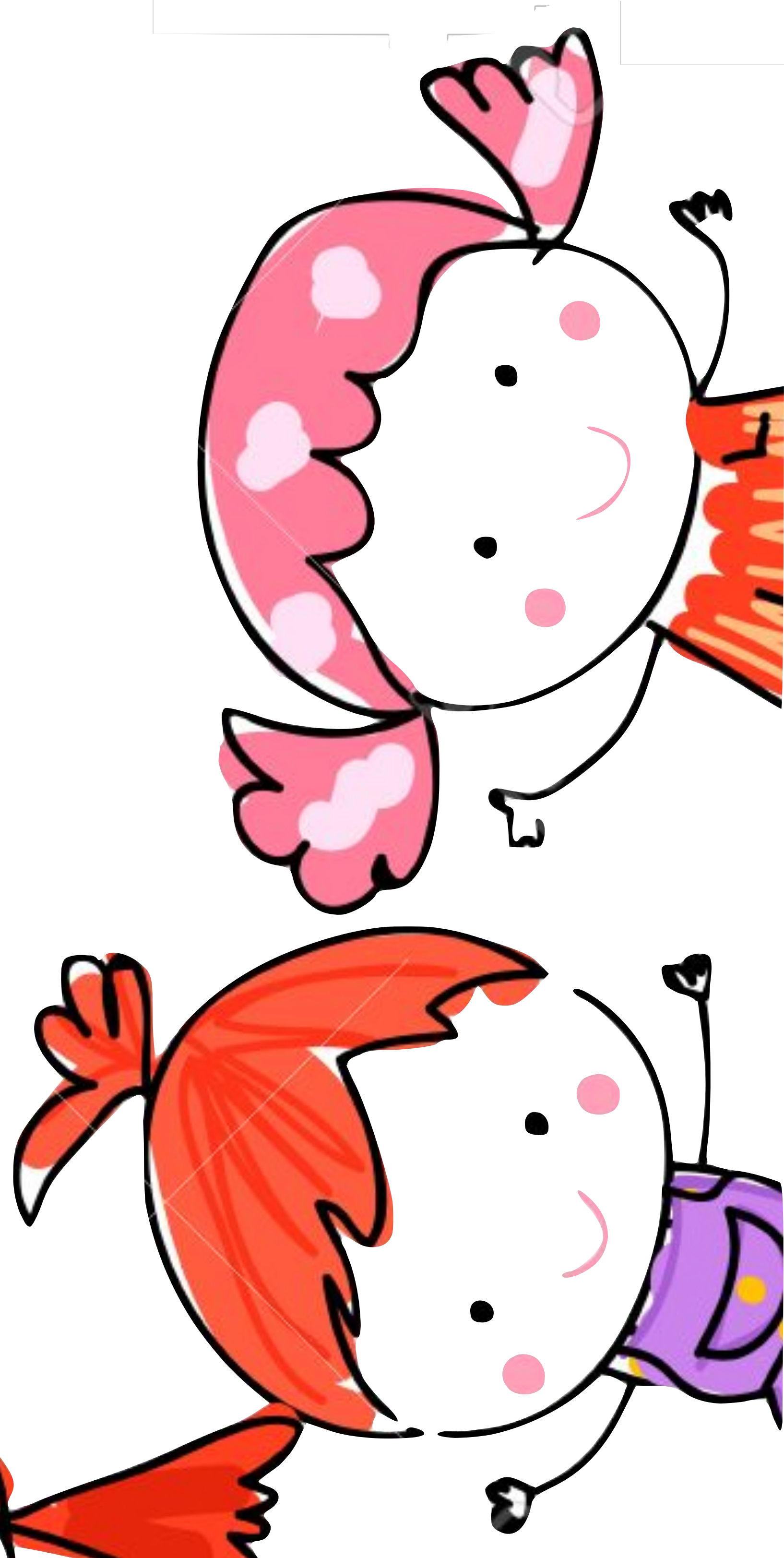


Let's build a network gathering data from this class



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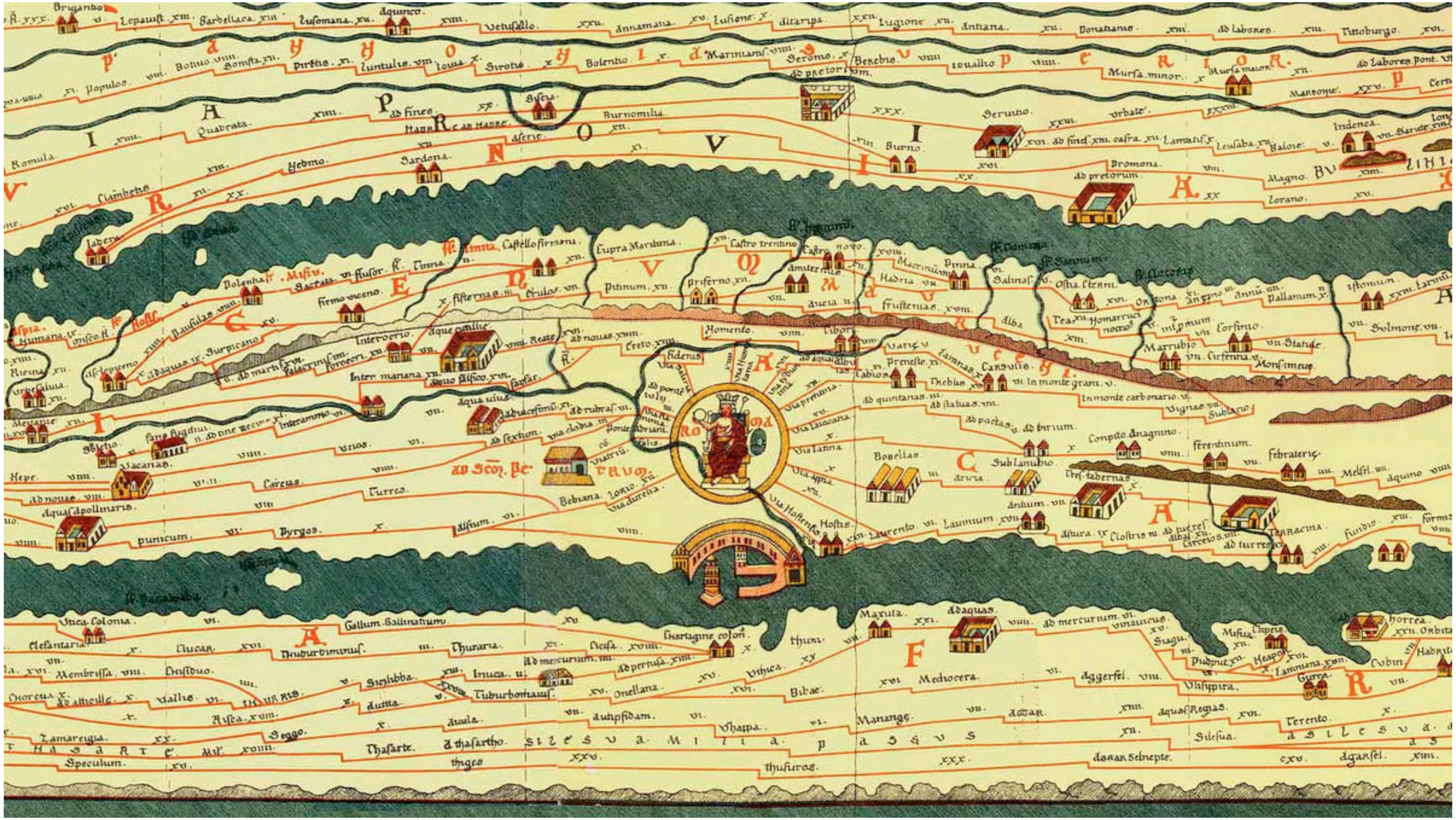

