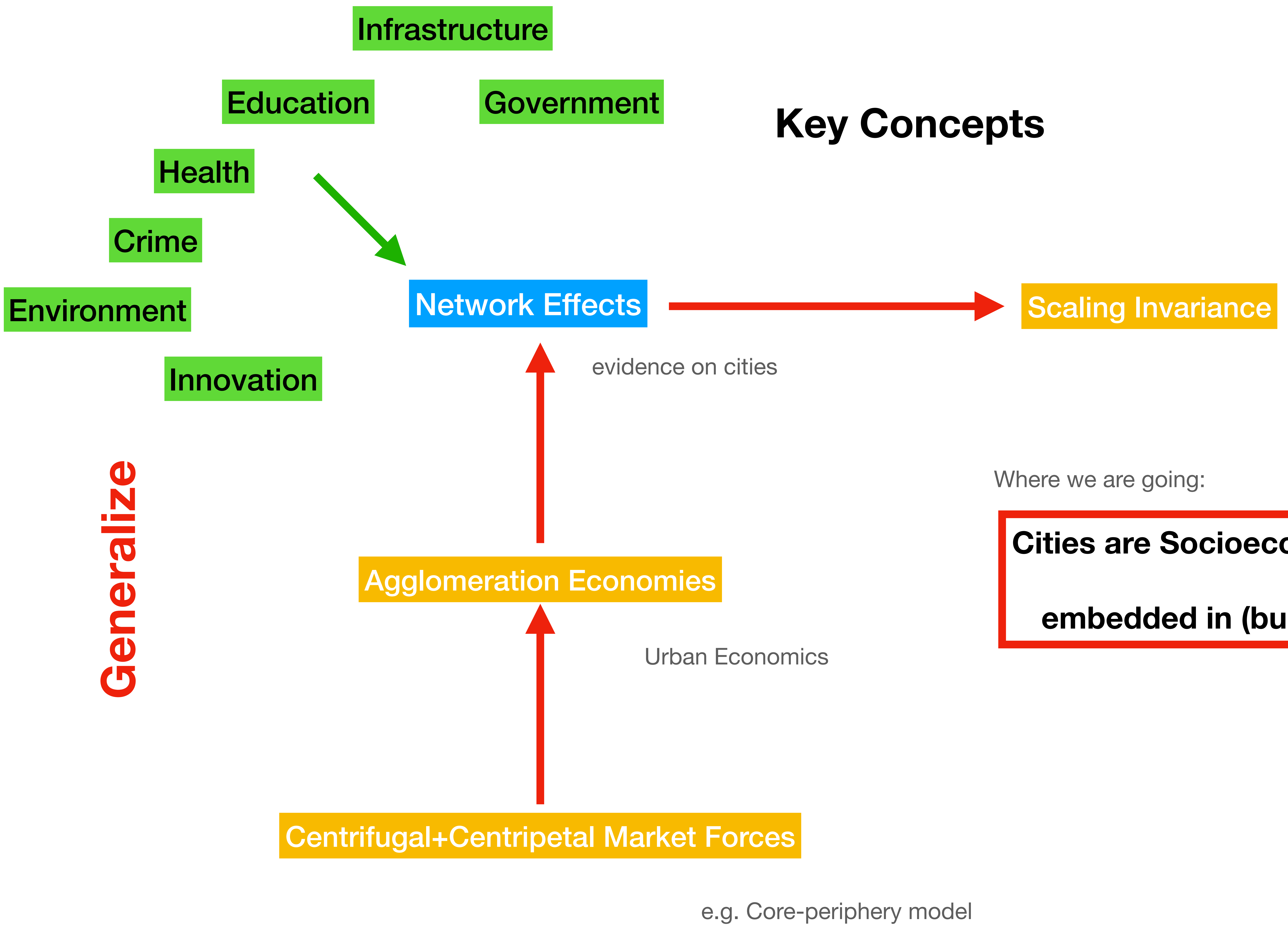
Lecture 5

Network Models of Cities

5.1 What are networks? Network Effects and Metcalfe's Law

IUS 3.2.1

Key Concepts



Where we are going:

Cities are Socioeconomic Networks

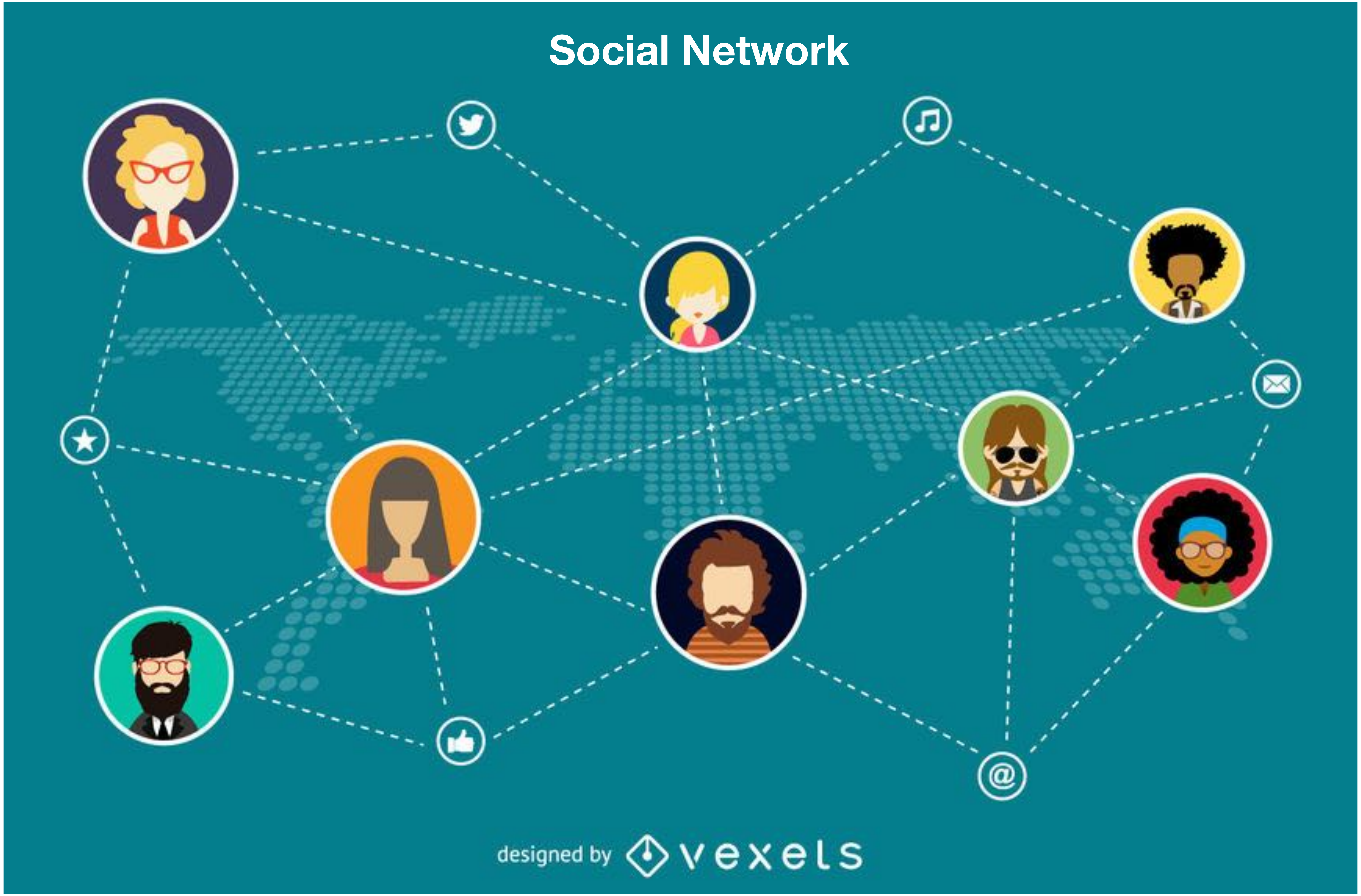
embedded in (built) Space-Time

Network models of cities

Basic Concepts:

What is a Network?

Network Effects!



