

Introduction to Networks

Kevin J.S. Zollman
Carnegie Mellon University

Structure

- Less radical: common structures exist in nature that are similar in virtue of their structural similarity.
 - By studying the properties of these structures we can learn about many different systems
- More radical: Only structure is “real” and by learning about structures we are learning all there is in the world.

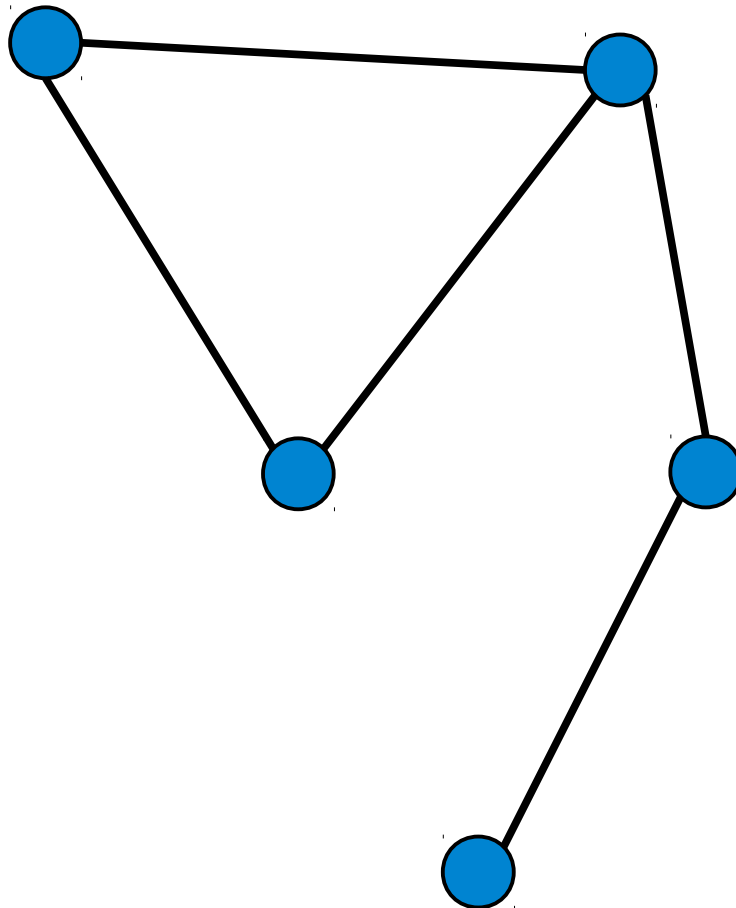
Three questions

- In a school, how many “cliques” are there?
- How hard would it be for a terrorist organization to completely disrupt the internet?
- What would be the impact on an ecosystem if all the mice died?

What's in common?

- Cliques
 - People
 - Friendship relations
- Internet
 - Cities
 - Backbone connections between them
- Ecosystems
 - Species
 - Predator/Prey relations