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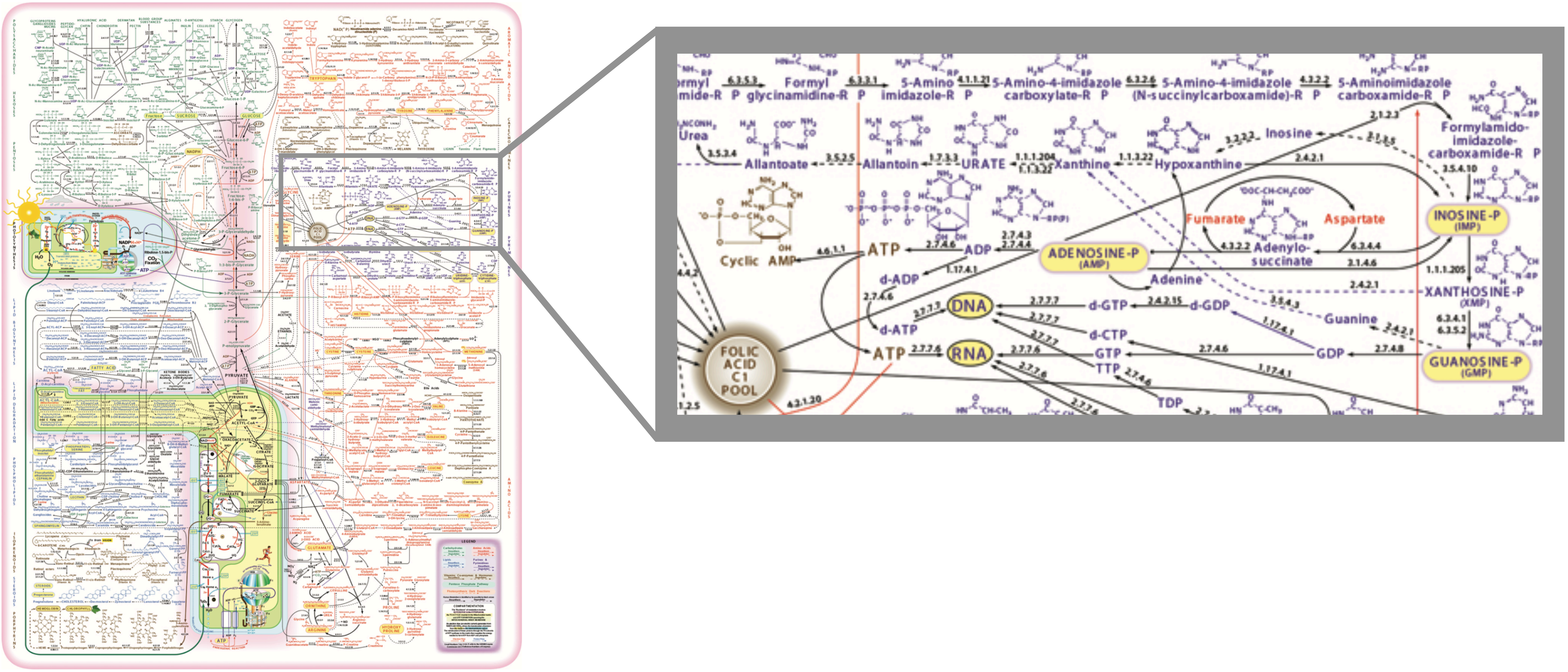

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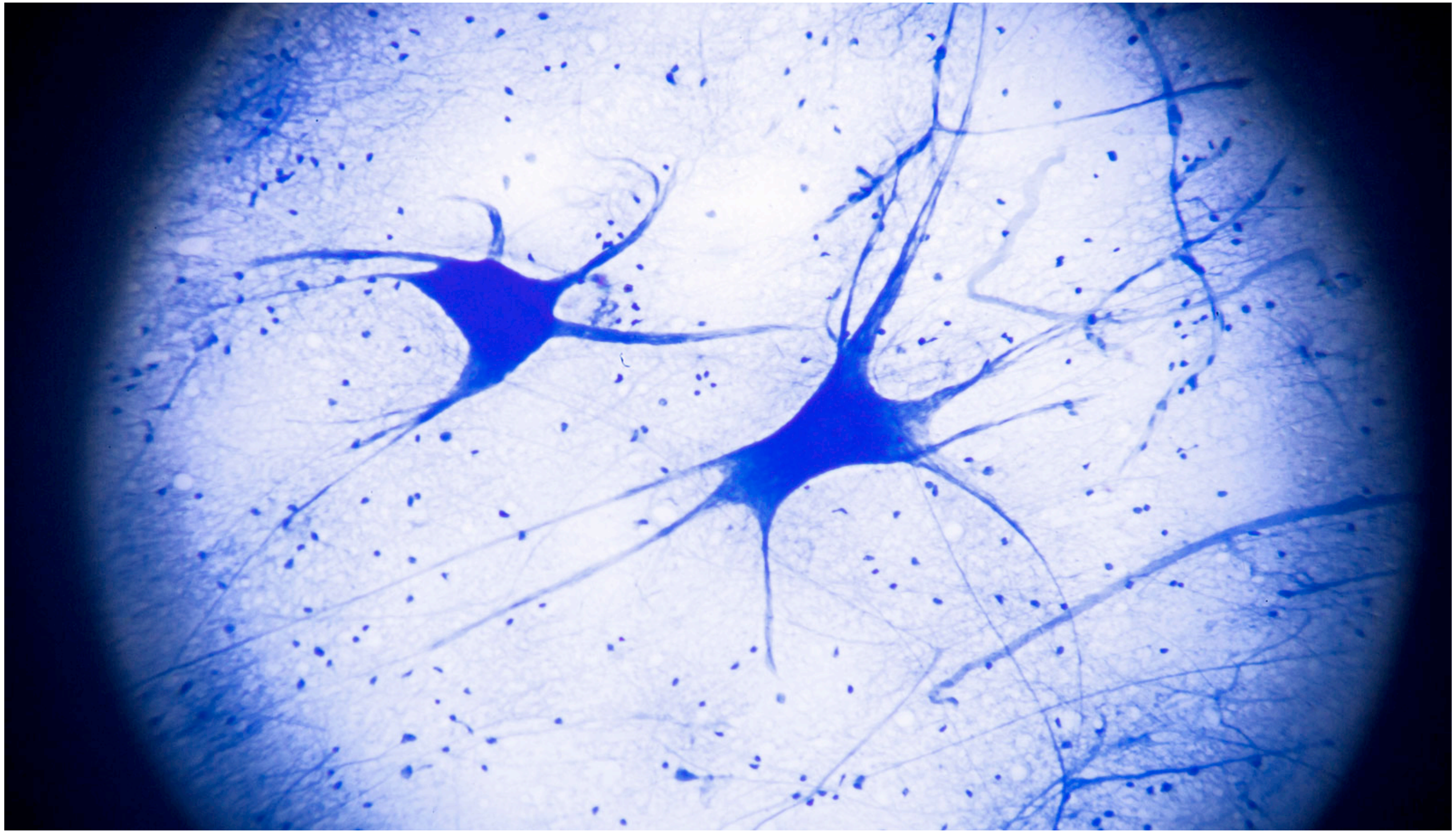

