Modelling the origin of *polis* in Anatolia. From conceptual to computational approaches.

CAA 2019 - S11: Pre-Modern Cities and Complexity

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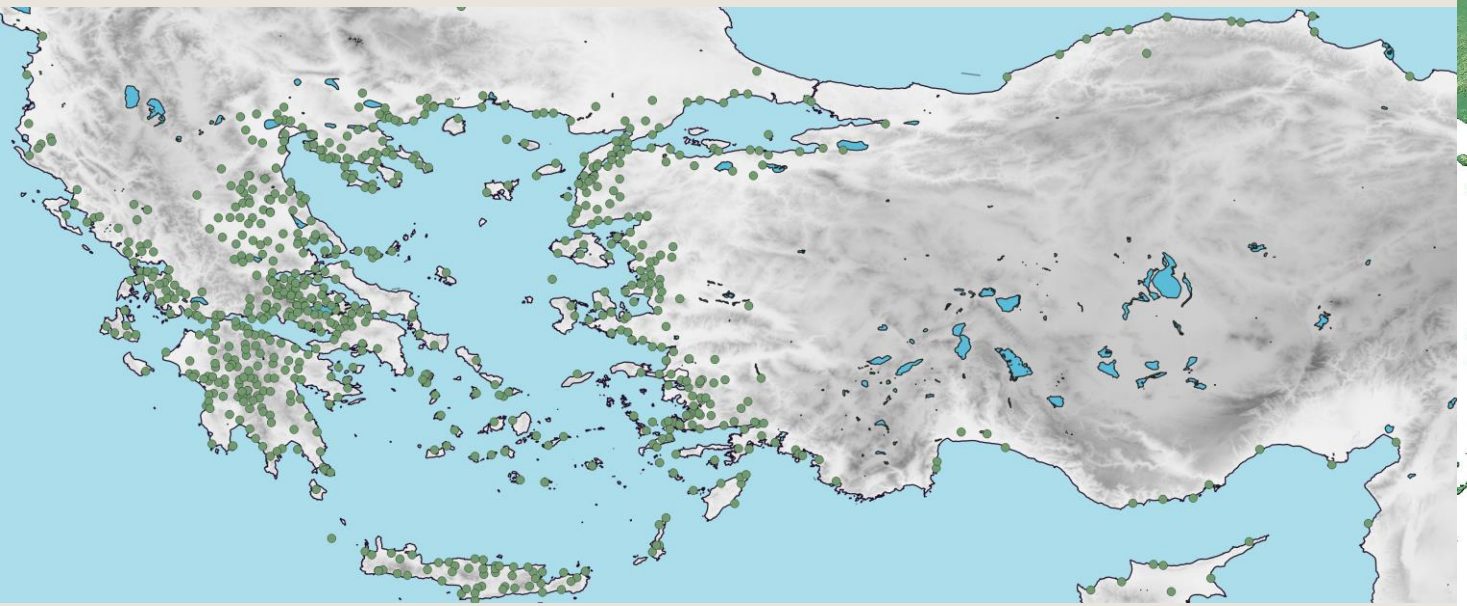
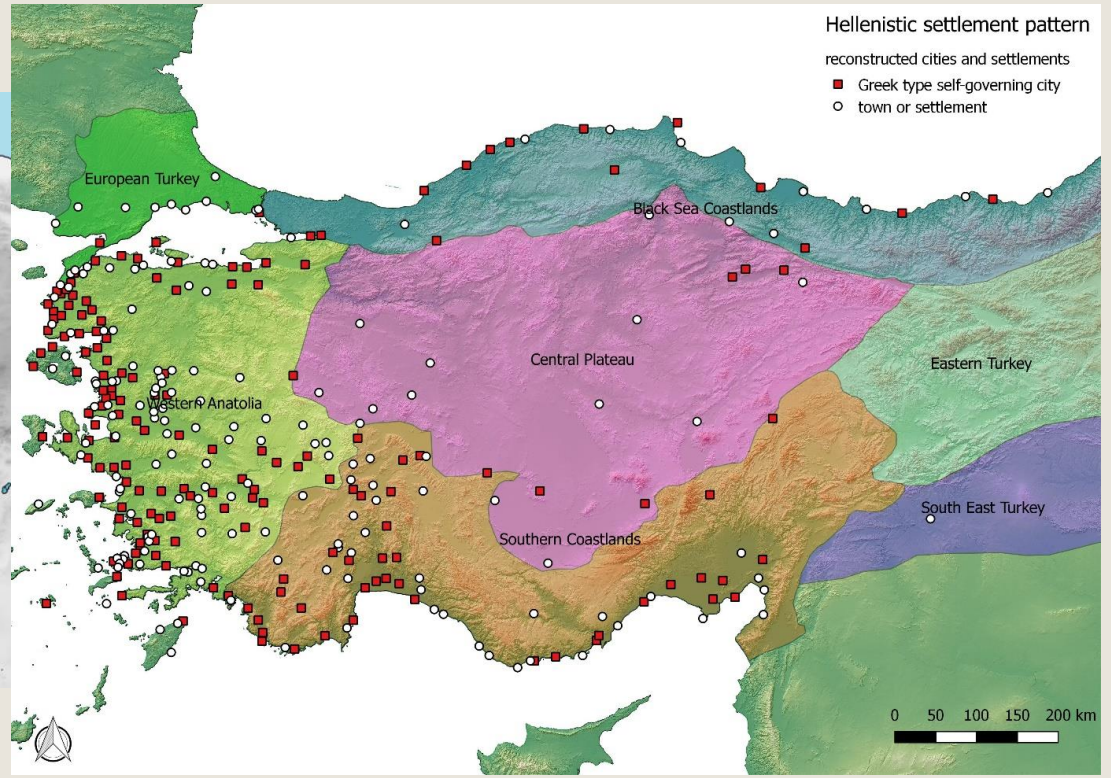
The *Polis* in Anatolia