A simplified scheme of who interacts with whom

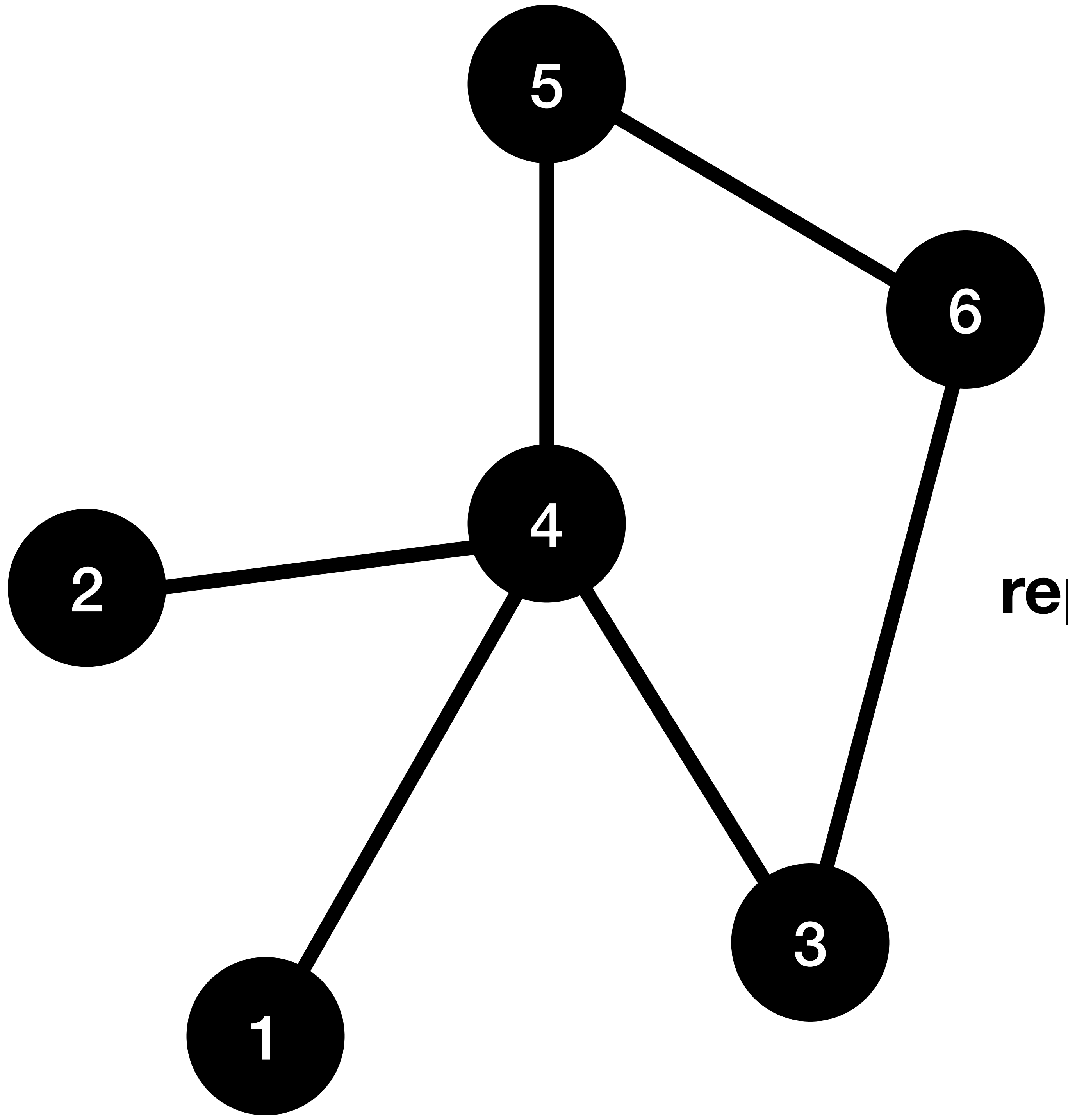
A physical network, abstracted

credit: Geoff Boeing

python software: OSMnx

Modena, Italy

A network is a “graph”