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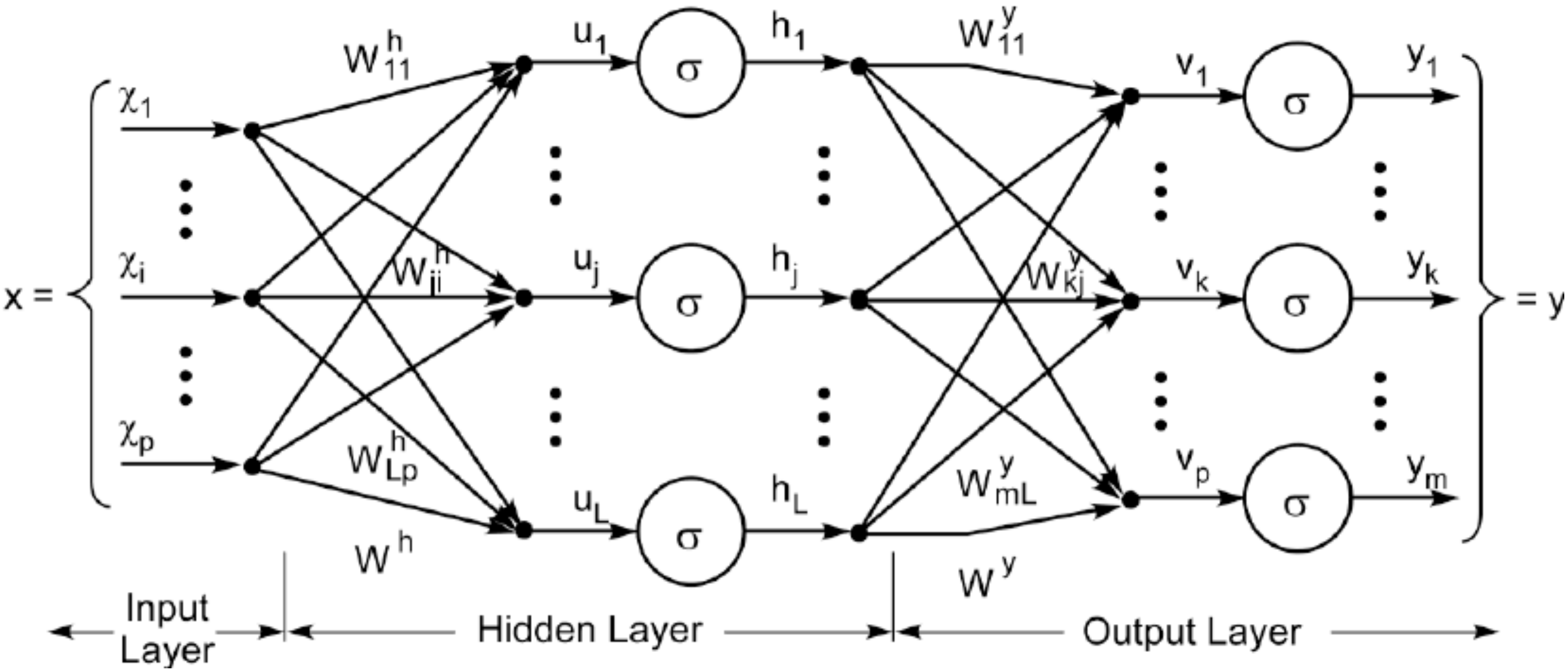

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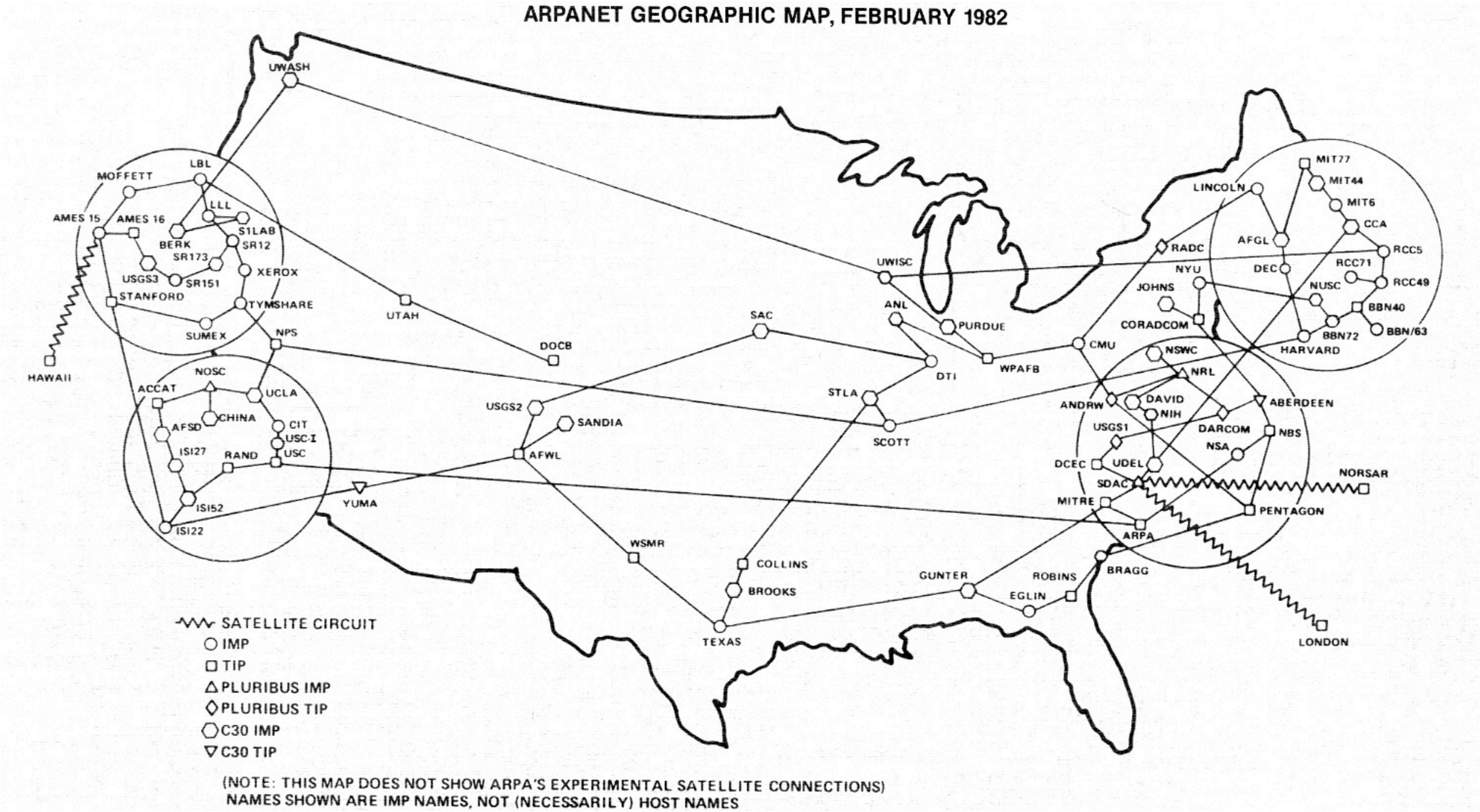
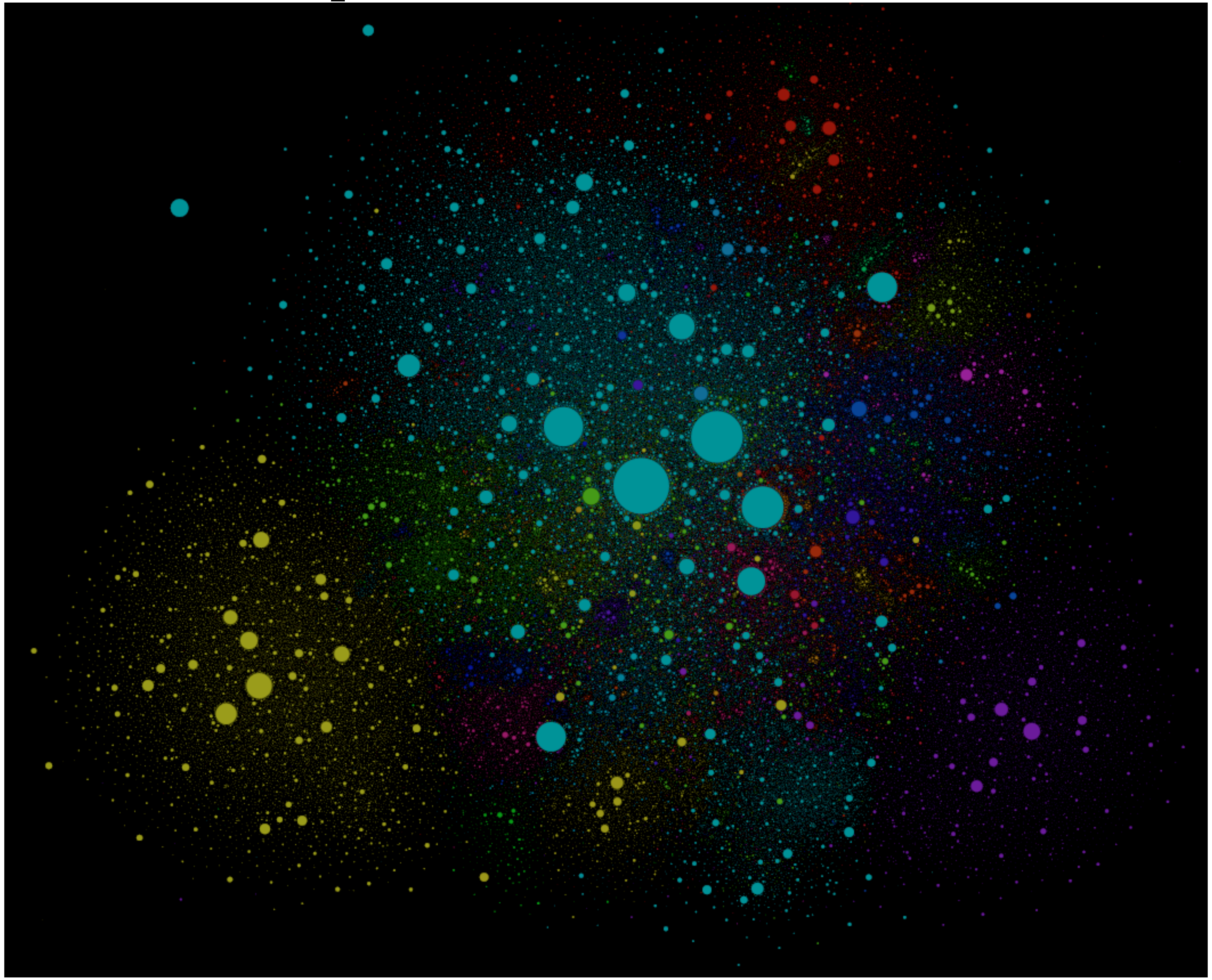