Archaic and Achaemenid periods



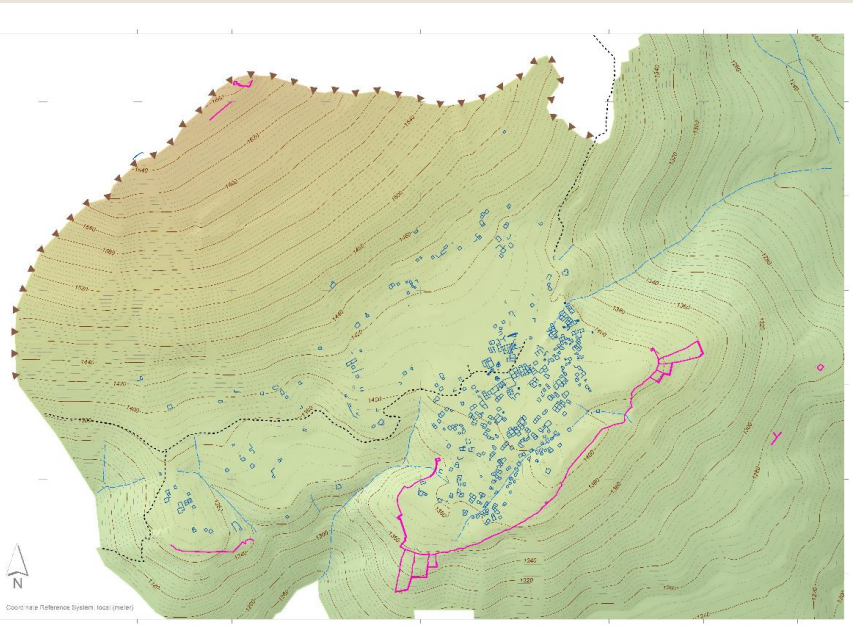
Made by author with dataset from POLIS website of Stanford University (http://polis.stanford.edu/); based on Hansen and Nielsen 2004.