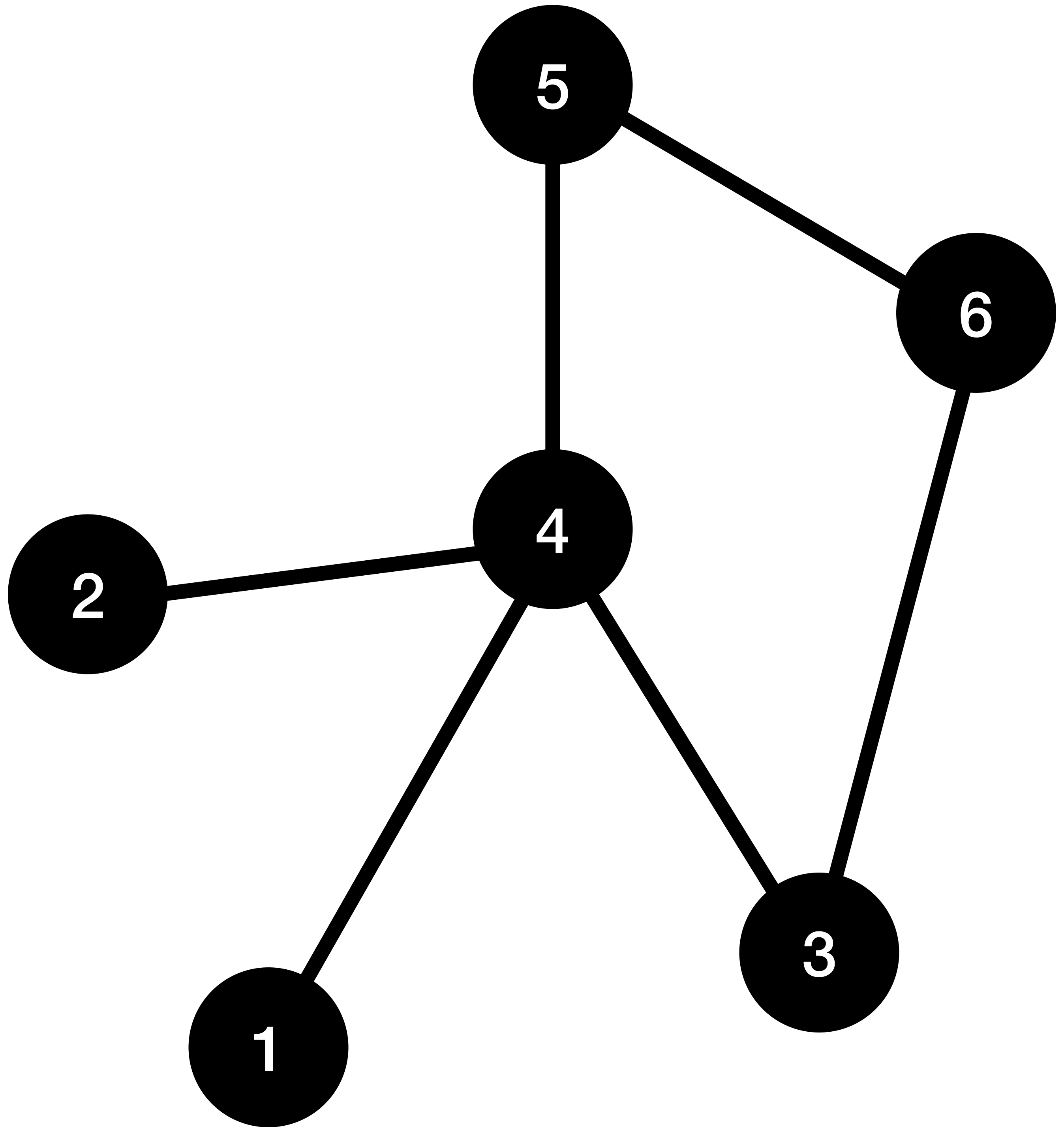
representation

$$F_{ij} = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \end{pmatrix}$$

“Adjacency Matrix”

Some Basic Network Concepts:

Degree of a Node:



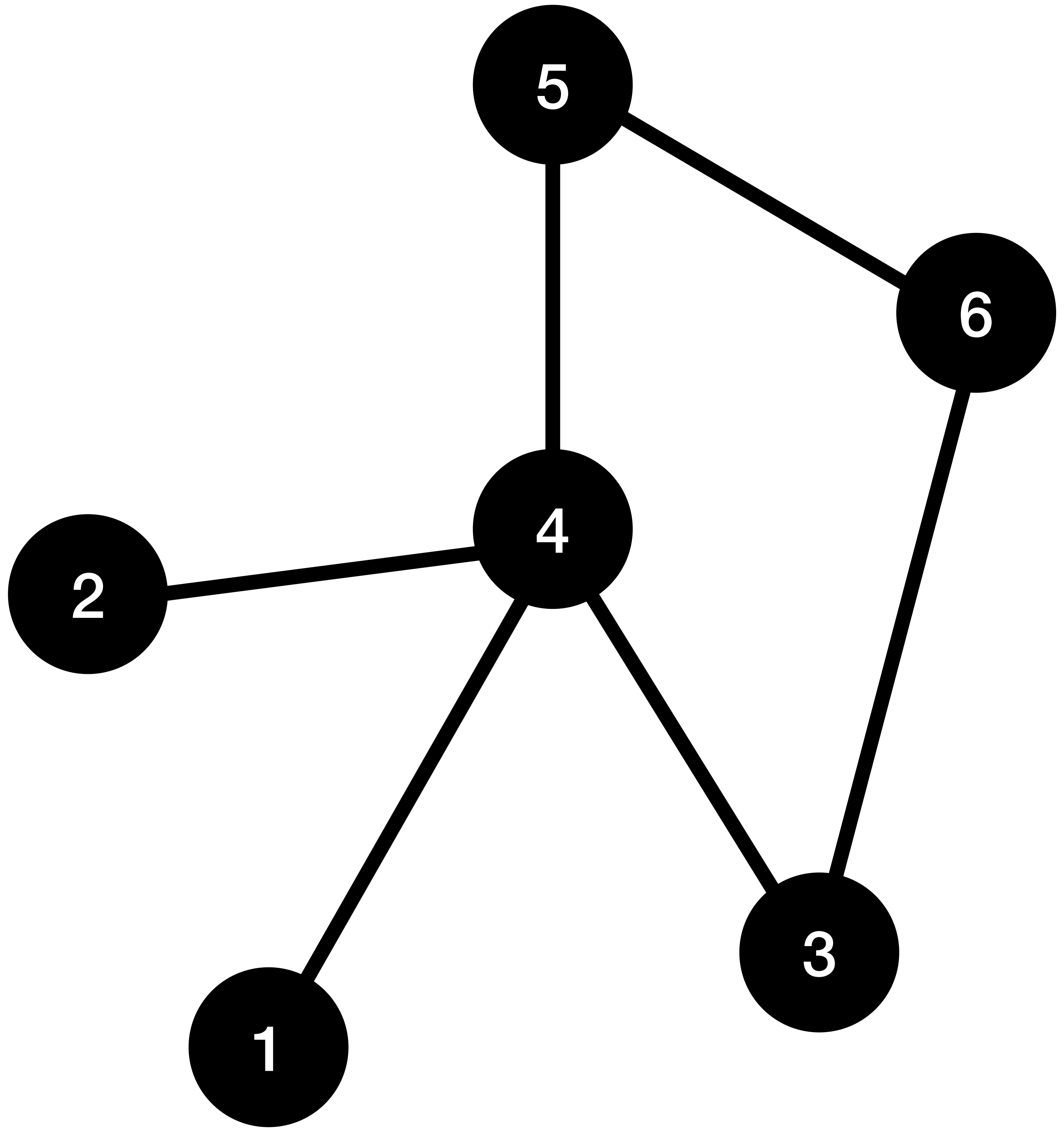
$$F_{ij} = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \end{pmatrix}$$

Node 4 has degree 4

Node 5 has degree 2

Node 6 has degree 2 …

Some Basic Network Concepts:



How many *possible* unique connections (all to all)?