Networks, examples

The Internet map



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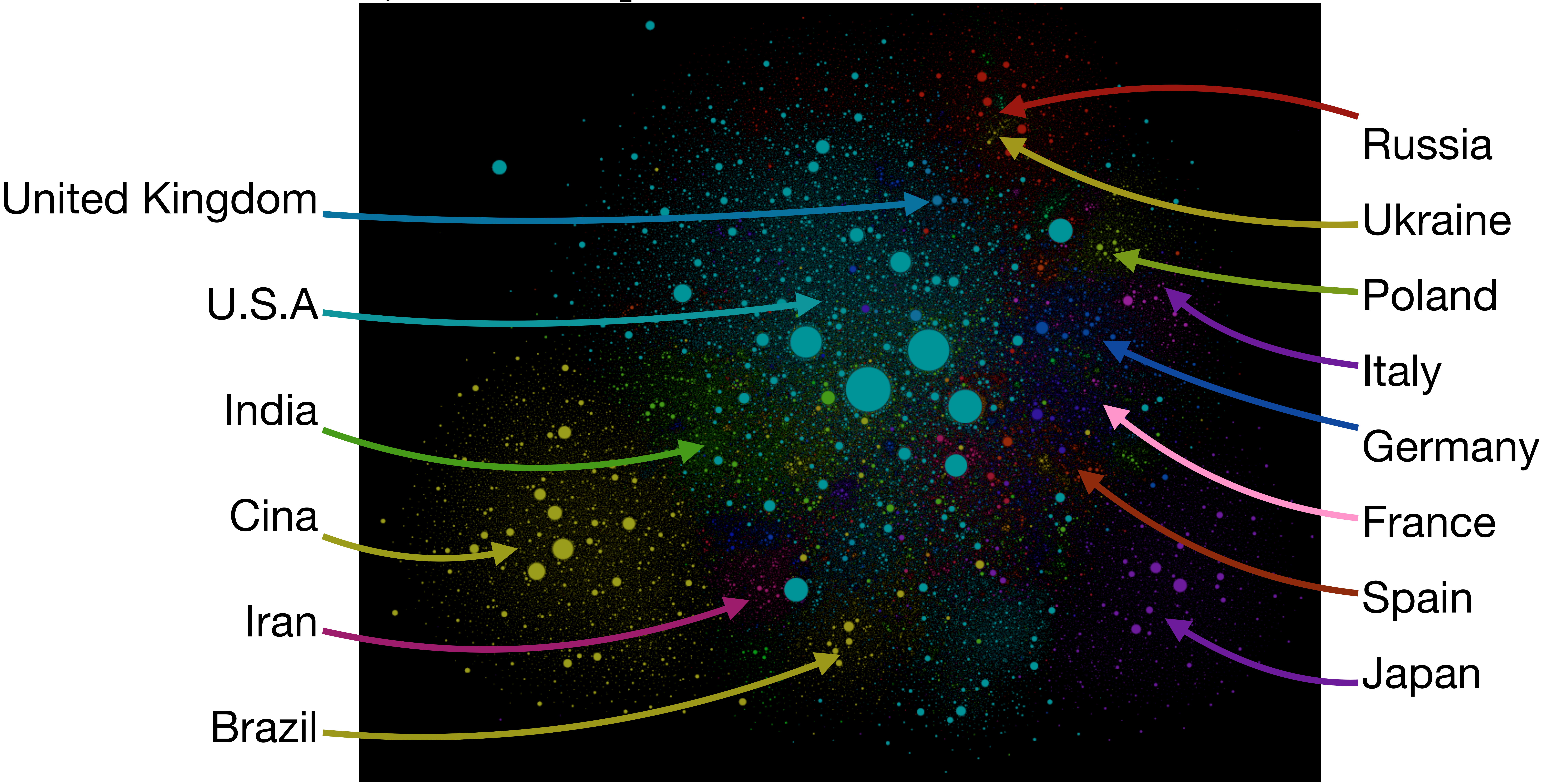


Network Analysis

The founding questions behind network analysis are:

- If we know the shape of a network, what can we learn about the nature and function of the system it describes?
- How are the structural features of a network related to the practical issues we care about?

Network Analysis

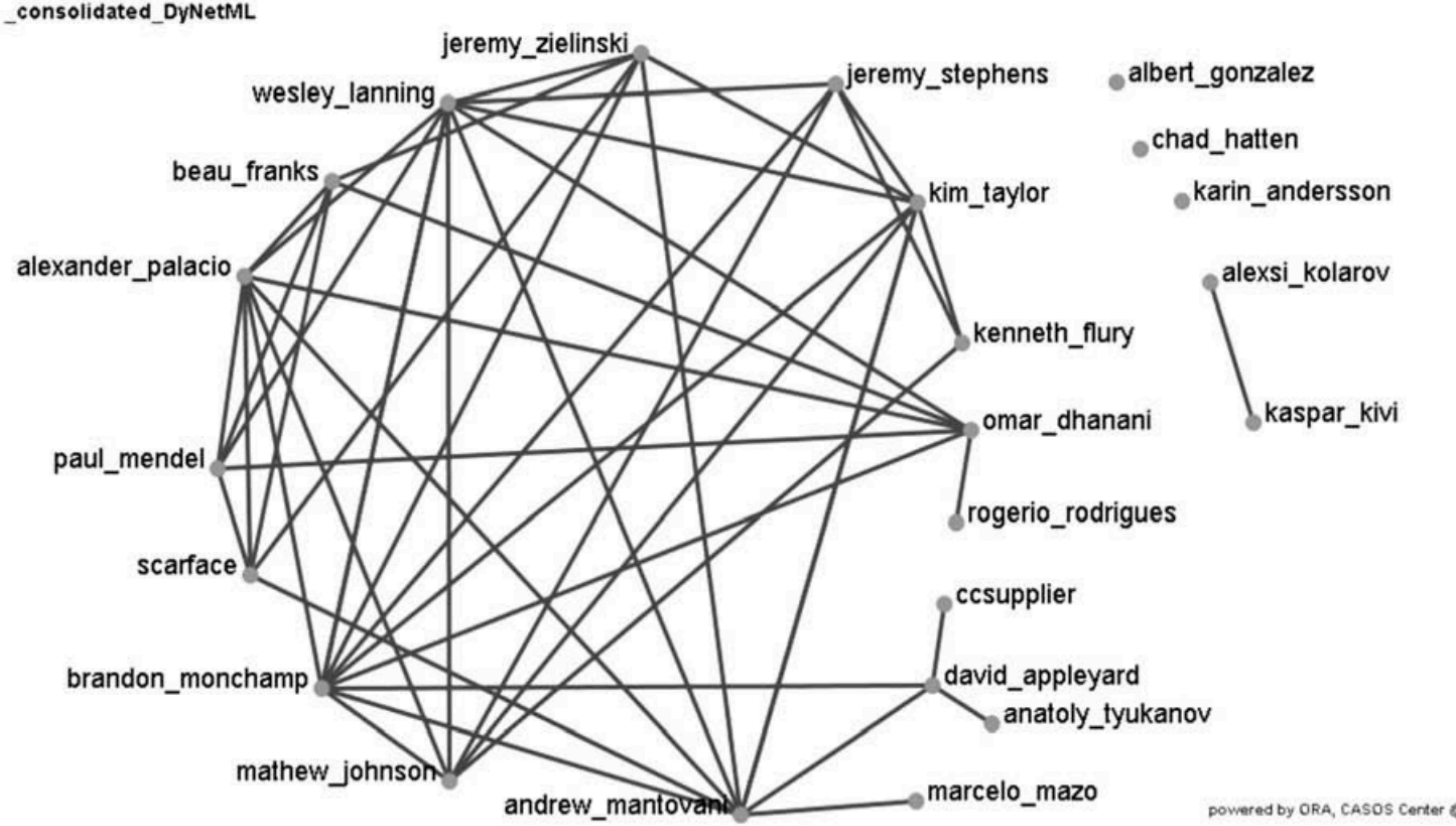
A first step in analysing the structure of a network is often to make a picture of it.