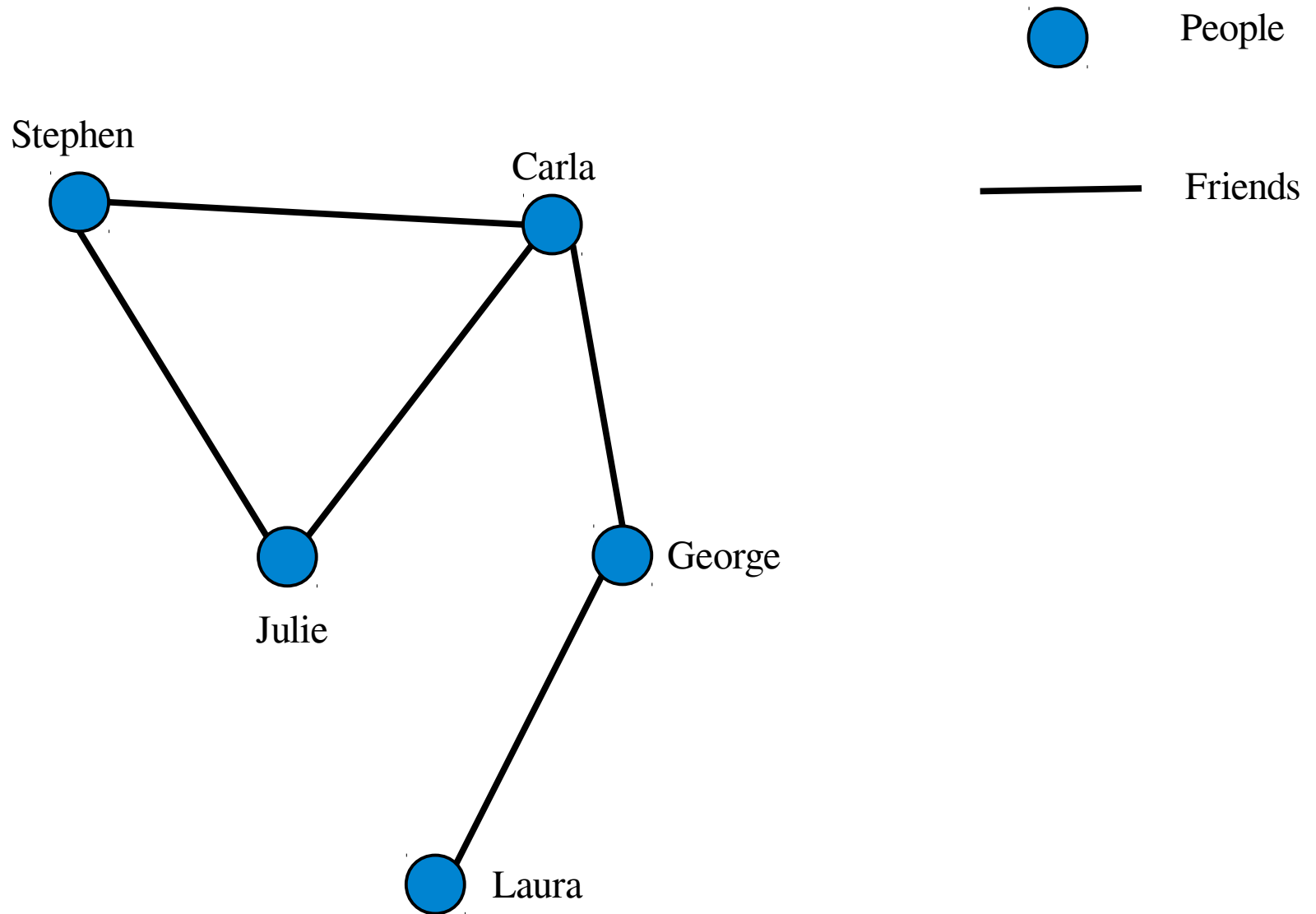
More abstractly



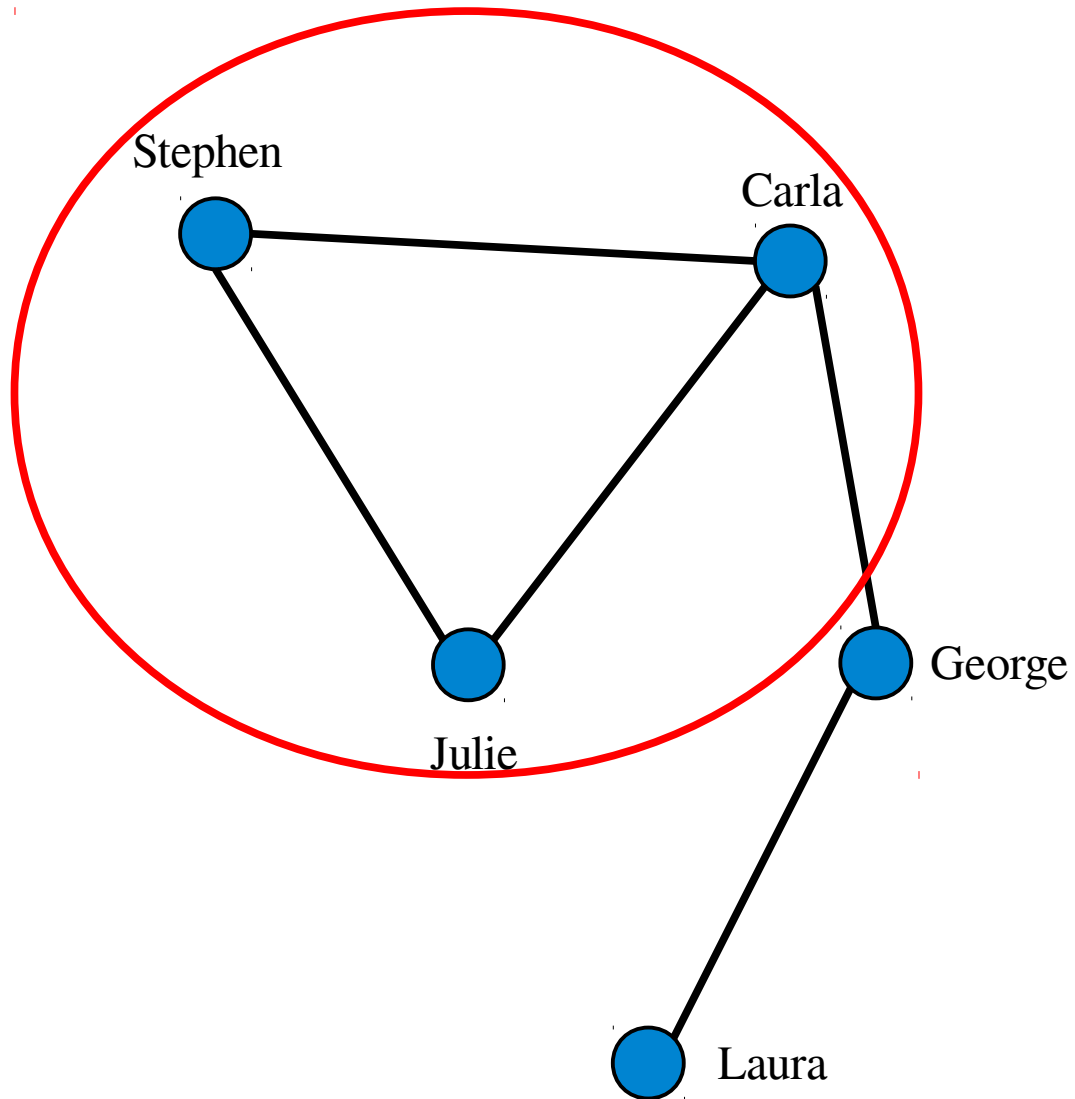
● Node

— Edge

Cliques



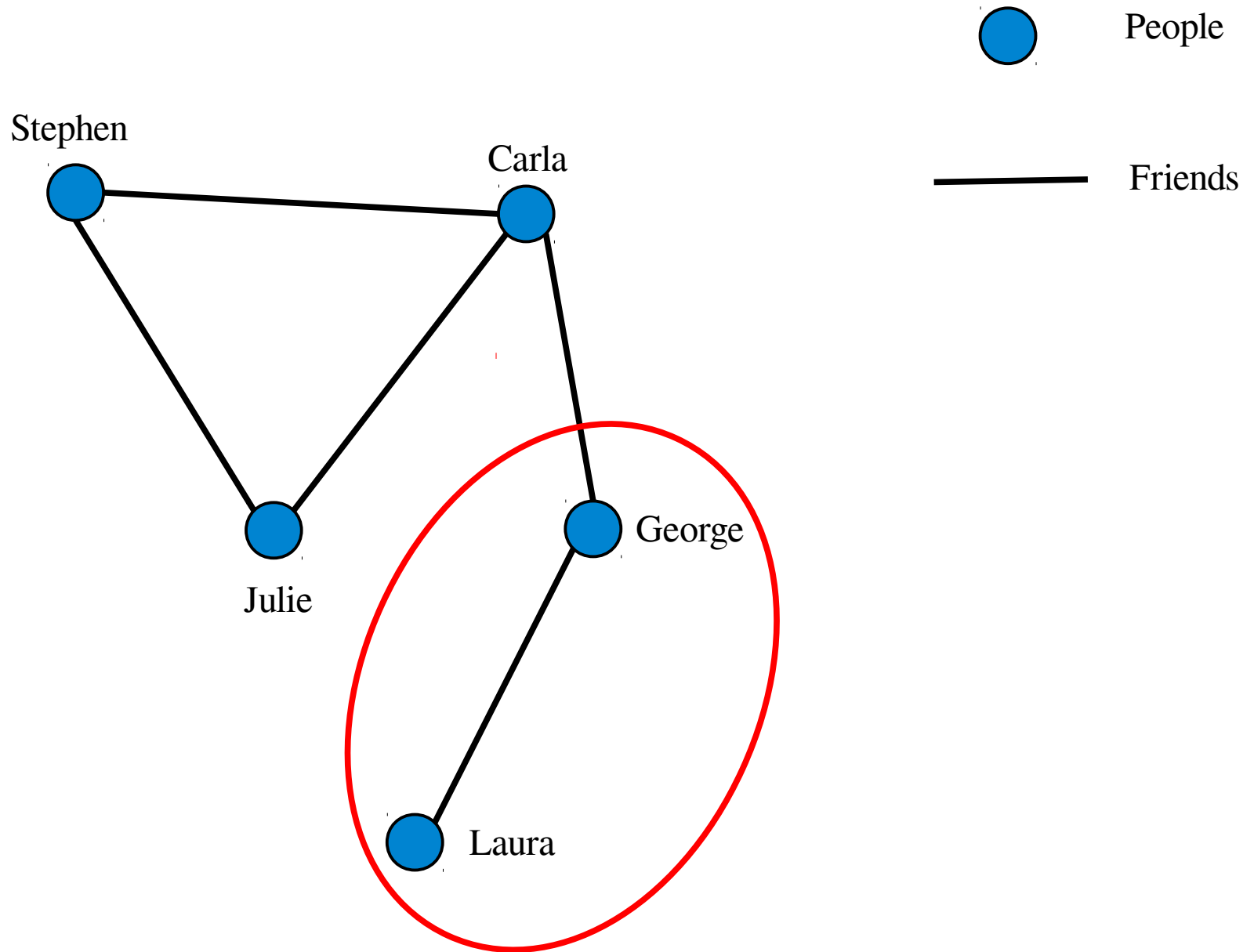
Cliques



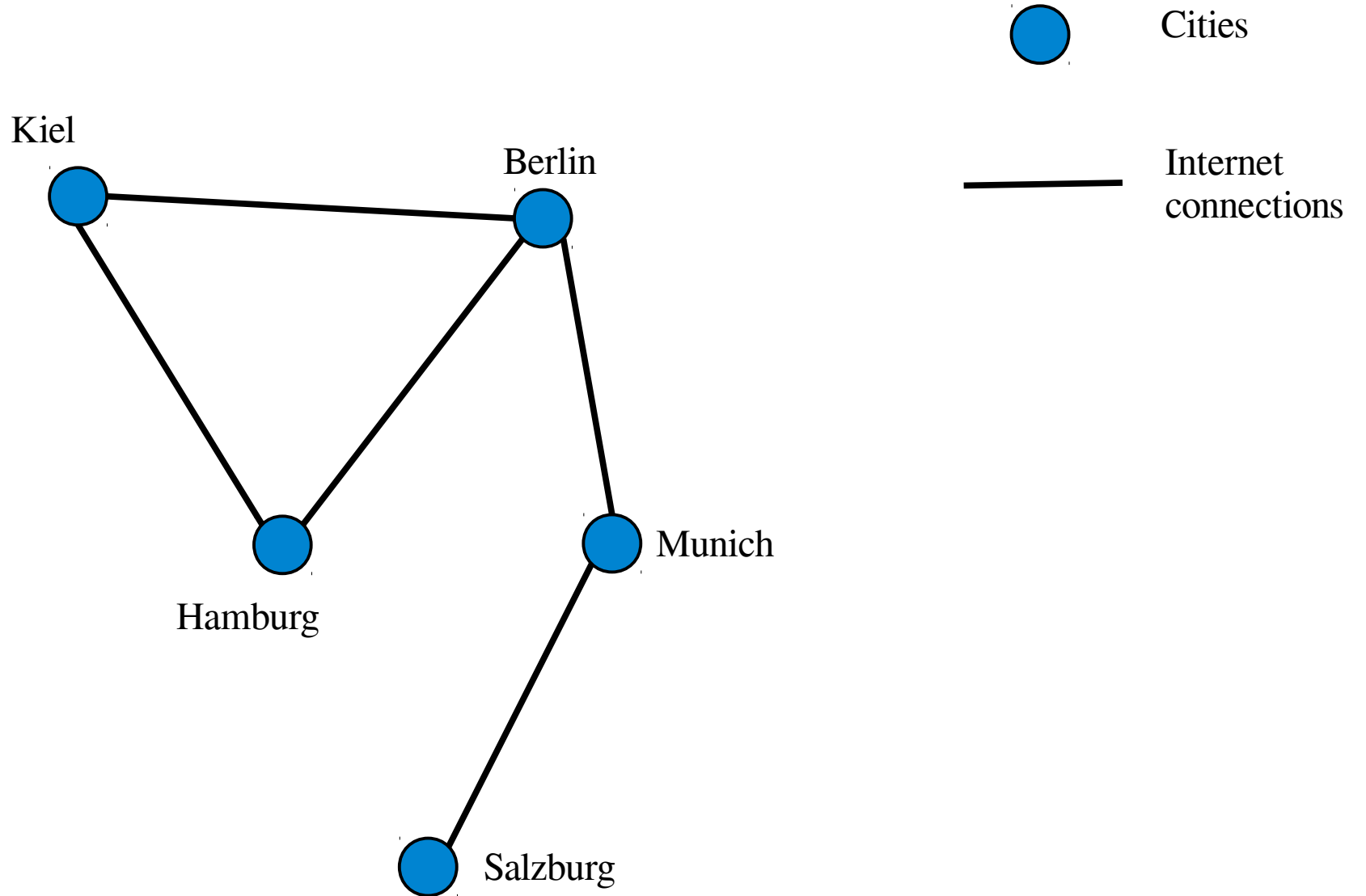
● People

— Friends

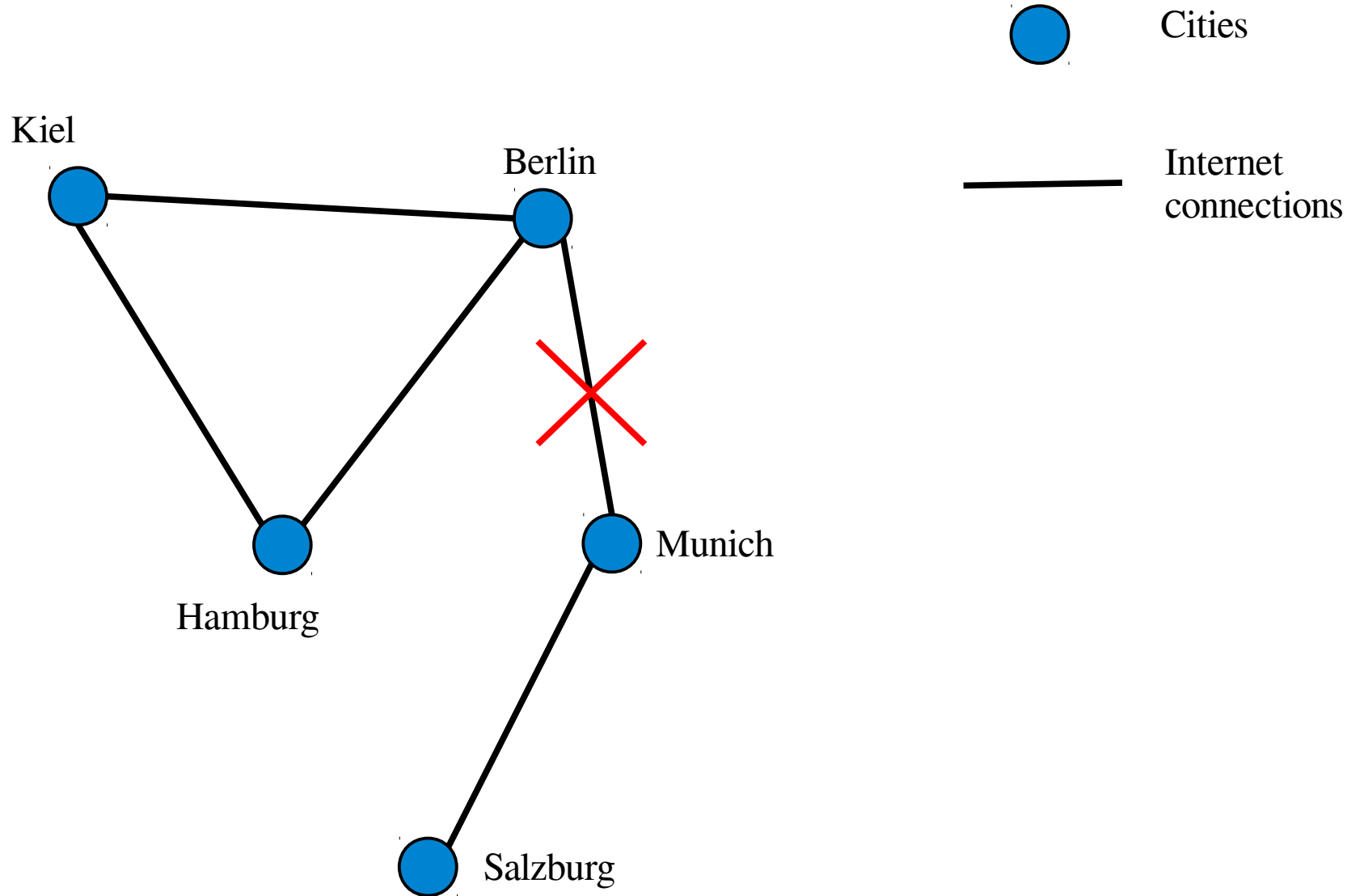
Cliques



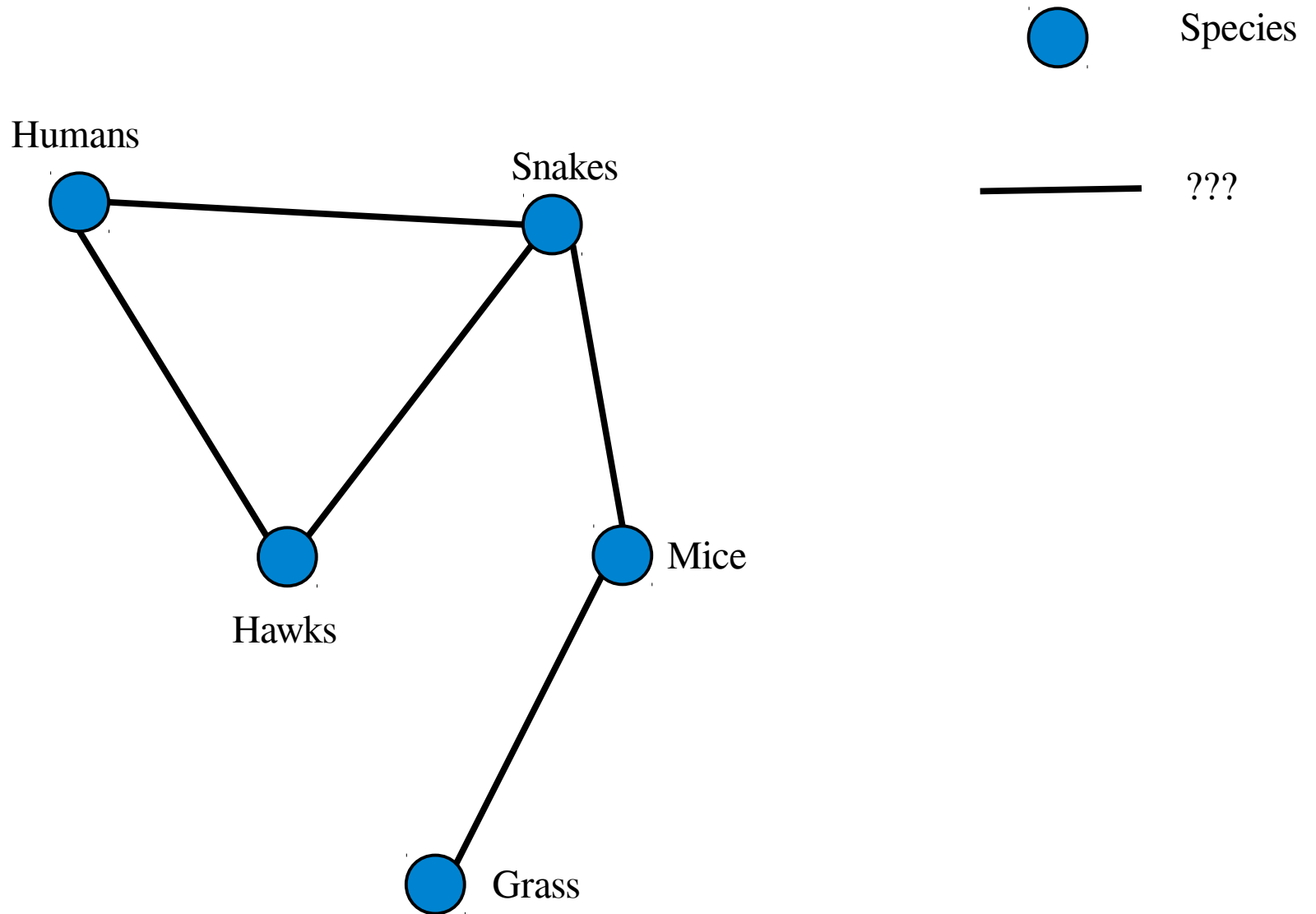
Internet



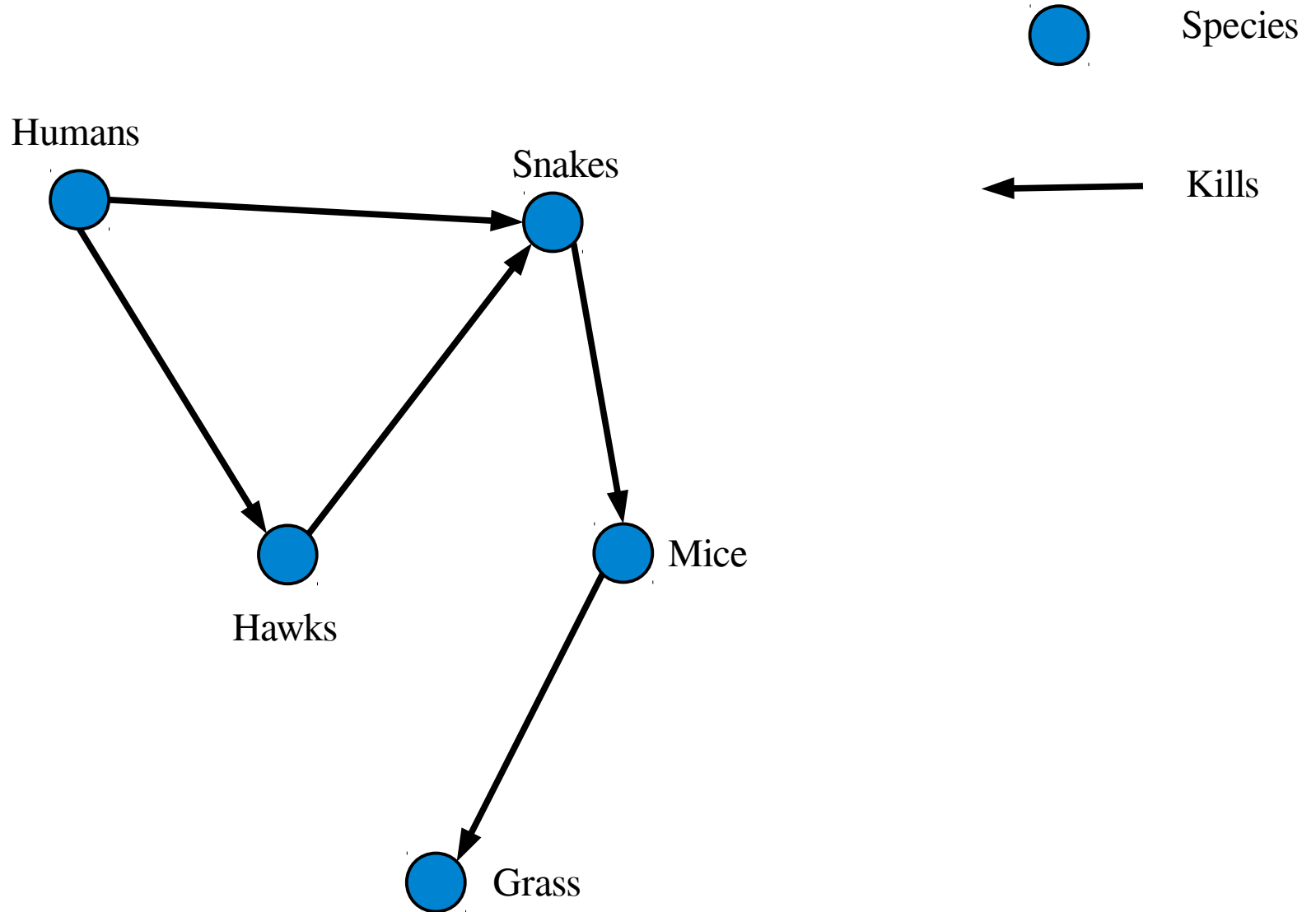
Internet



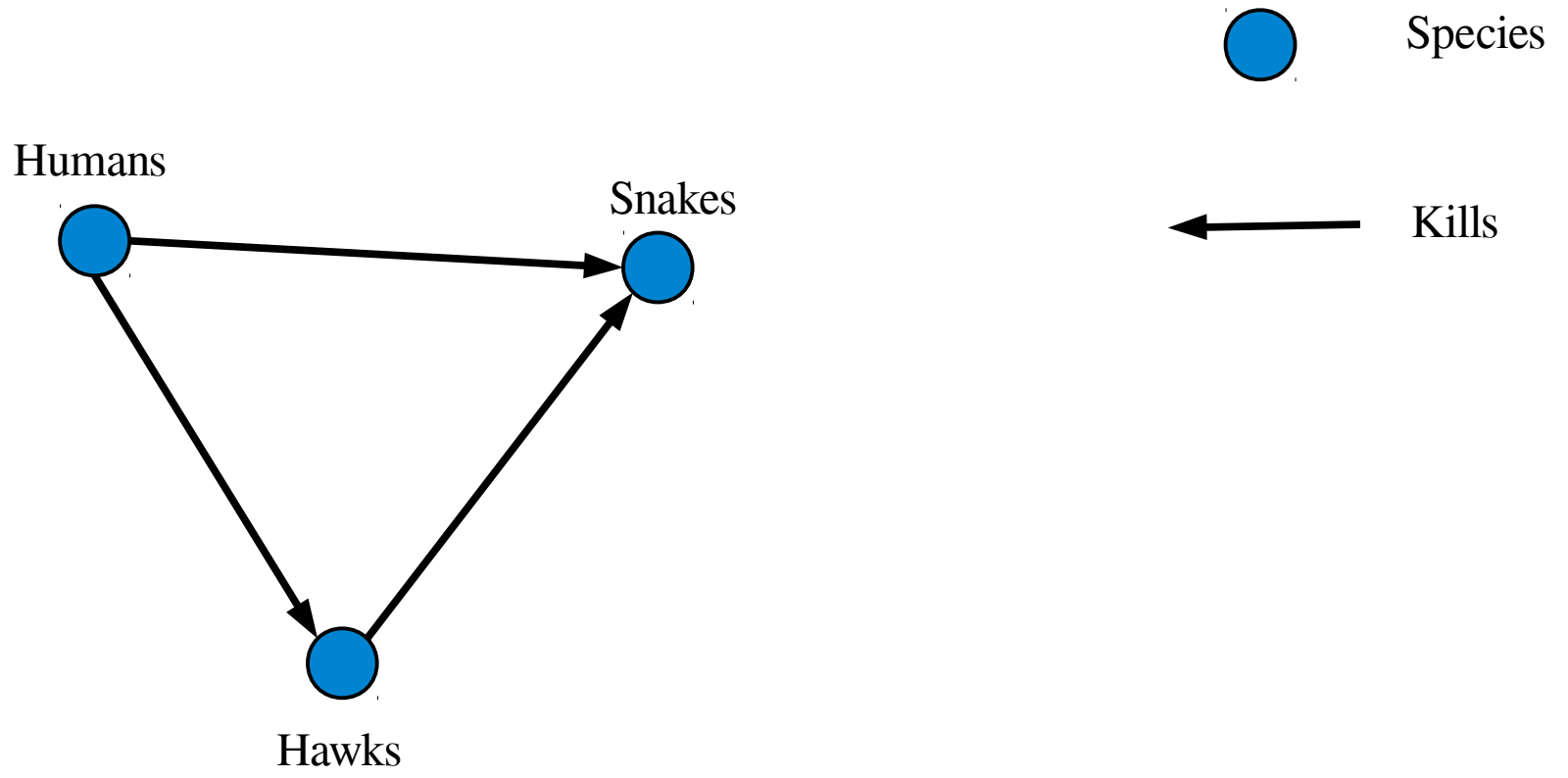
Species



Species



Species



● Species

← Kills

● Grass

Basics of graphs

- Nodes
 - A finite collection of basic objects
 - May have additional properties
- Edges
 - Connect two node