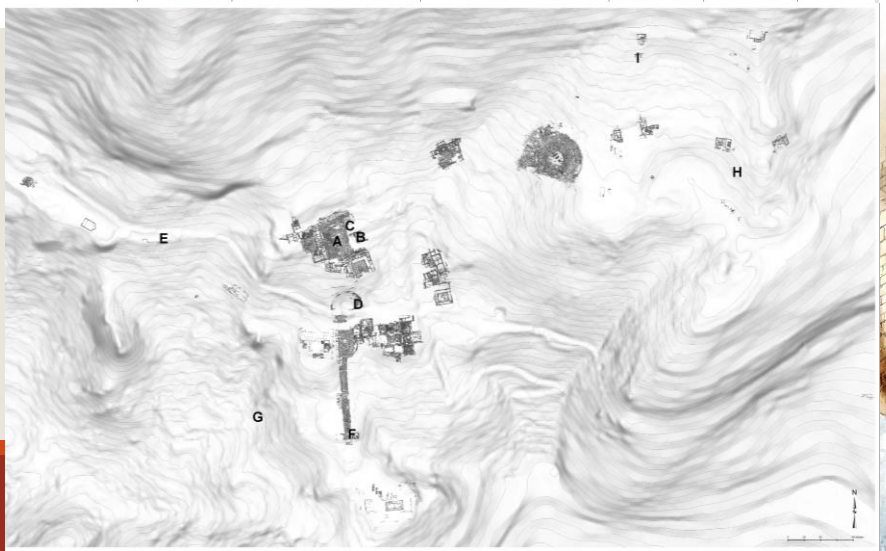


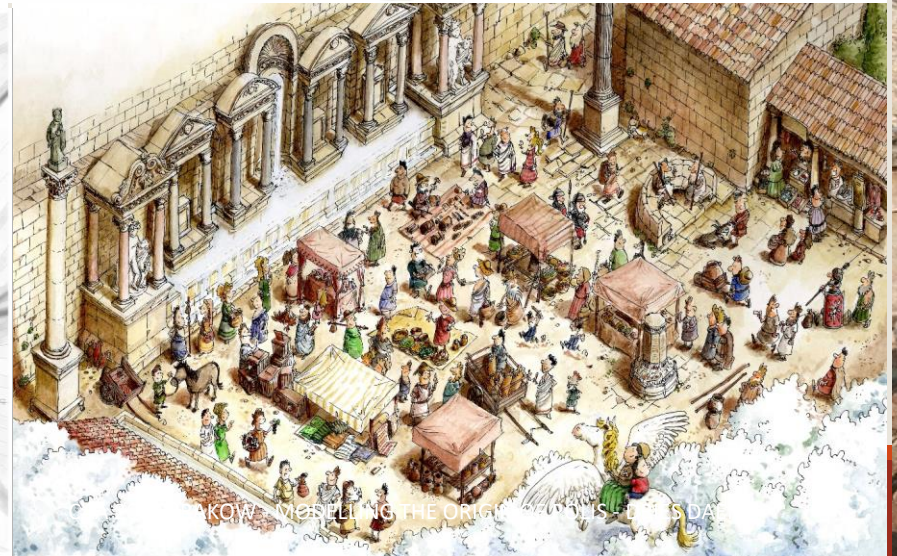
Map made by Willett (2019)

Hansen & Nielsen (2004) Inventory of Poleis
Willet 2019 The Geography of Urbanism in Roman Asia Minor

The *Polis* in Anatolia: Düzen Tepe and Sagalassos







Designing Models

- Model properties:
  - Representation (what?)
  - Simplification (how?)
  - Purpose (why?)
- **What?** Origin and development of *poleis* in Anatolia
- **How?** Focus on key properties:
  - Fusion-fission cycles
  - Urban scaling
  - Centrality
- **Why?**
  - Untapped potential of computational modelling approaches in Classical Archaeology
  - Testing existing hypotheses and exploring possibility space