Automatic tools help in managing, visualising, and exploring networks.

Visualisation is a useful tool in the analysis of network data, allowing us to instantly *see important structural features* that would otherwise be difficult to pick out of the raw data.

The human eye is enormously gifted at **discerning patterns**, and visualisations allow us to put this gift to work on our network problems.

Networks, examples



Network Analysis

While we are good at spotting patterns, we can feasibly do that manually up to a few hundreds or thousands of nodes and for networks that are relatively sparse—whose number of edges is quite small.

To address these issues, network theory has developed a large tool-chest of measures and metrics that “mimic” some specific abilities of our eyes, to help us when visualisation is impossible or unreliable.

Network Analysis

- An example of a useful (and widely used) class of network measures are the **centrality measures**.
- Centrality quantifies **how important nodes are in a network**.
- While the concept is clear, what it (mathematically) means for a node to be central in a network may vary.
- The simplest centrality measure is called **degree**. The degree of a node in a network is the number of edges attached to it.
- In many cases, the nodes with the highest degrees in a network also *play major roles* in the functioning of the system. Hence the node's degree can be a useful guide to focus our attention on a system's most important elements.

Networks, examples

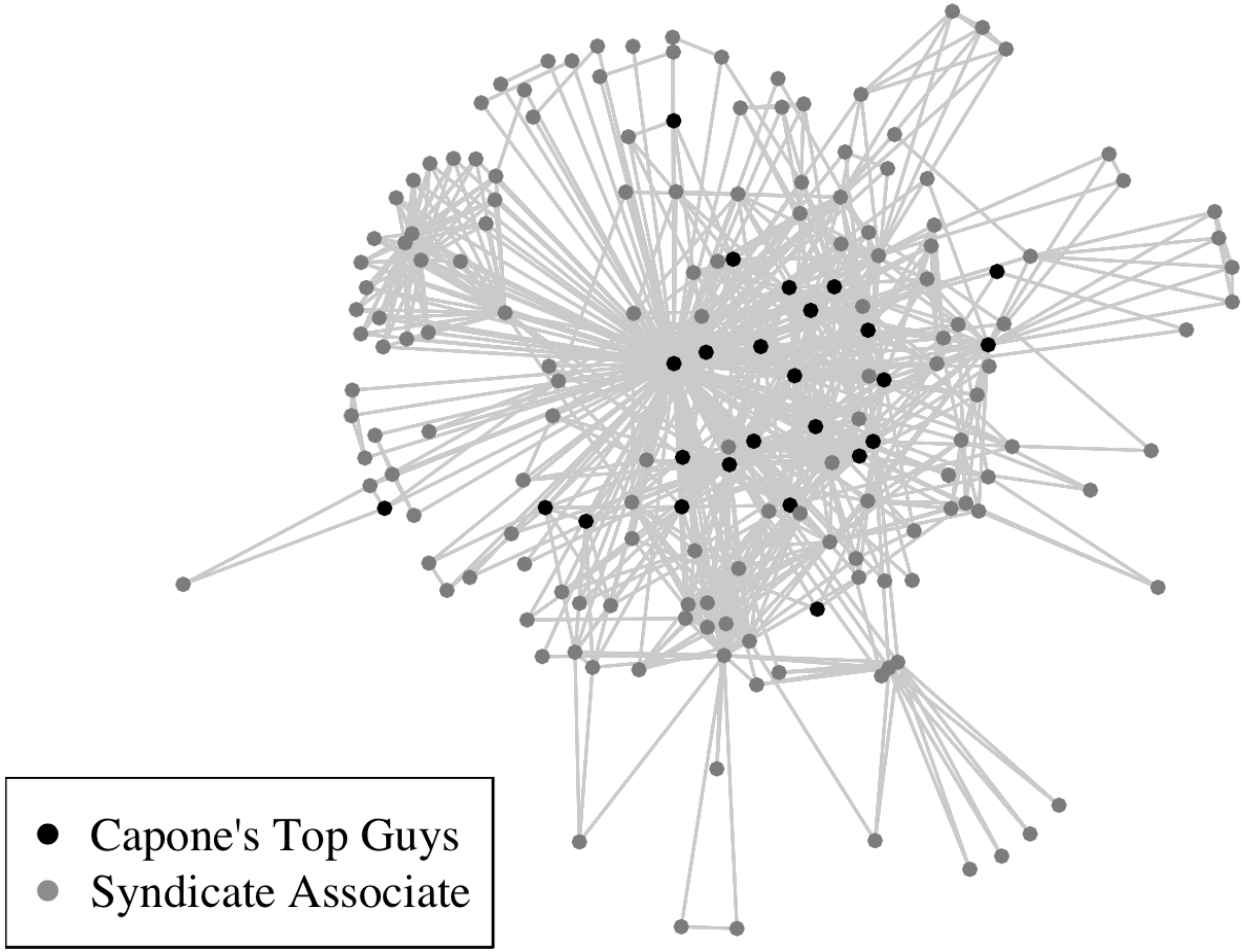
Network Analysis

- Another example of a network concept that arises repeatedly and has real practical implications is the so-called **small-world effect**.

- Given a network, one can ask what the shortest distance is, through the network, between a given pair of nodes. In other words, what is the minimum number of edges one would have to traverse in order to get from one node to the other?

- Although first studied in the context of friendship networks (the famous "six degrees of separation"), small-world effect appear to be widespread, occurring in essentially all types of networks.