 - Maybe “directed” or “undirected”
 - May have additional properties

How are graphs used in philosophy?

- Modal logic
 - Node: State of affairs (possible world)
 - Edge: Possibility
- Causation
 - Node: A measurable variable
 - Edge: Causal connection

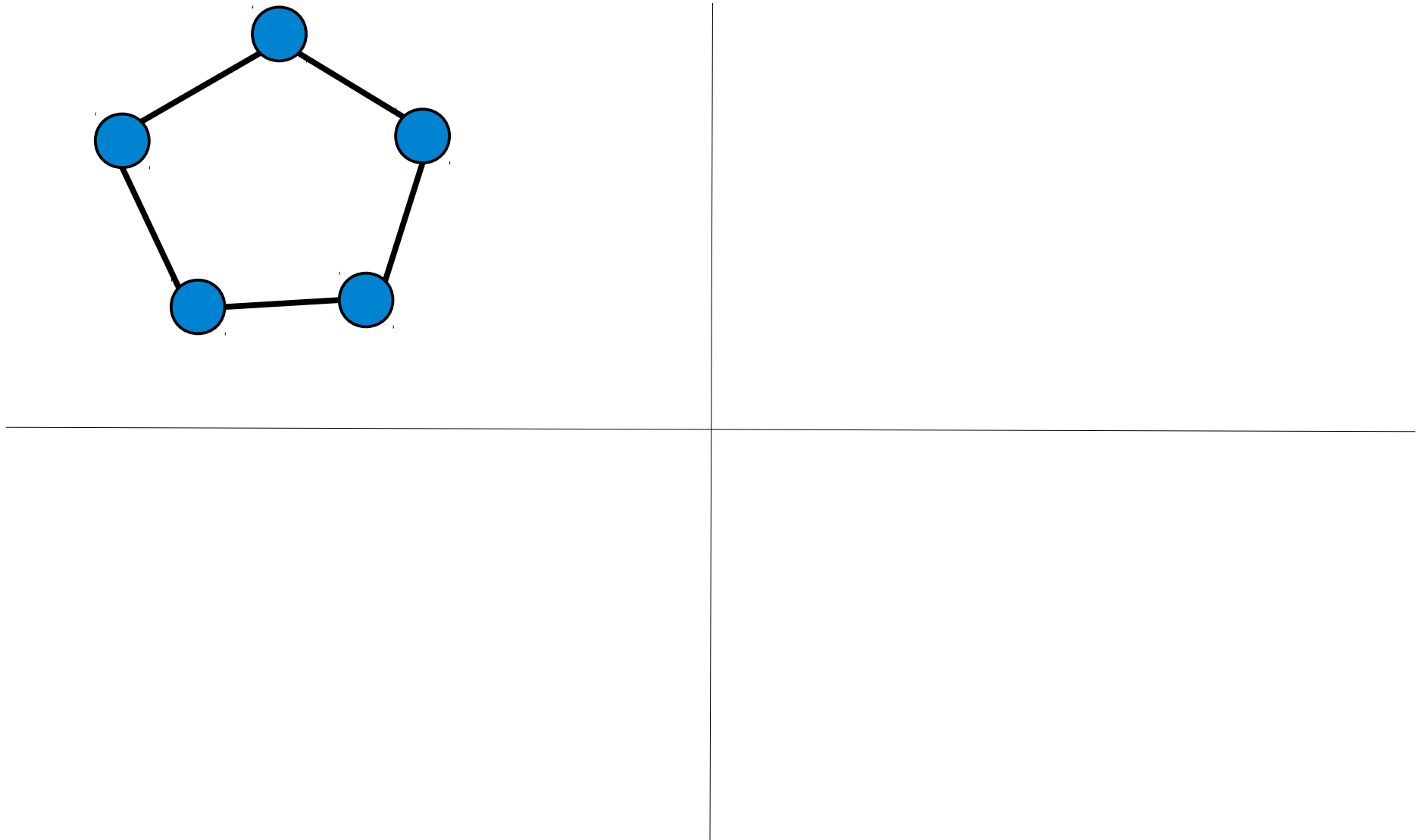
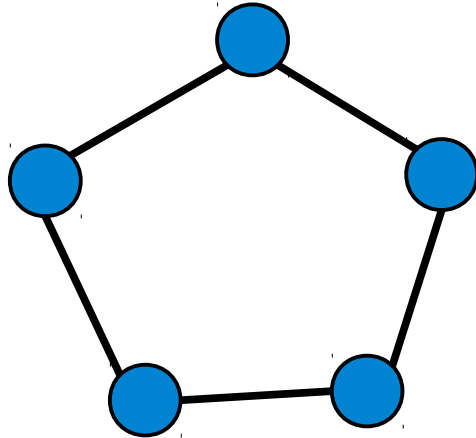
How are graphs used in philosophy?

- Representing beliefs
 - Nodes: Propositions
 - Edges: Logical or probabilistic dependence
- Social and political interactions
 - Nodes: People
 - Edges: Political or social interaction
- Science
 - Nodes: Scientists
 - Edges: Lines of communication