6 nodes:

Node 1 connects to 2,3,4,5,6 = 5 connections

Node 2 connects to 3,4,5,6 = 4 connections

Node 3 connects to 4,5,6 = 3 connections

Node 4 connects to 5,6 = 2 connections

Node 5 connects to 6 = 1 connections

=15 connections

For a graph with N nodes there can be: $$\frac{N(N-1)}{2}$$

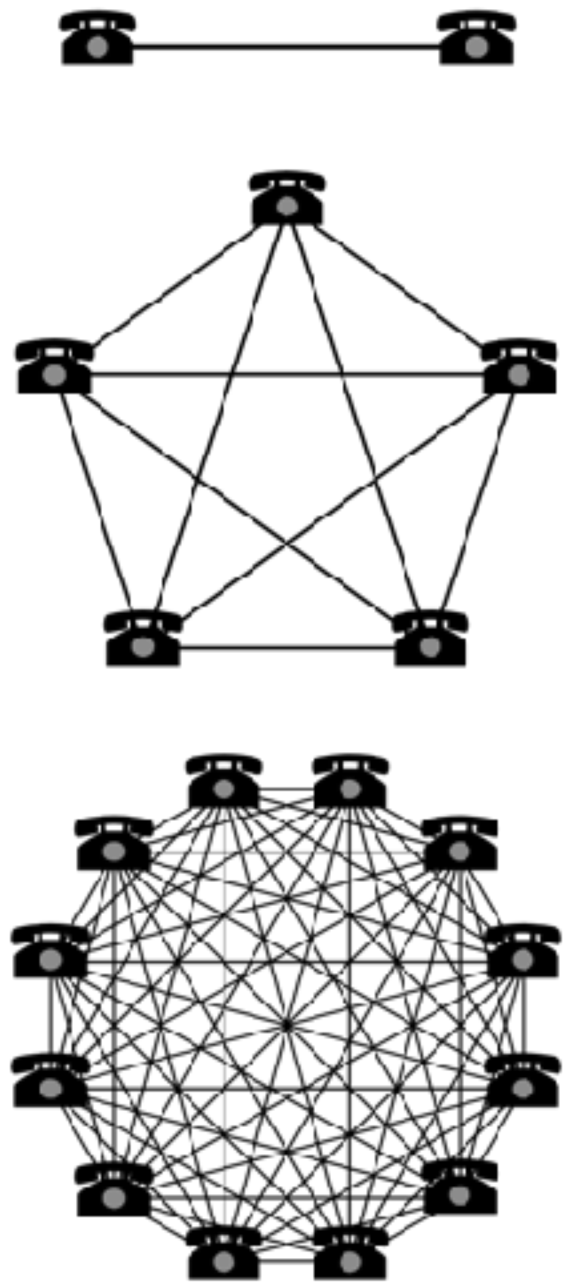
Graph Connectivity ~ N^2 Number of Nodes

Some Basic Network Concepts:

Metcalfe's law

From Wikipedia, the free encyclopedia

Metcalfe's law states the effect of a telecommunications network is proportional to the square of the number of connected users of the system (n^2). First formulated in this form by George Gilder in 1993,[1] and attributed to Robert Metcalfe in regard to Ethernet, Metcalfe's law was originally presented, c. 1980, not in terms of users, but rather of "compatible communicating devices" (for example, fax machines, telephones, etc.).[2] Only later with the globalization of the Internet did this law carry over to users and networks as its original intent was to describe Ethernet purchases and connections.[3] The law is also very much related to economics and business management, especially with competitive companies looking to merge with one another.



In 2015, Zhang, Liu and Xu extend Metcalfe's results utilizing data from Tencent, China's largest social network company, and Facebook. Their work showed that Metcalfe's law held for both, despite the difference in audience between the two sites; Facebook serving a worldwide audience and Tencent serving only Chinese users. The Metcalfe's functions of the two sites given in the paper were $V_{Tencent} = 7.39 \times 10^{-9} \times n^2$ and $V_{Facebook} = 5.70 \times 10^{-9} \times n^2$ respectively. [12]

Some Basic Network Concepts:

Network Effects

The “value” of a network is proportional to the number of connections, not nodes

Connections grow *faster than proportionally* to the number of nodes

$$Y \sim N^{\beta_M} \qquad \beta_M = 2$$

Metcalfe

Can this happen for cities? How can it not !