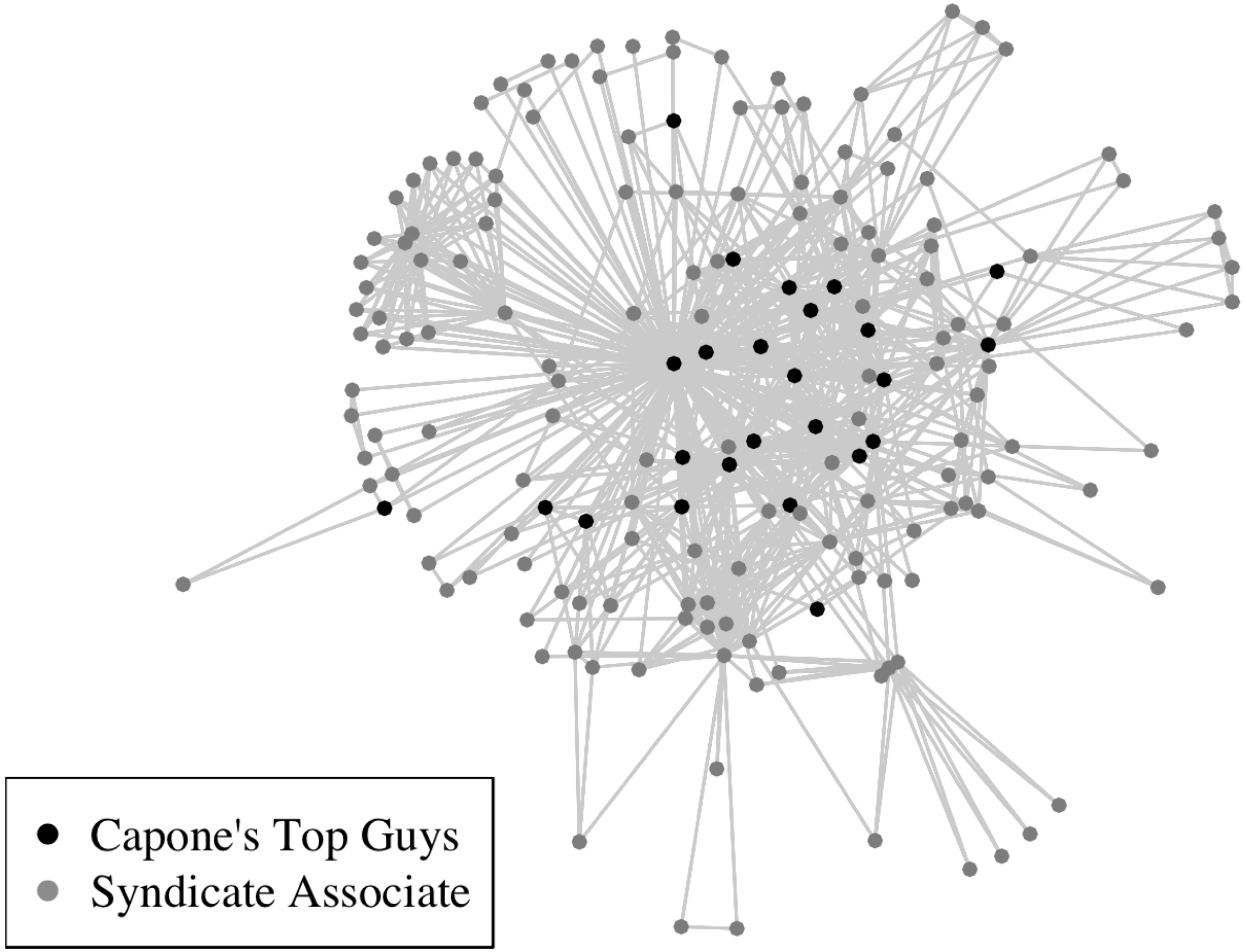
Networks, examples



Network Analysis

An example of small-world configuration is the occurrence of clusters or communities of a small number of individuals linking the majority of nodes in the network

Networks, examples



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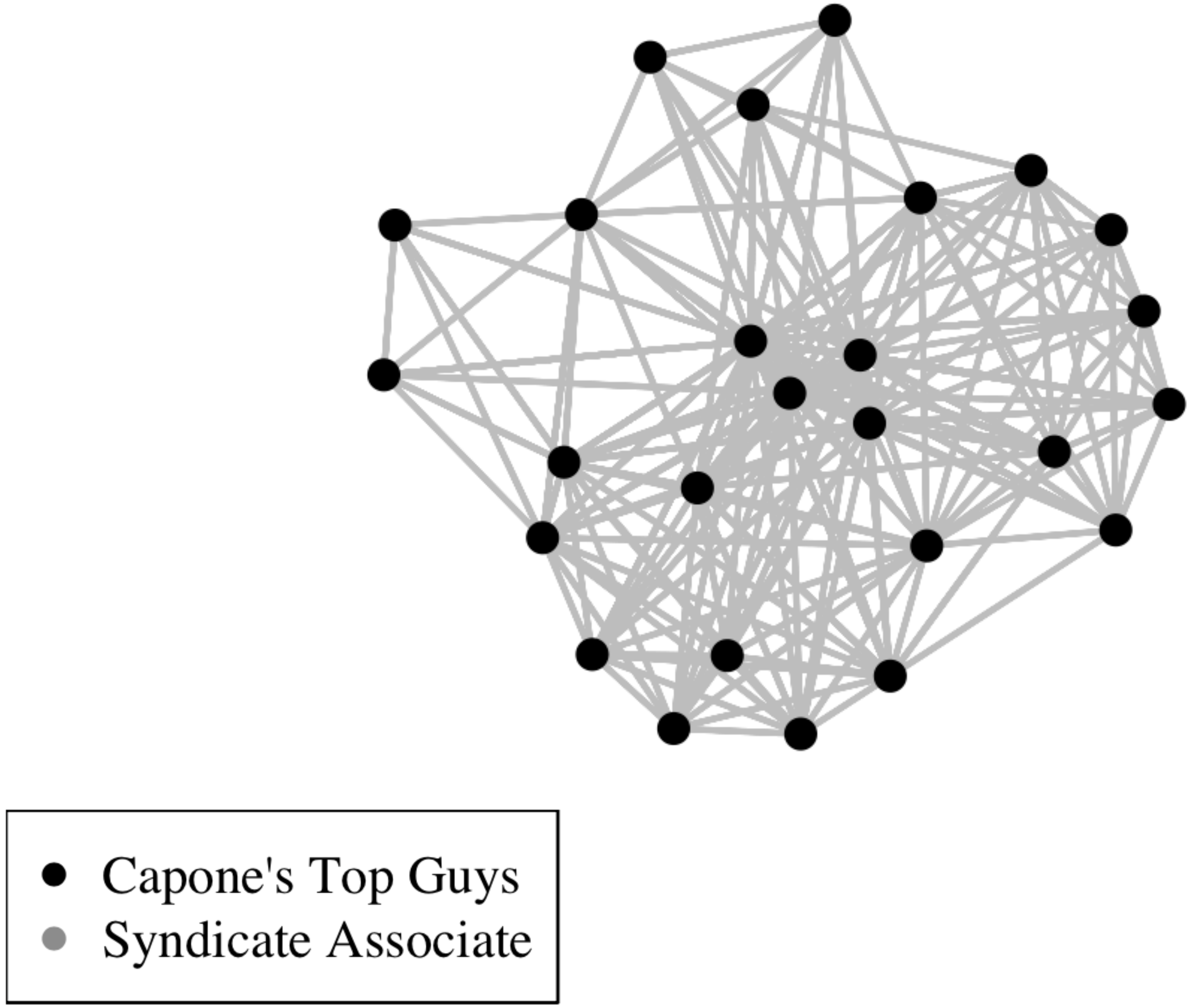