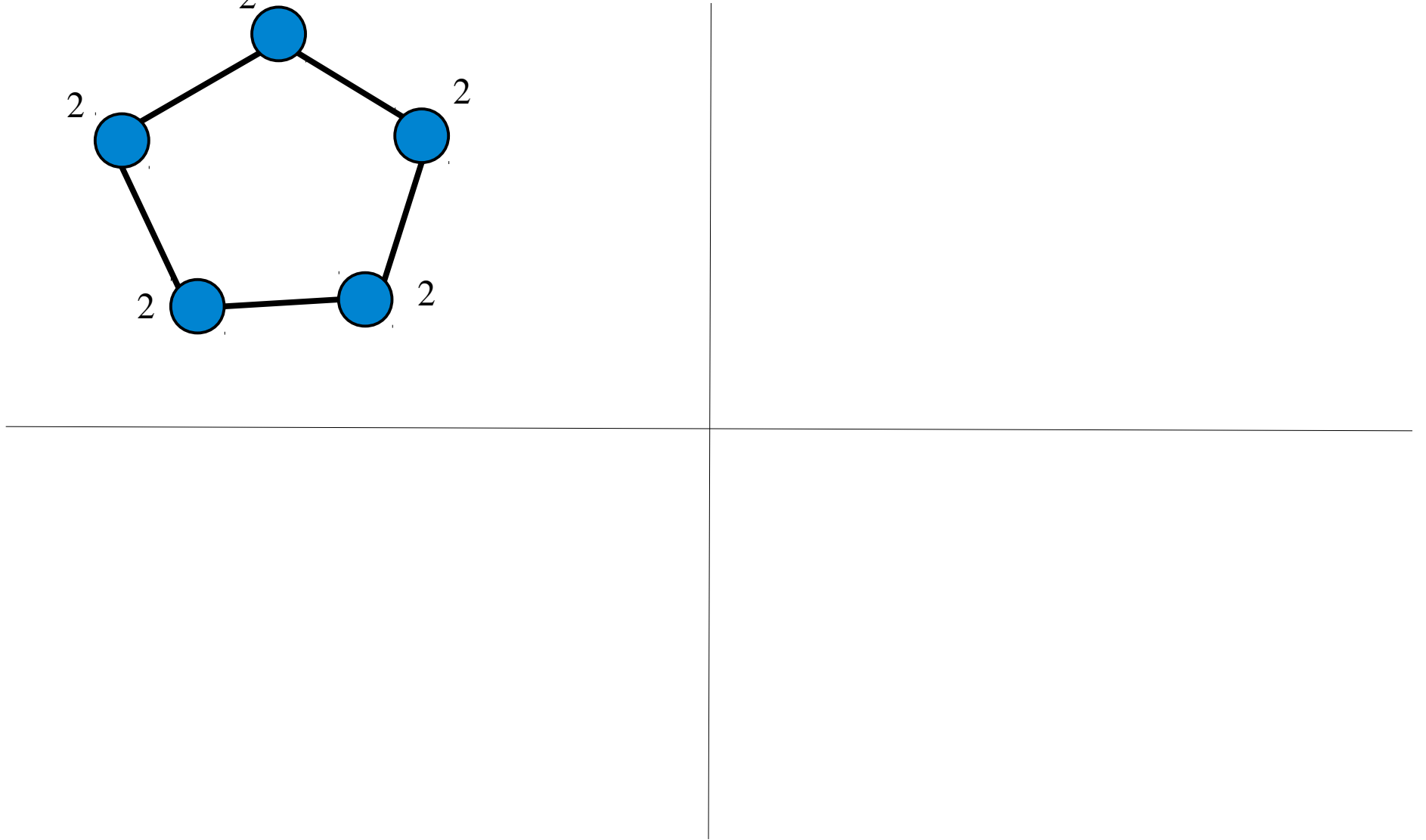
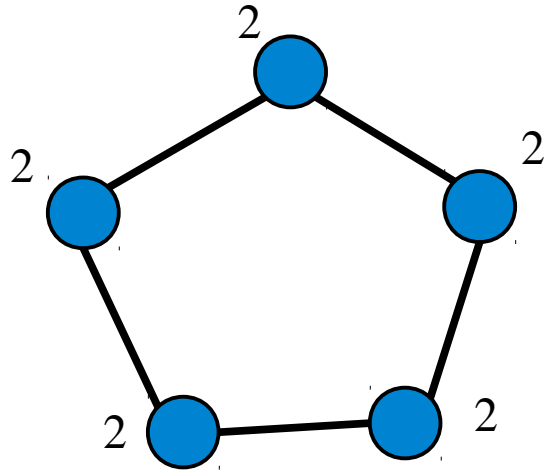
Degree distribution

“On average, everyone has two friends.”

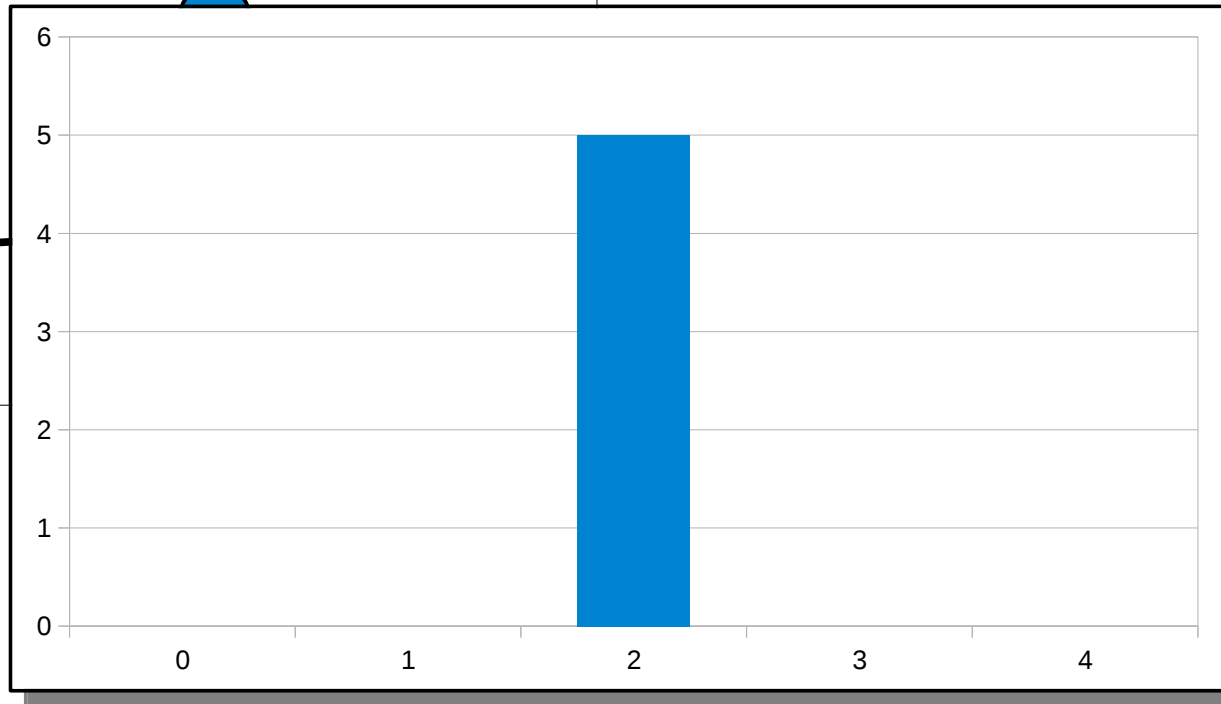
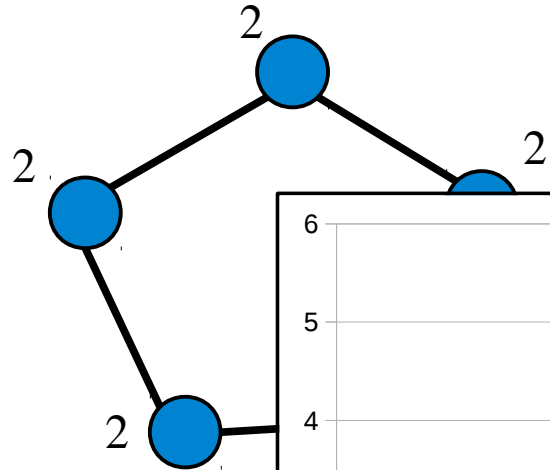
Degree distribution



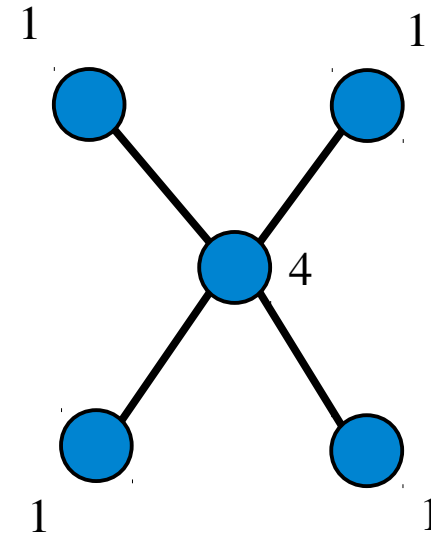
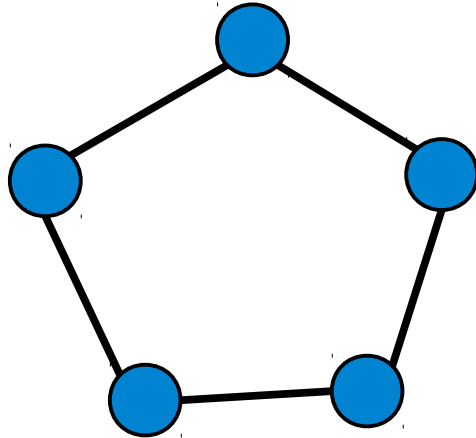
Degree distribution



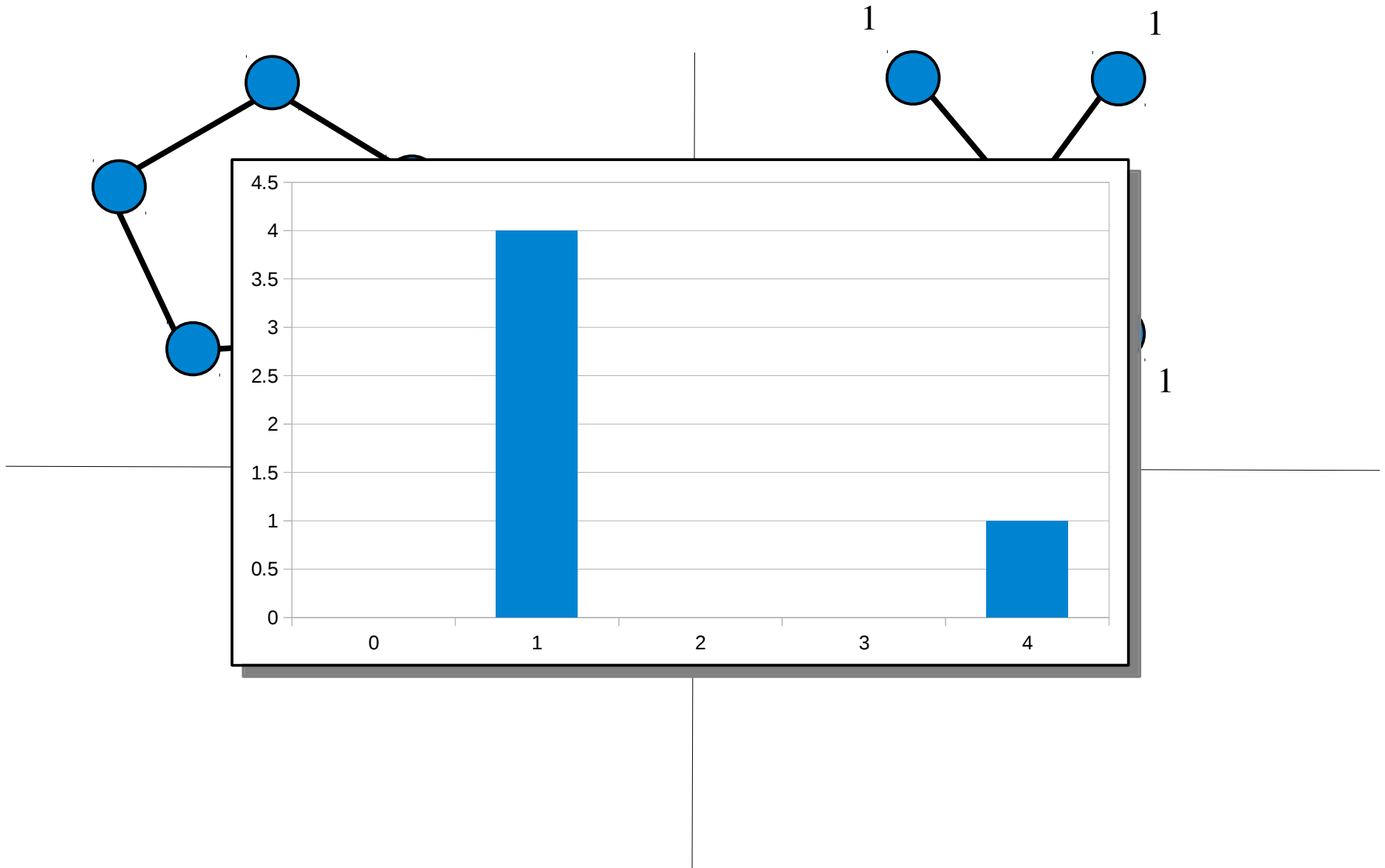
Degree distribution



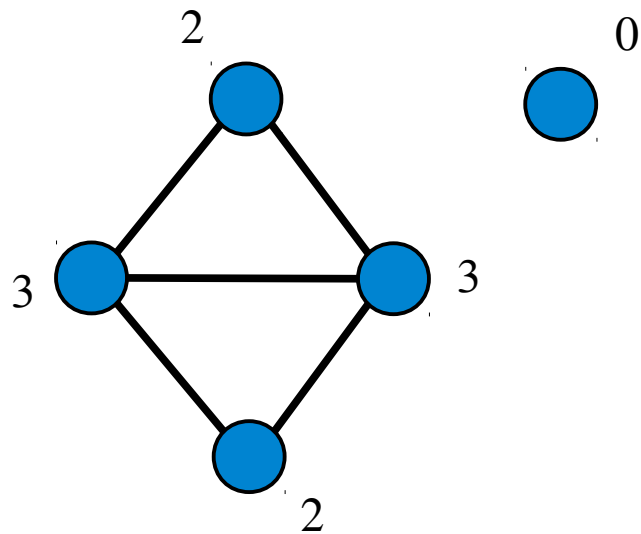
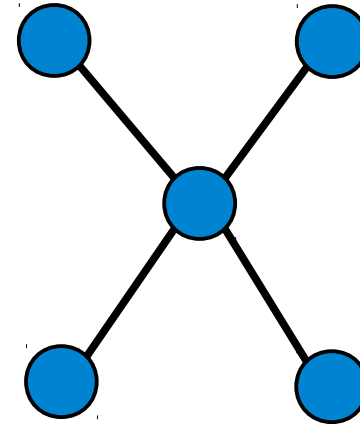
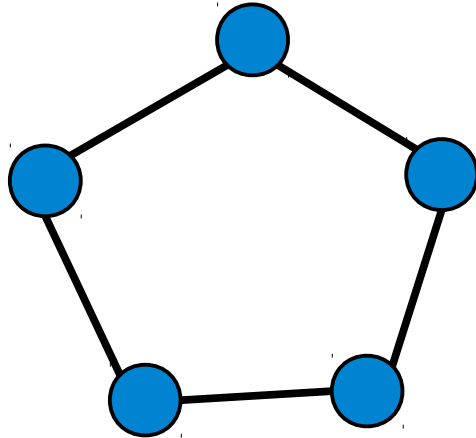
Degree distribution



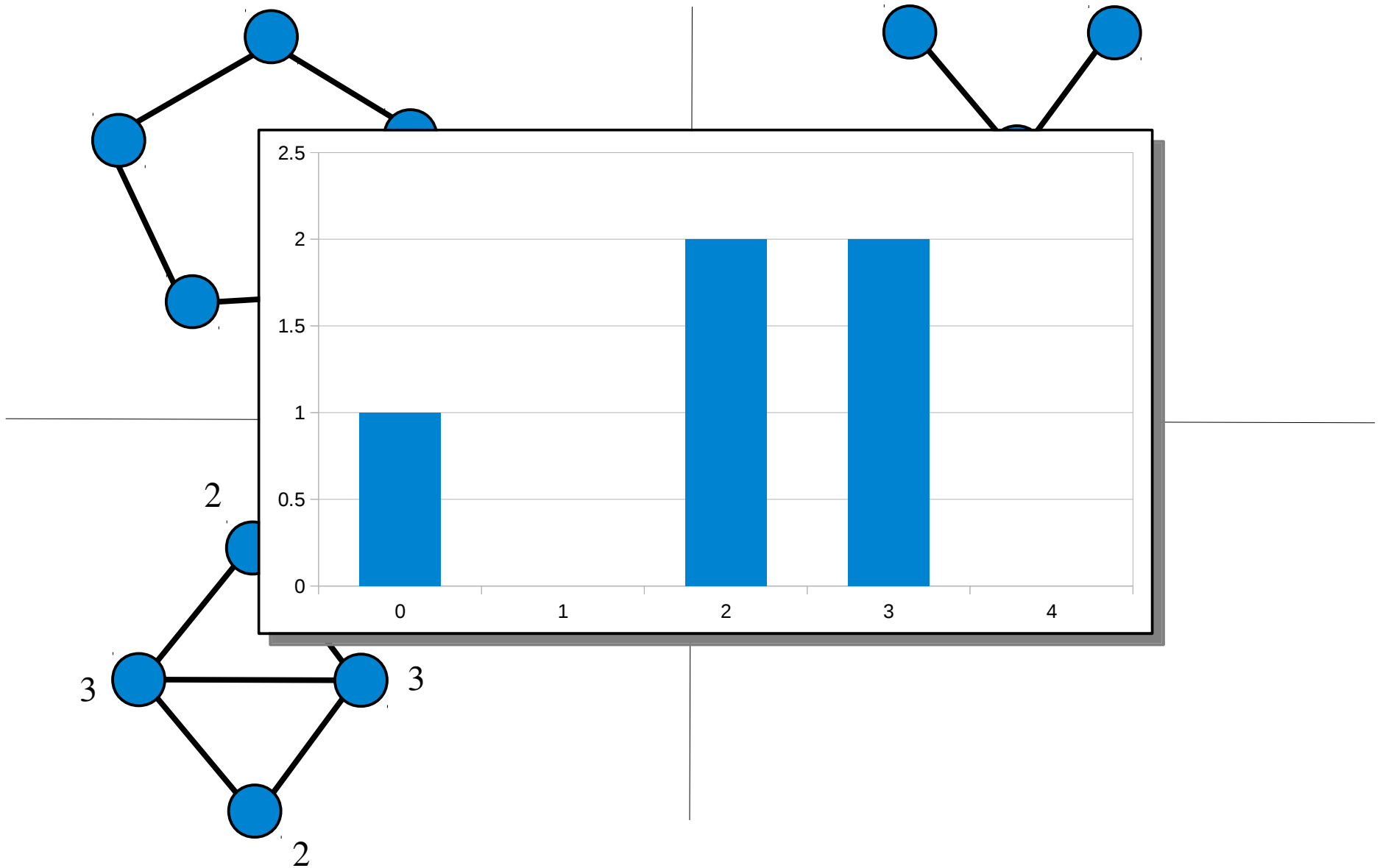
Degree distribution



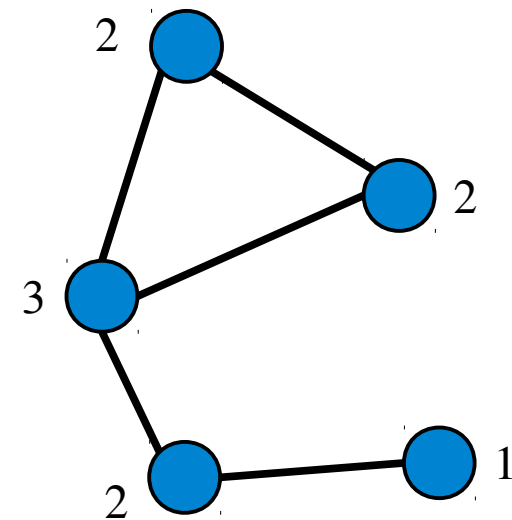
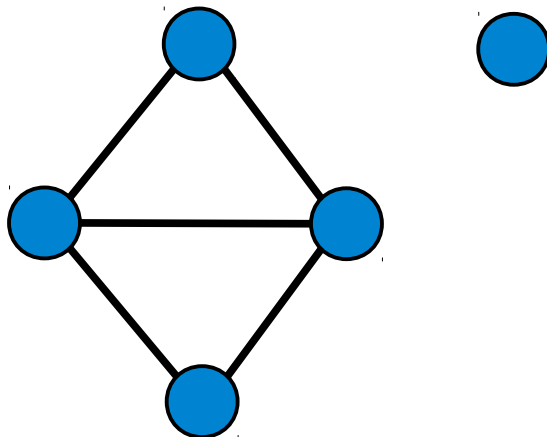
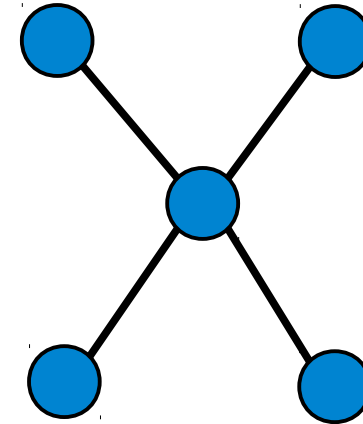
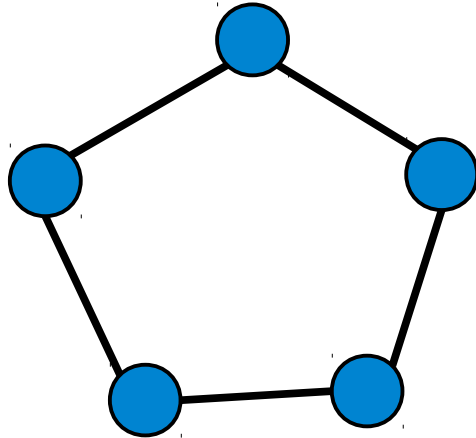
Degree distribution