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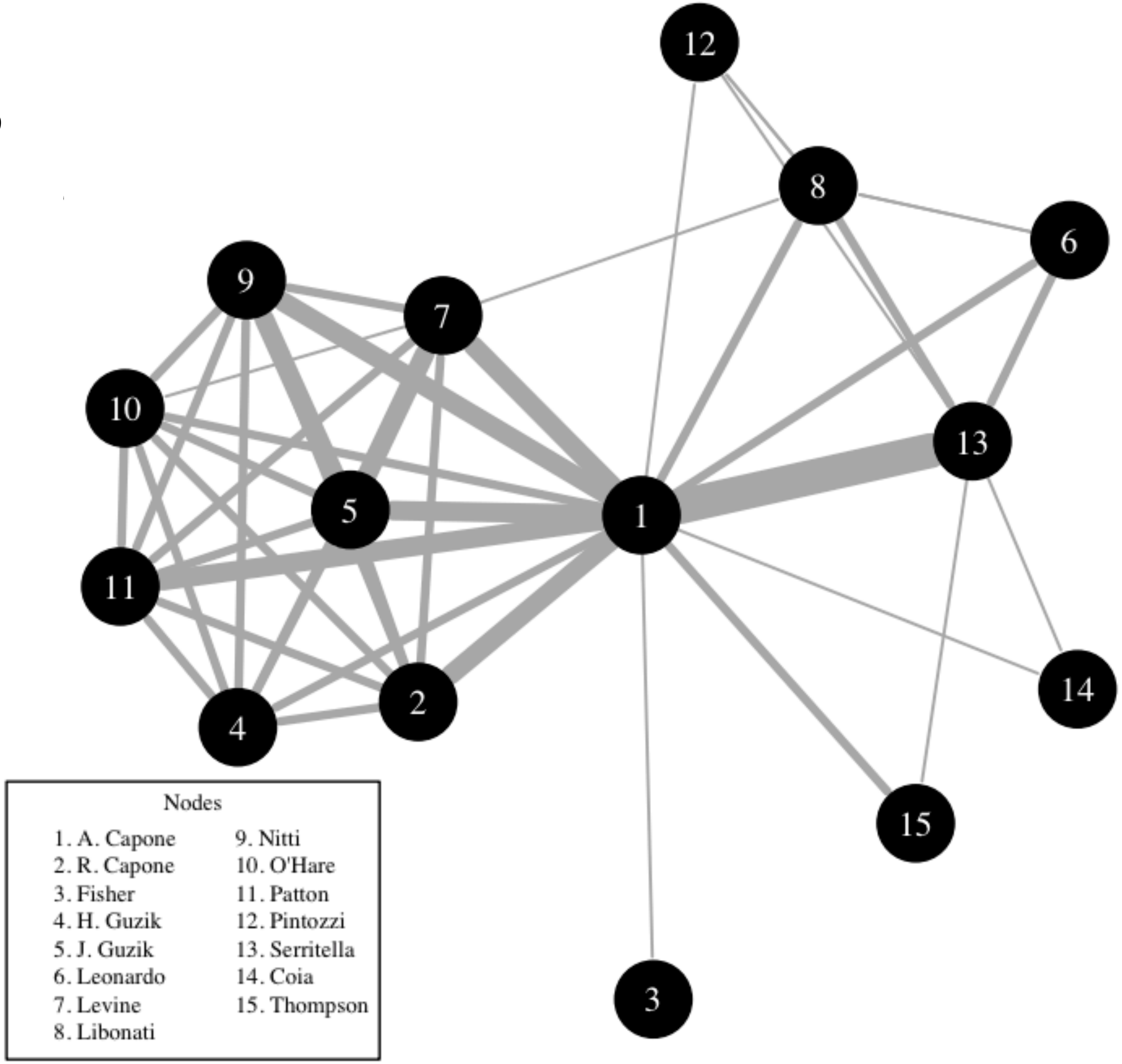


Width of Edge indicates N of Tie Types

Network analysis

- Scientists in a wide variety of fields have developed an extensive set of **mathematical and computational tools** for analysing, modelling, and understanding the **current status** of a network (e.g., which is the best connected node or how similar two nodes are to one another) and make **predictions** about processes taking place on networks (e.g., the way a disease will spread through a community).

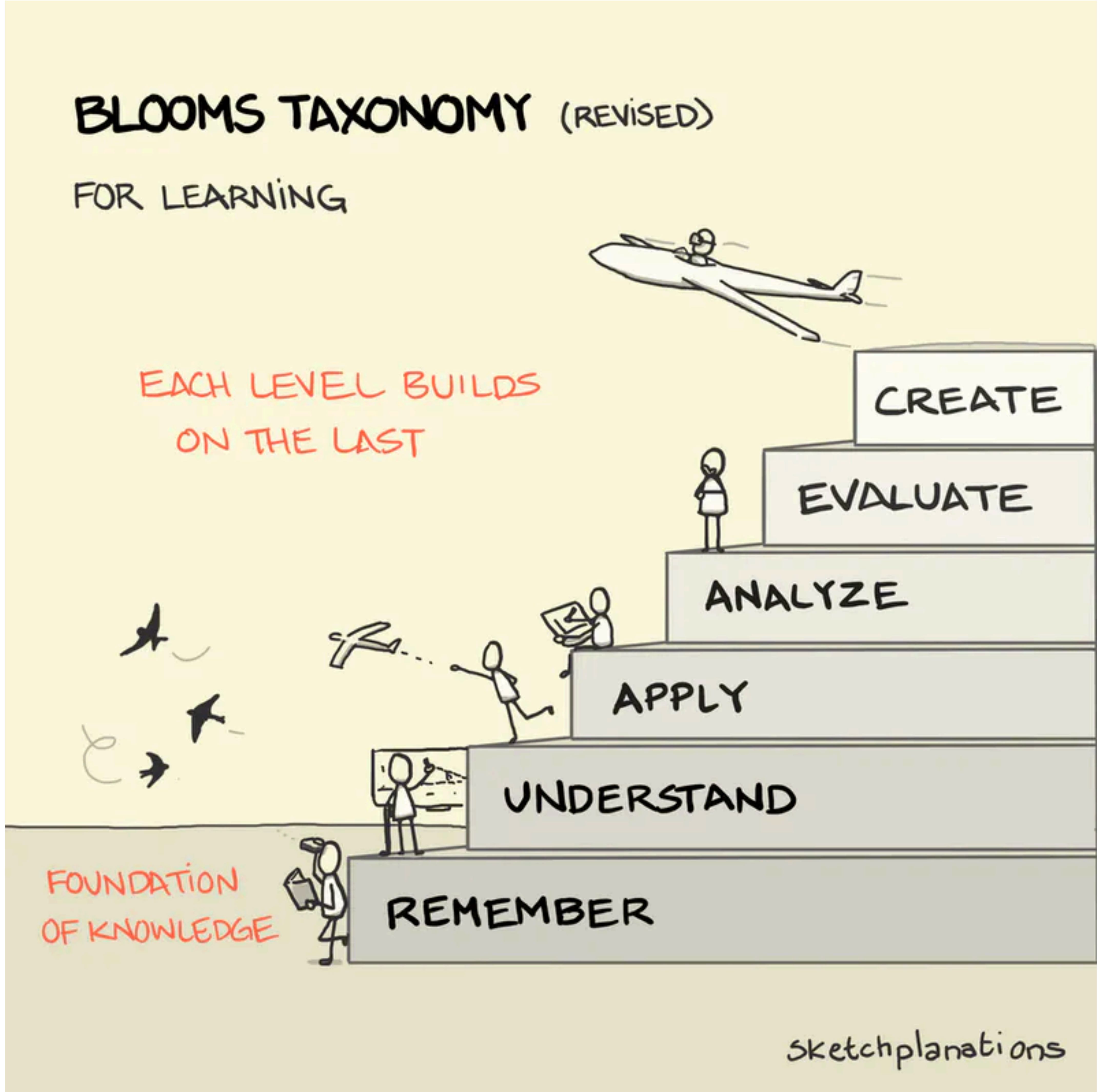
- Since networks **abstract specific details of the system they represent**, the same mathematical tools can be applied to almost any system that has a network representation (the power of abstraction).

This course (1/3)

- We study applications of network analysis on diverse fields—literature, philosophy, biology, computer science, economics, and forensics (but not only limited to those)—to understand both **the motivations** and **techniques employed**;