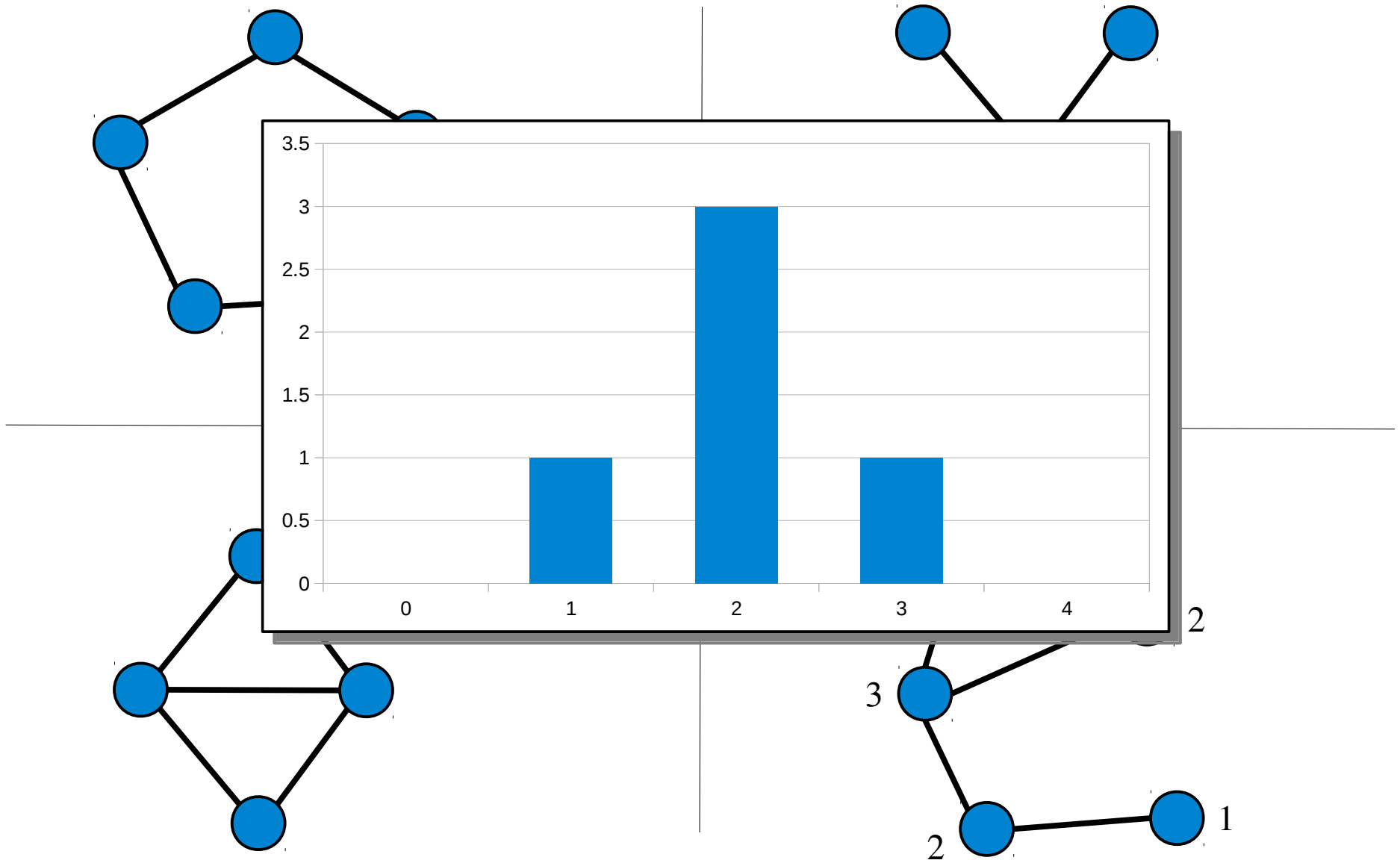
Degree distribution



Degree distribution



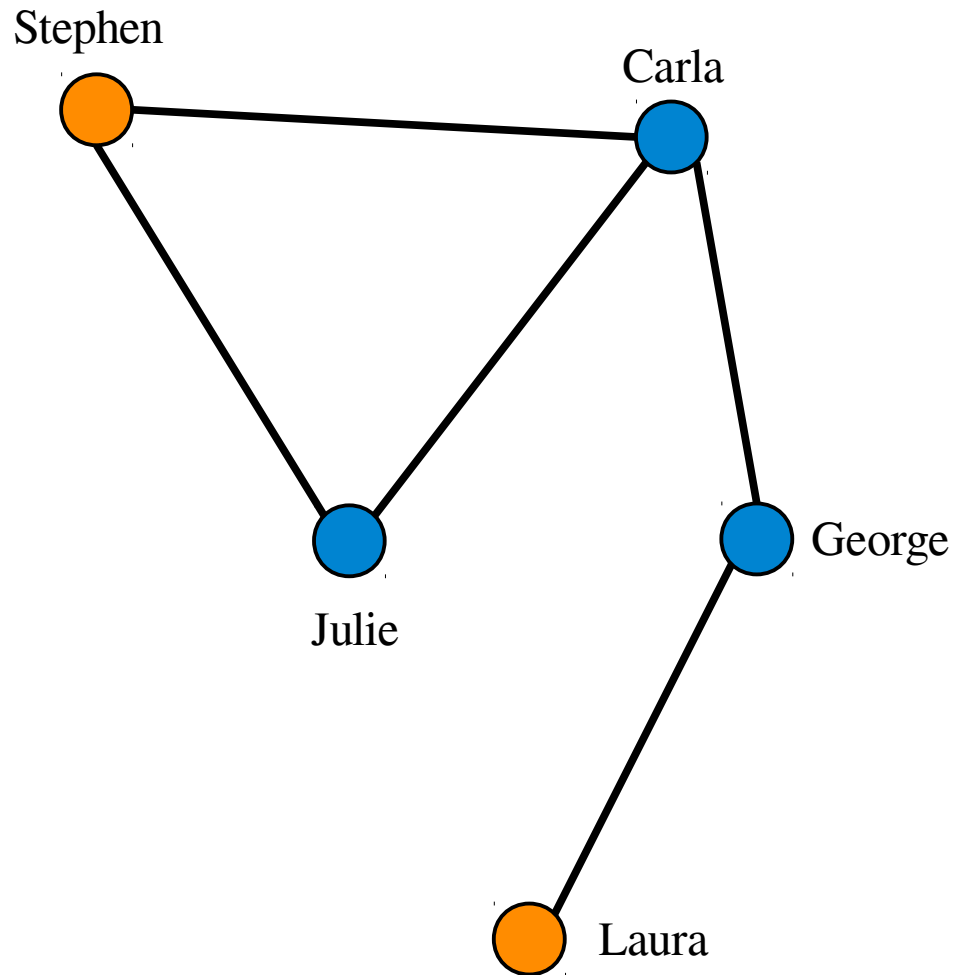
Degree distribution



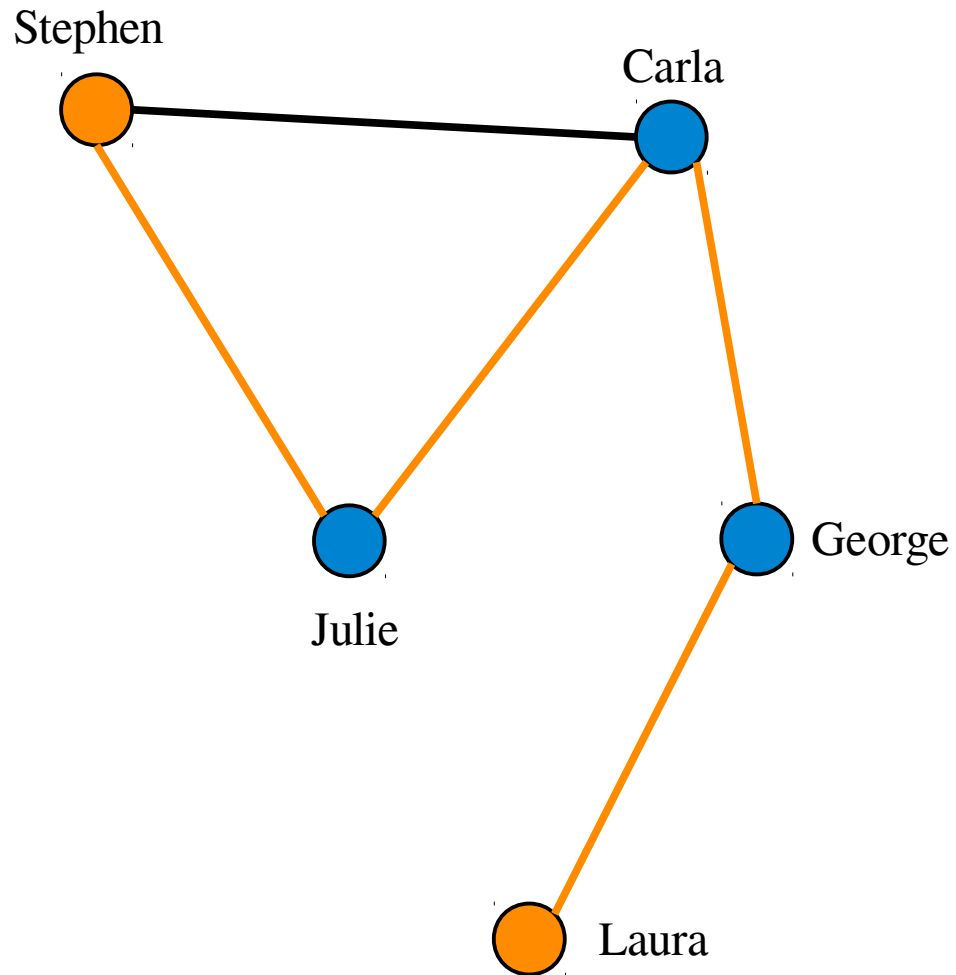
Path length

Six degrees of separation

Path length

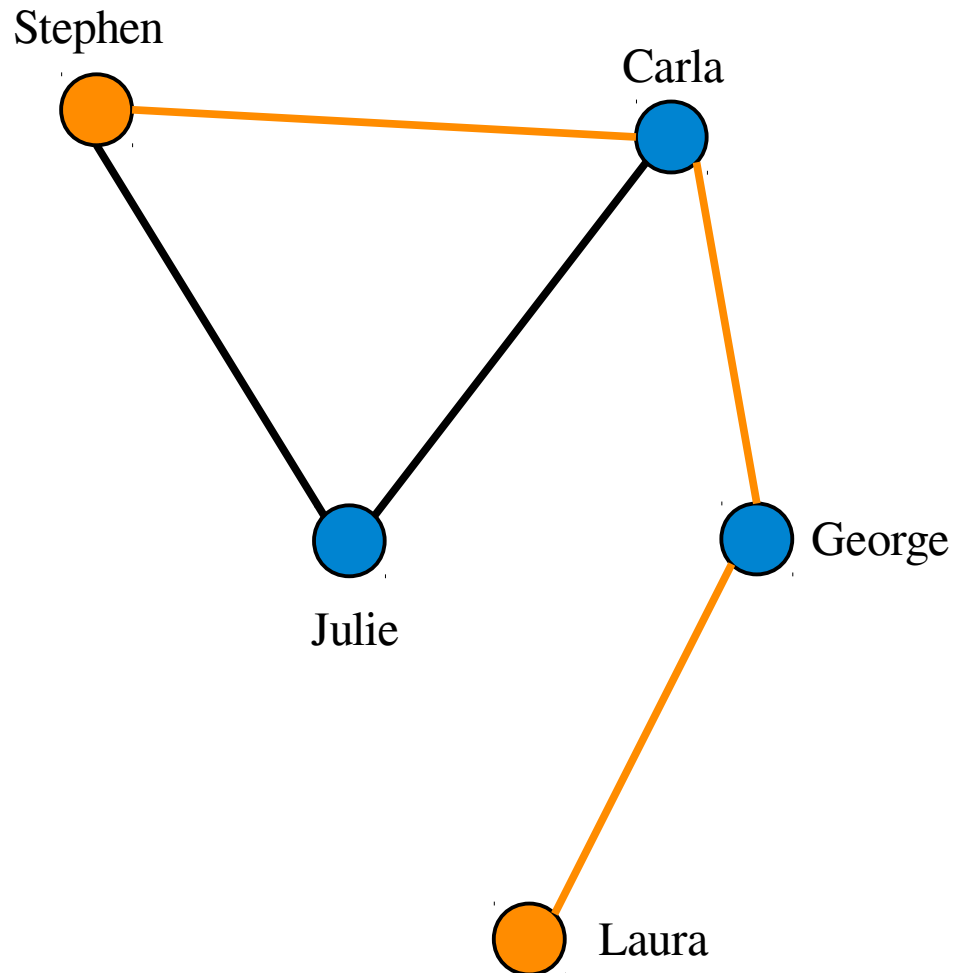


Path length



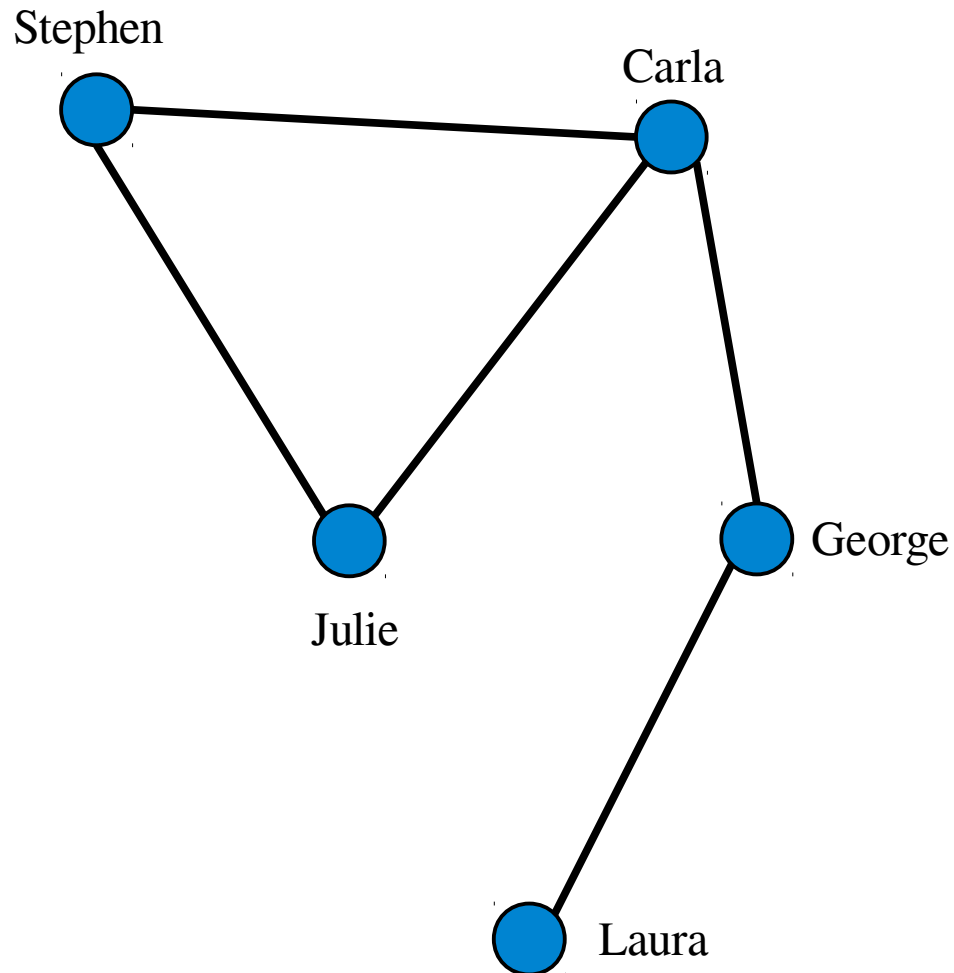
This path length: 4

Path length



Last path length: 4
This path length: 3

Mean path length



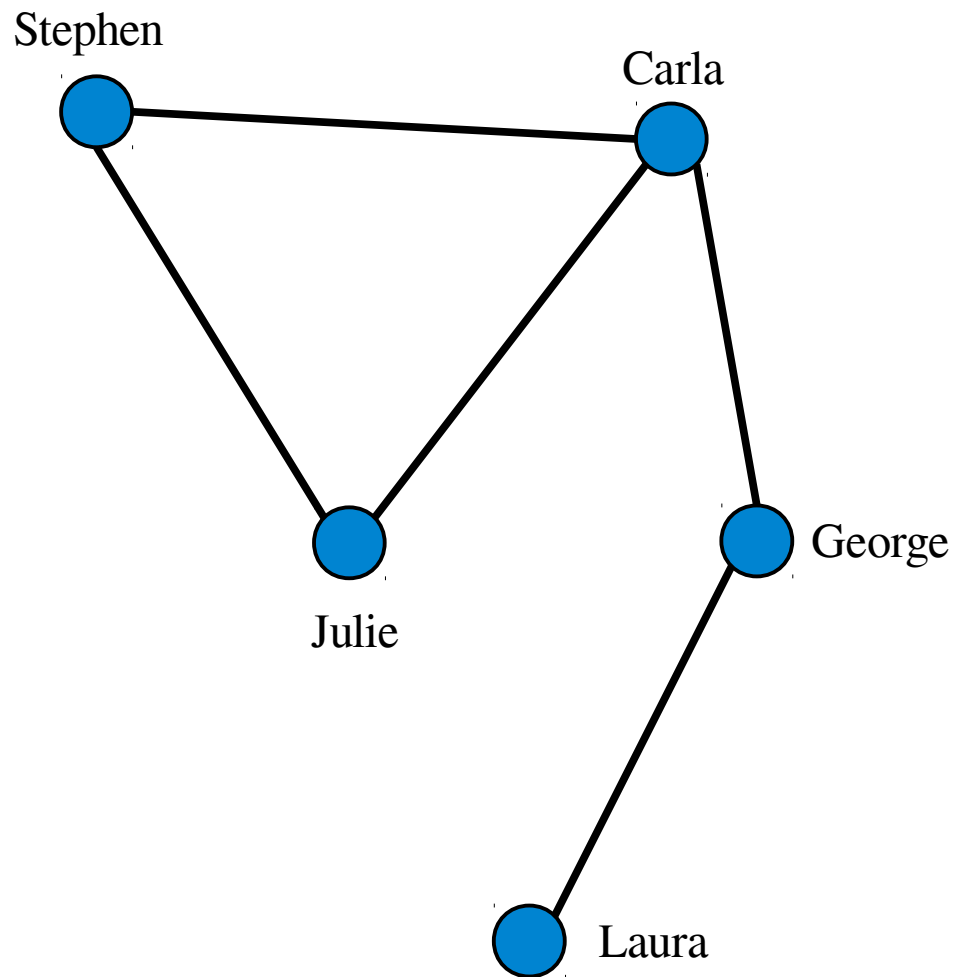
- 1 – (Stephen, Carla)
- 1 – (Stephen, Julie)
- 2 – (Stephen, George)
- 3 – (Stephen, Laura)
- 1 – (Carla, Julie)
- 1 – (Carla, George)
- 2 – (Carla, Laura)
- 2 – (Julie, George)
- 3 – (Julie, Laura)
- 1 – (George, Laura)