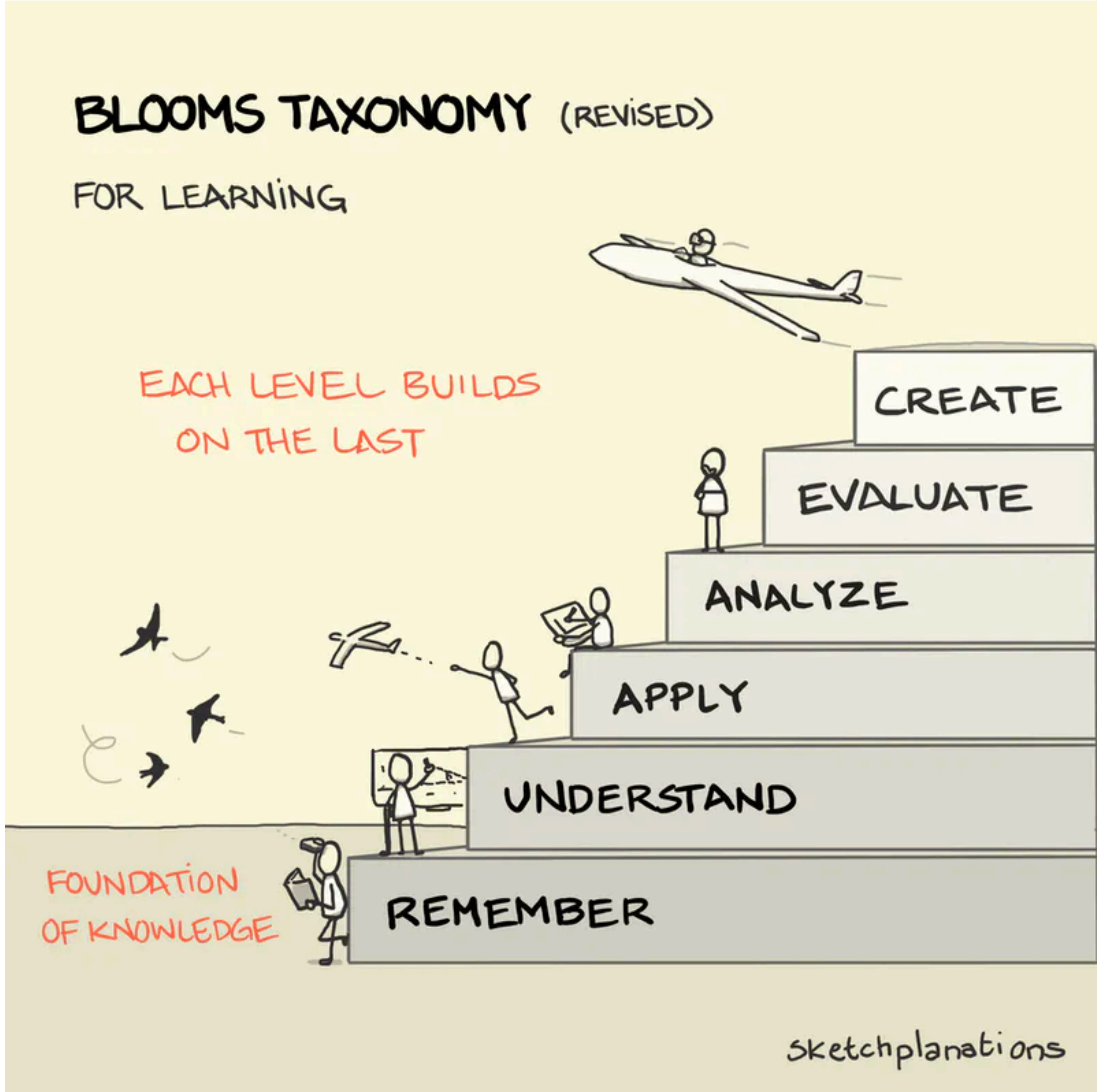
- We acquire proficiency in ***information literacy*** to learn how to discover network information and develop an understanding of how that information is produced and its use in creating new knowledge;

- We study relevant theory of network analysis;



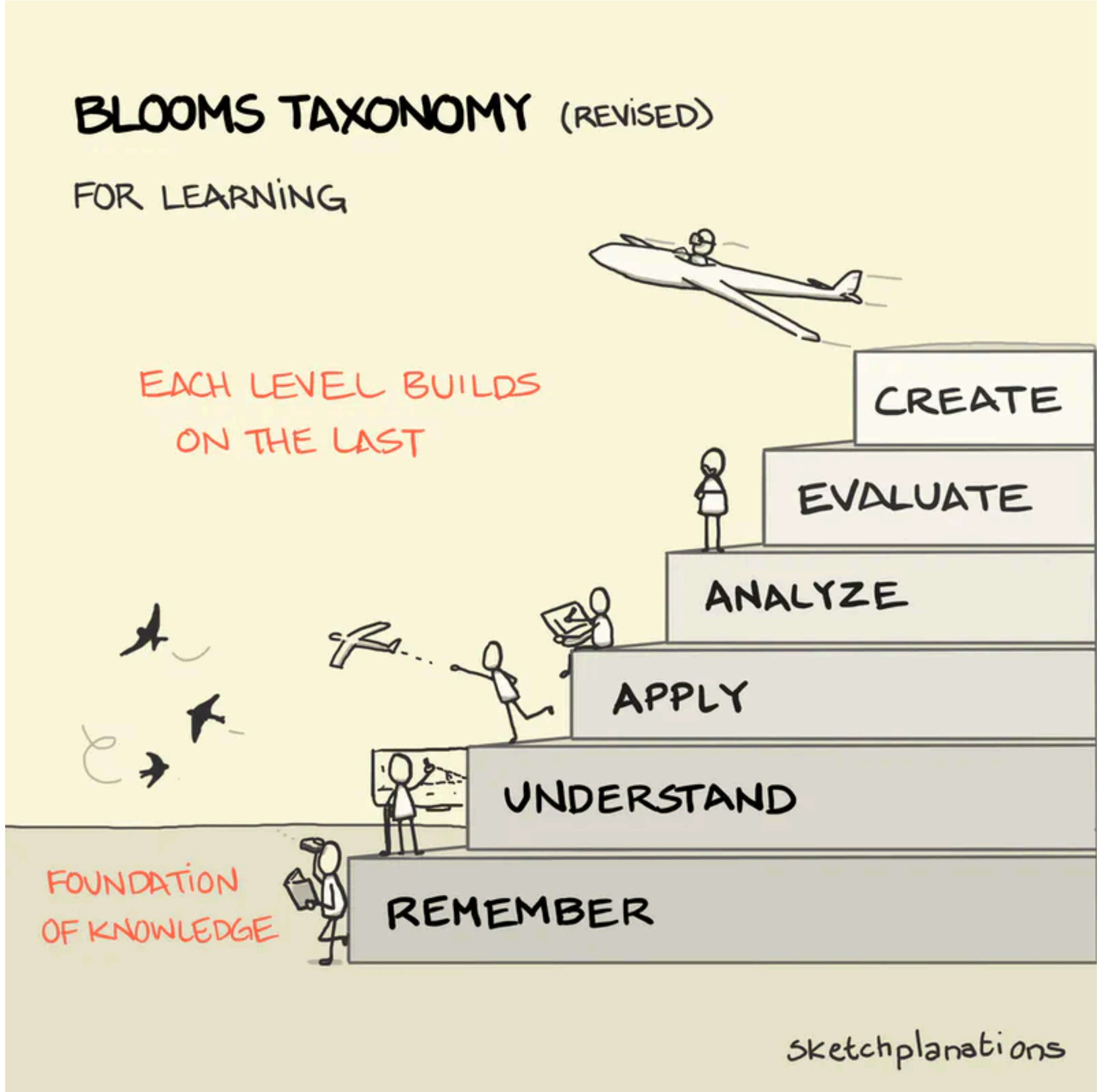
This course (1/3)

- We learn how to perform the **research design** of a network analysis study, divided in its primary elements:
  - formulation of theories and definition of hypotheses;
  - data collection and data management;
  - identification and application of network measures;
  - visualisation and interpretation of the measure results.



This course (3/3)

- This is a fairly interactive course:
  - we will see the application of the theory with automatic tools;
  - students will form groups, analyse research papers, and give seminars to the rest of the class.



The exam

- The exam consists in an hand-in project **report on a network analysis research designed and performed by a group of students**. The group comes up with the subject of the research, the goals, and the data.

- Students can ask for an overall feedback on their project before starting to work on it by sending a short abstract via email to the teacher.

- Rolling deadline: you can deliver your **report** when you deem it ready. It will be evaluated at the next exam's deadline (look at the website for the dates and the details)

- Possible starting points for the project are:

  - **Reproducing results from previous papers**, possibly increasing their results with additional questions, measures, and interpretations

  - **exploring and interpreting the characteristics of some network**. E.g., "to understand the dynamics of network *X*, we apply measures *Y*, *W*, and *Z*, and give an interpretation of the results, following some related studies in the literature."

  - **finding predictors.** "in the context of *X,* is relation *Y* a predictor for phenomenon *Z*?"

  - **proposing new measures**: "We present measure *X* which is an indicator of *Y* in a network of shape *Z*."