Average: 1.7

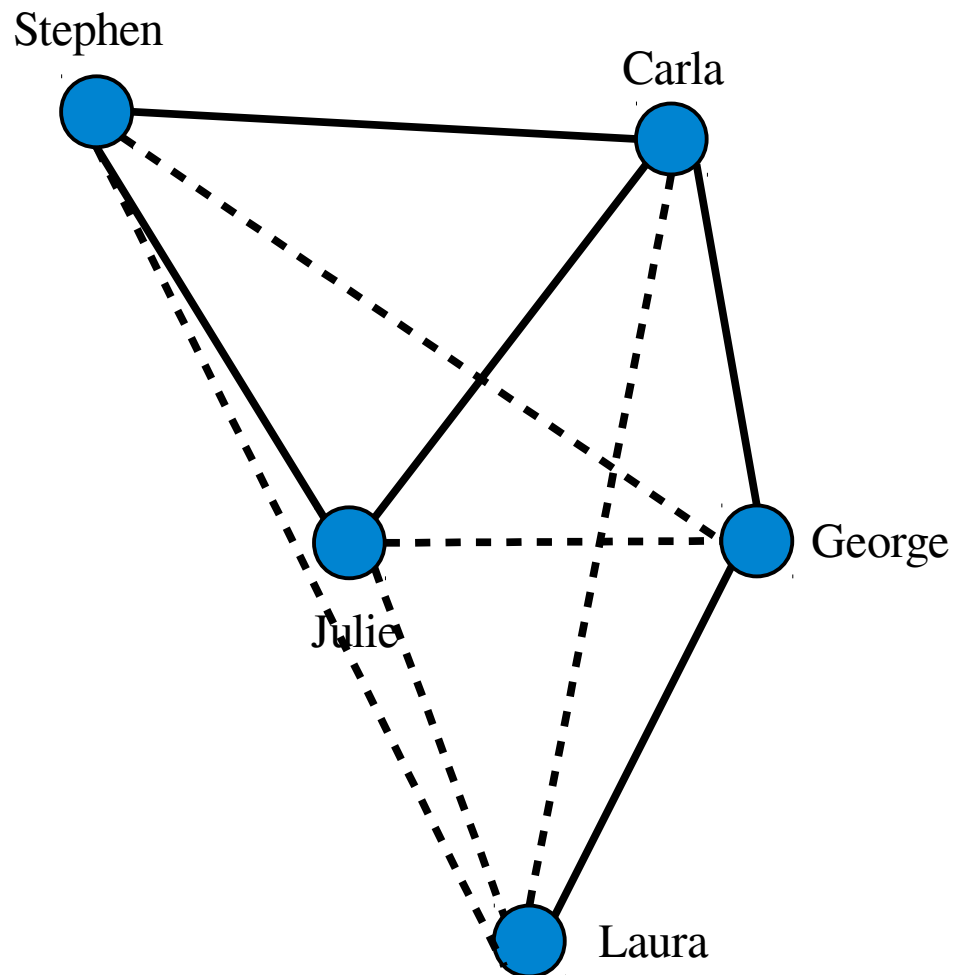
Density

How “connected” is the network?

Density



Density



5 – Solid

5 – Dotted

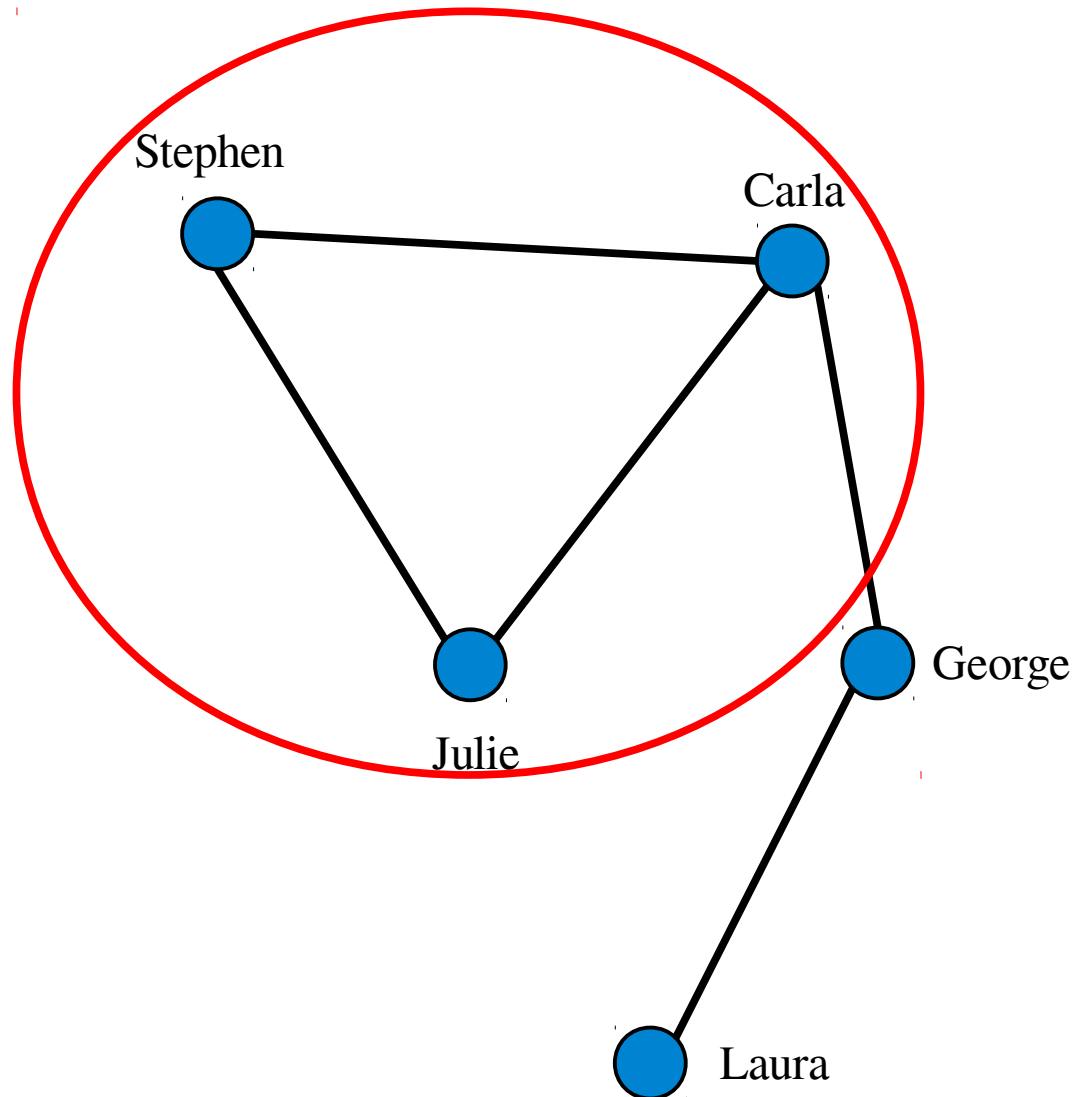
$$5 / (5 + 5) = \frac{1}{2}$$

Density: $\frac{1}{2}$

Cliques

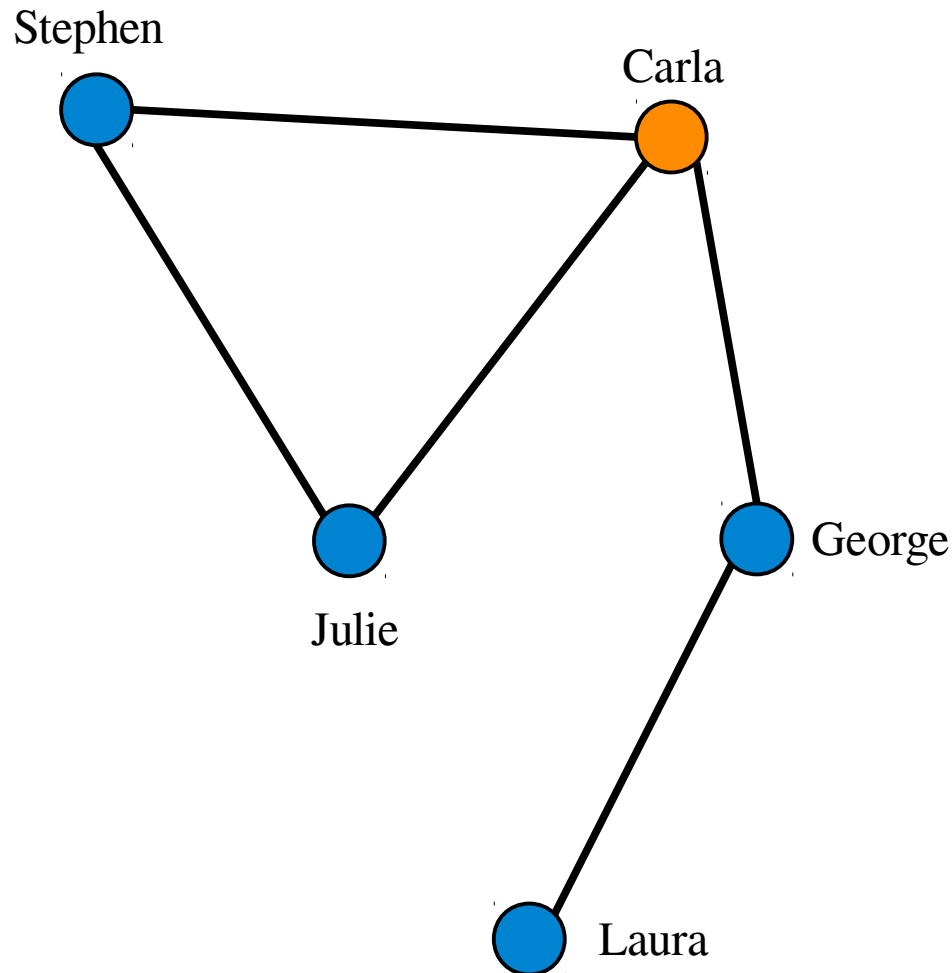
How clique-ish is the network?

Cliques version 1



Count the size and number of groups (>3) where everyone is friends with everyone else

Cliques version 2 (clustering)

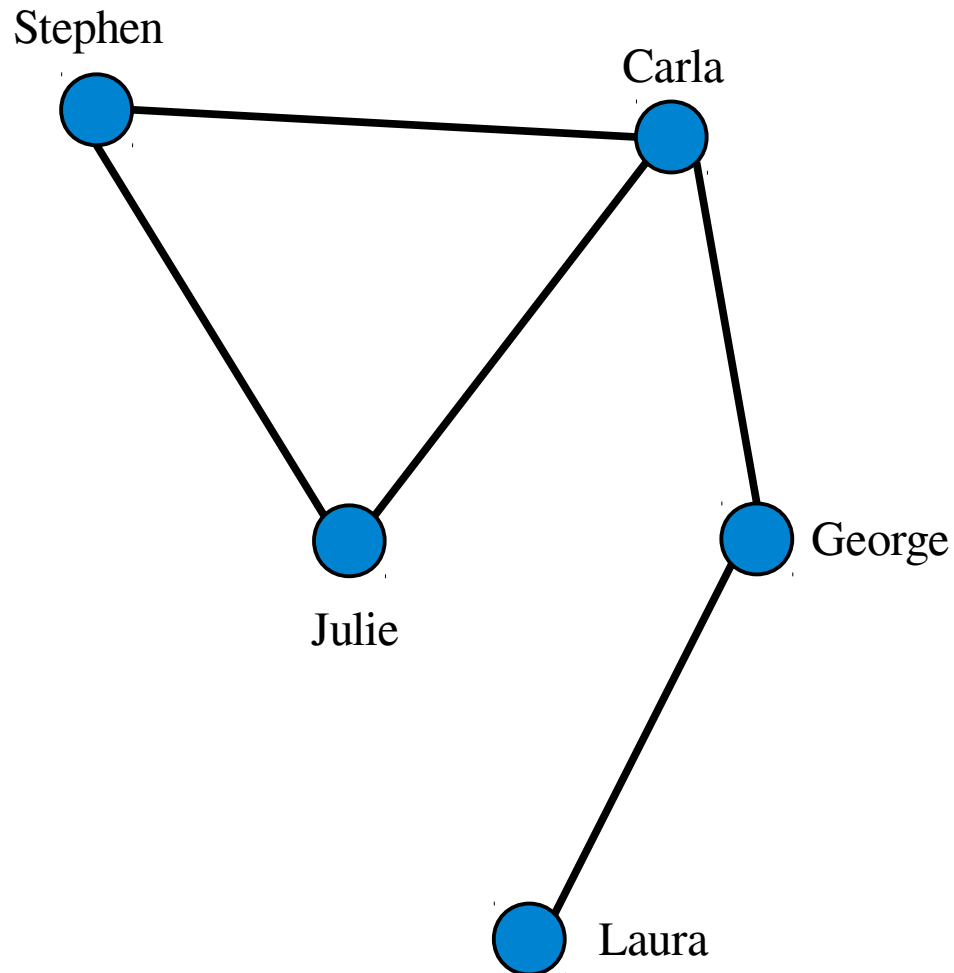


How many of my friends are friends with each other?

Yes – (Stephen, Julie)
No – (Stephen, George)
No – (Julie, George)

Carla's clustering = $1/3$

Cliques version 2 (clustering)



1/1 Stephen

1/3 Carla

1/1 Julie

0/1 George

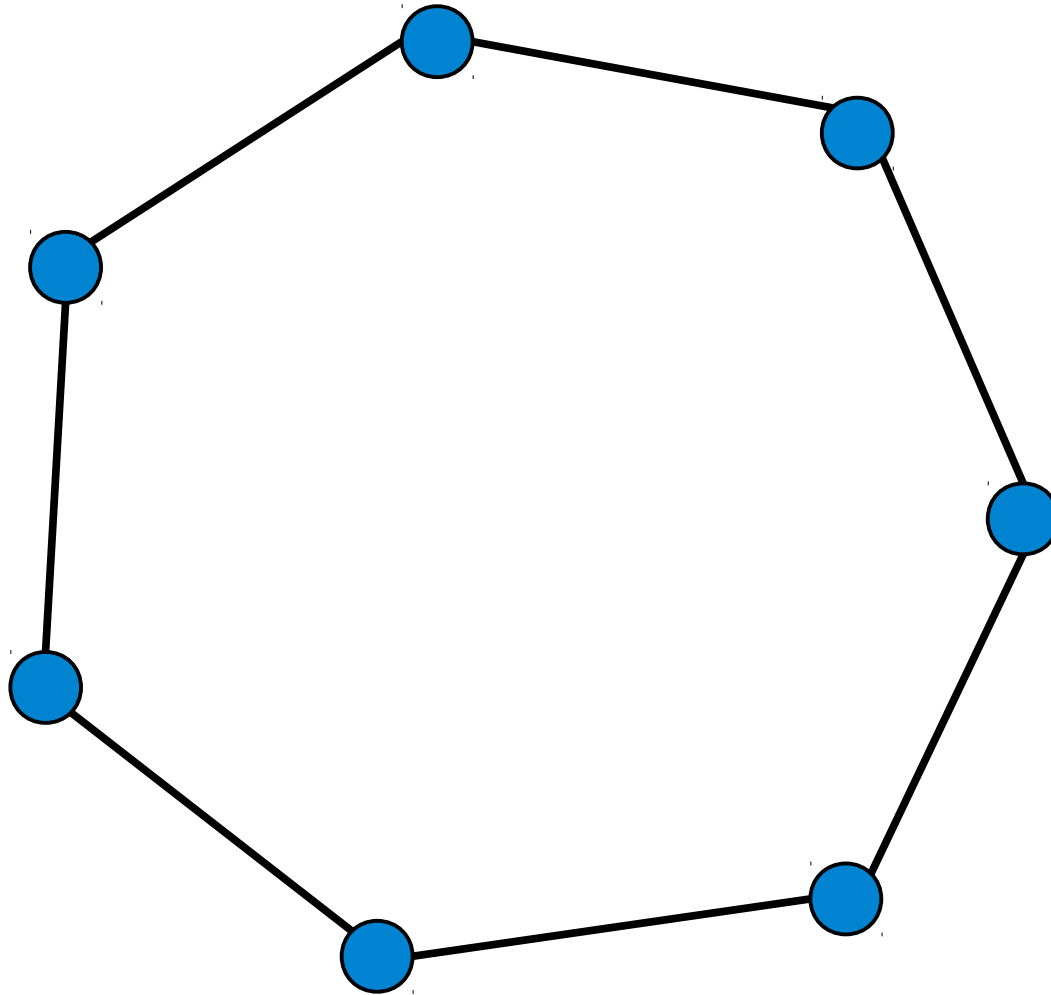
0/0 Laura

3/6 Clustering coefficient

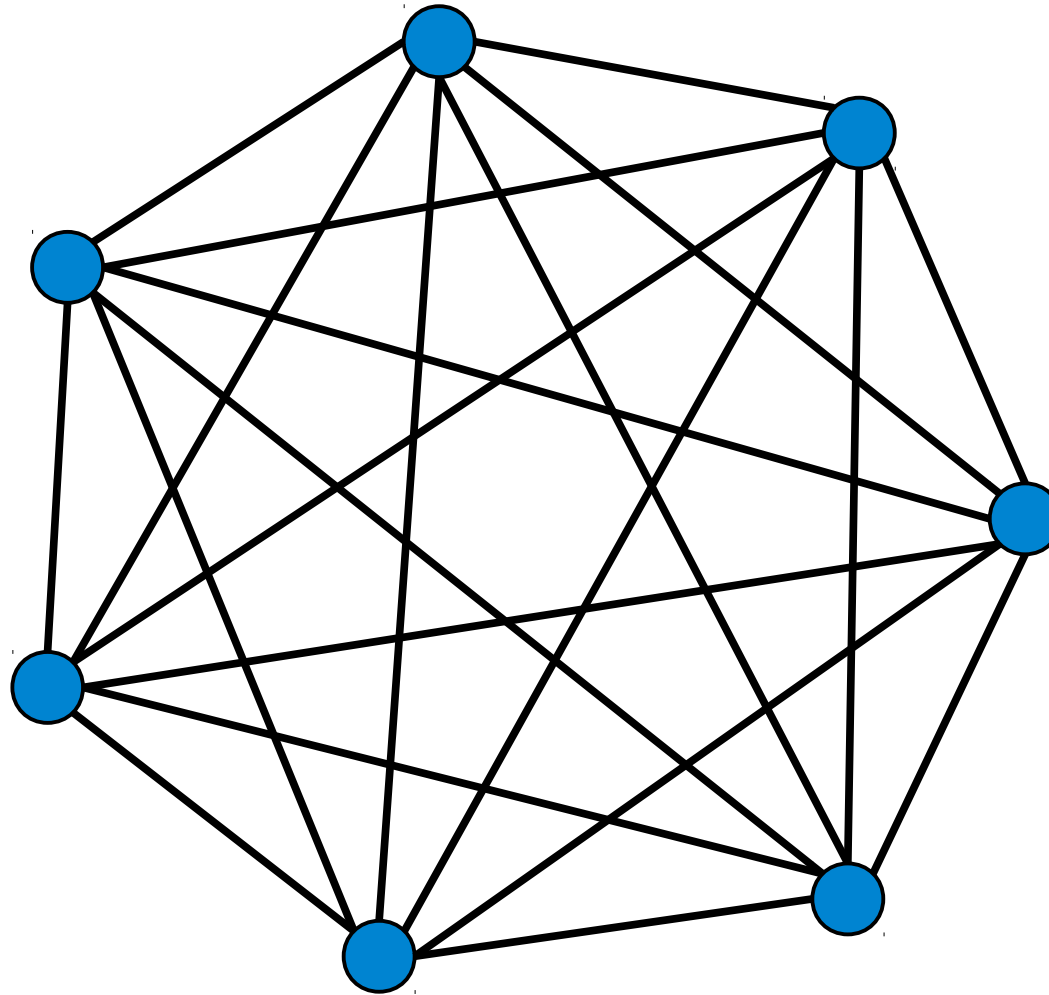
Important networks

Some particular types of networks re-occur often

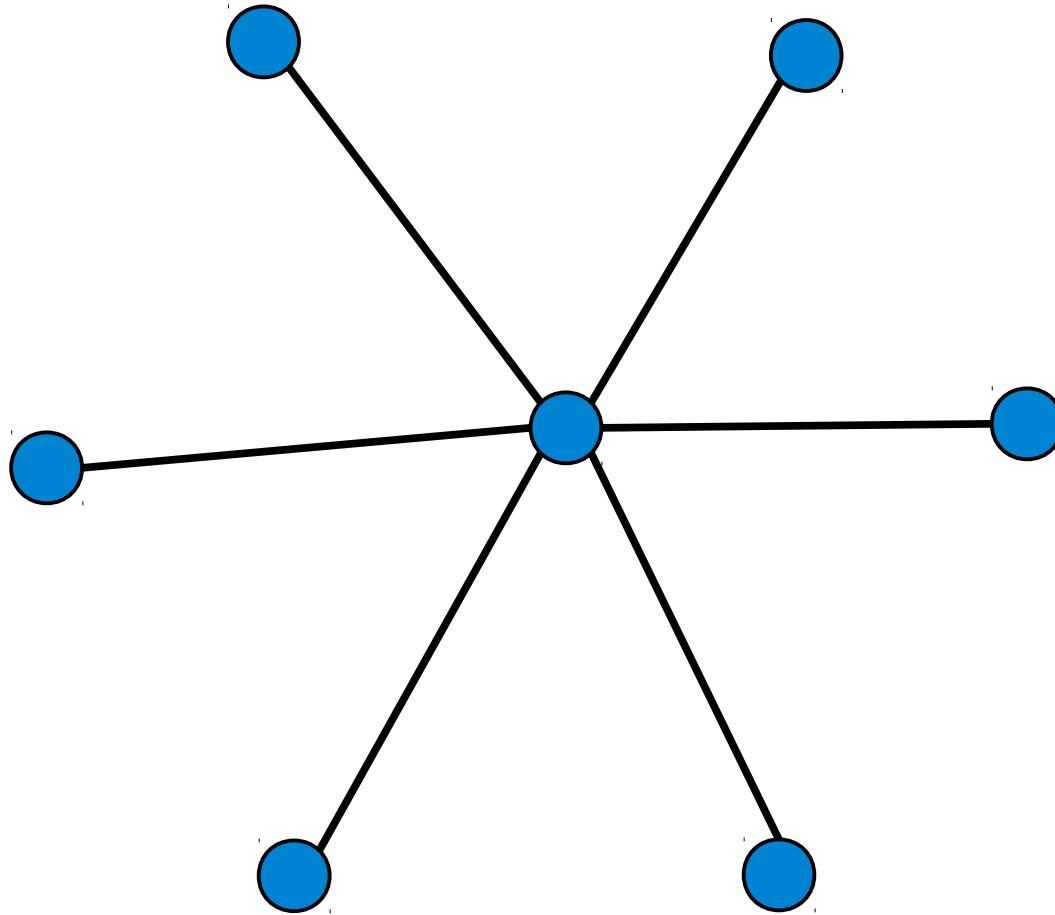
Cycle



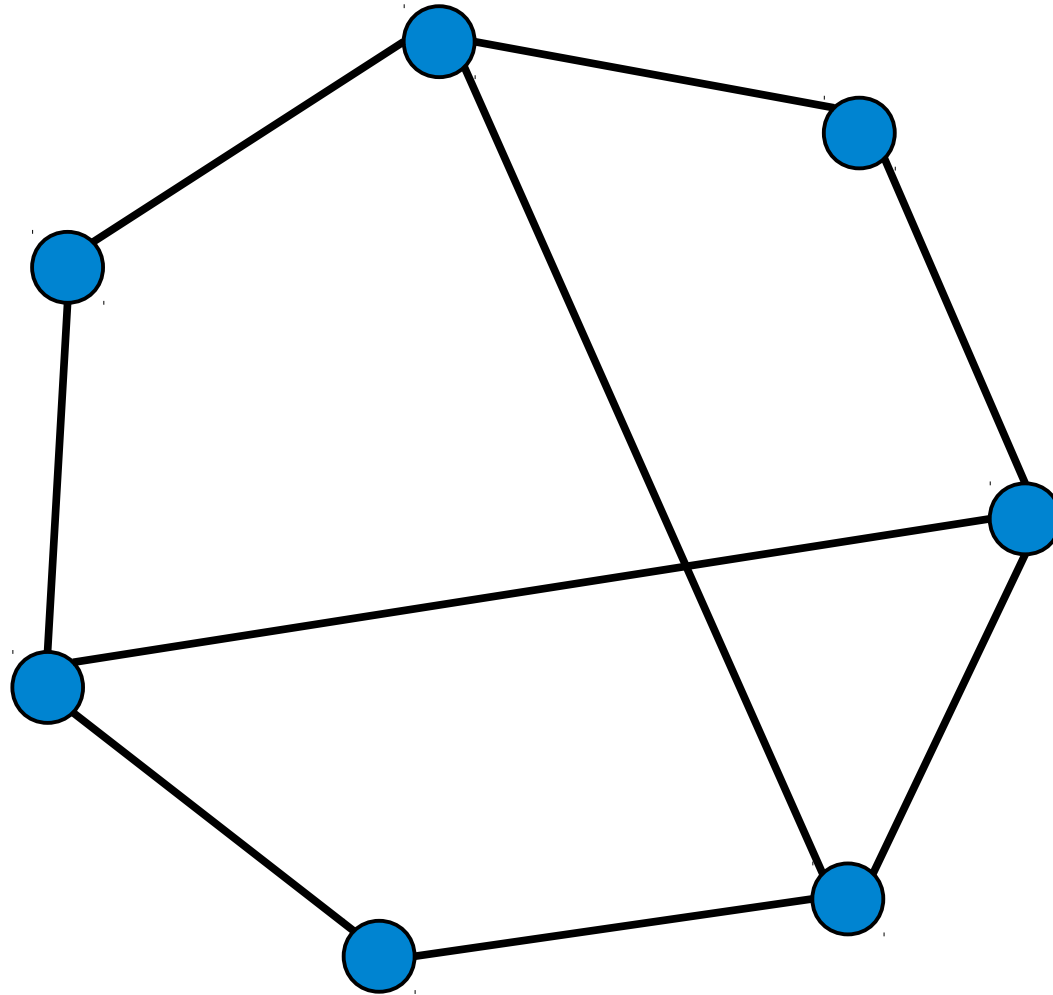
Complete graph



Star



Small world



Conclusions

- Networks allow us to represent commonalities between many different types of social relationships
- Can be extended to other sciences easily
- Gives a common framework to express certain types of results
 - Constraints on possibilities
 - Relationships among various properties (like MPL, degree, etc.)

Application to philosophy

- Ethics and social evolution (tomorrow)
 - How does the presence of social networks effect the emergence of ethical judgments?
 - Do our current ethical norms depend on a certain type of social network structure?
- Epistemology and Philosophy of Science
 - Does network structure effect learning?
 - What networks will arise “endogenously?”