Conceptual Modelling

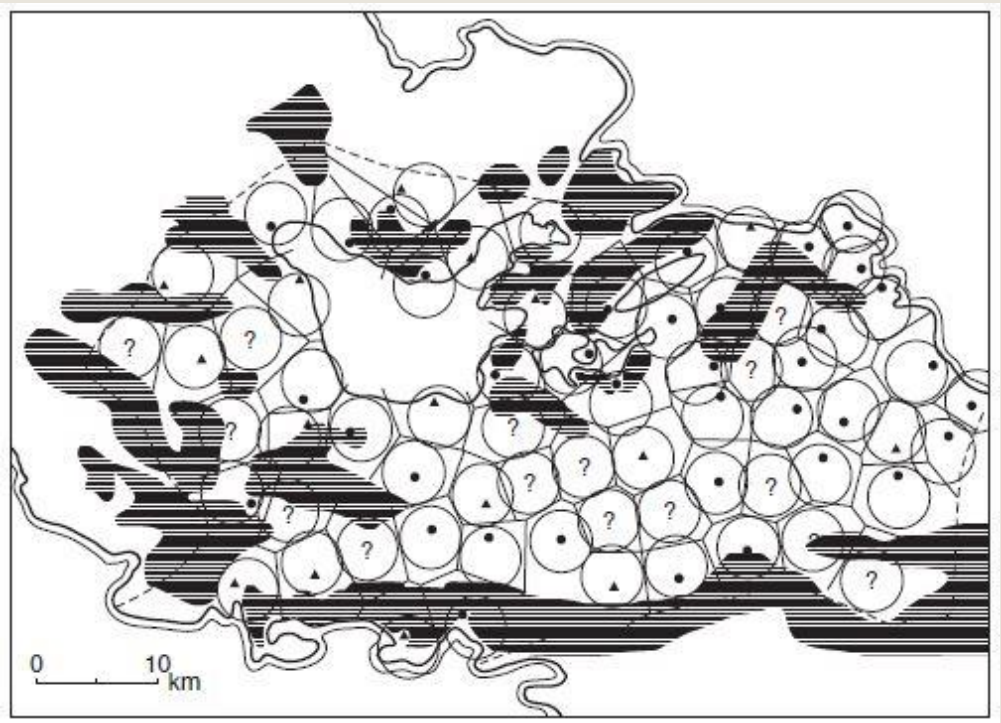
"A model that is made of ideas or concepts is called a *conceptual model*" (Gonzalez-Perez 2018)

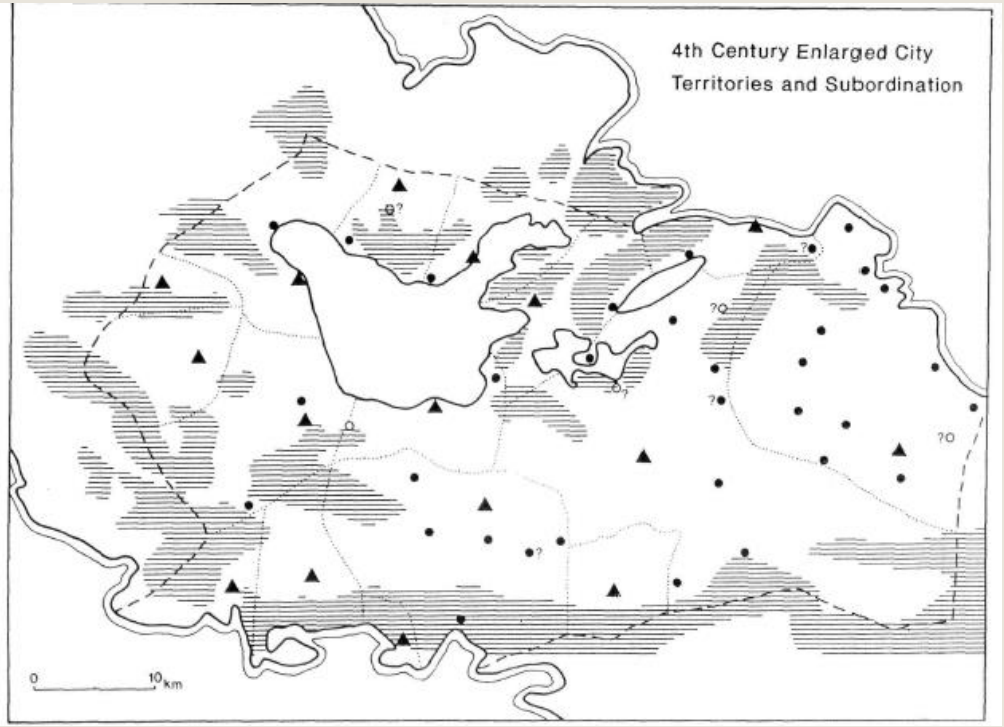
Focus on dynamics within and between communities:

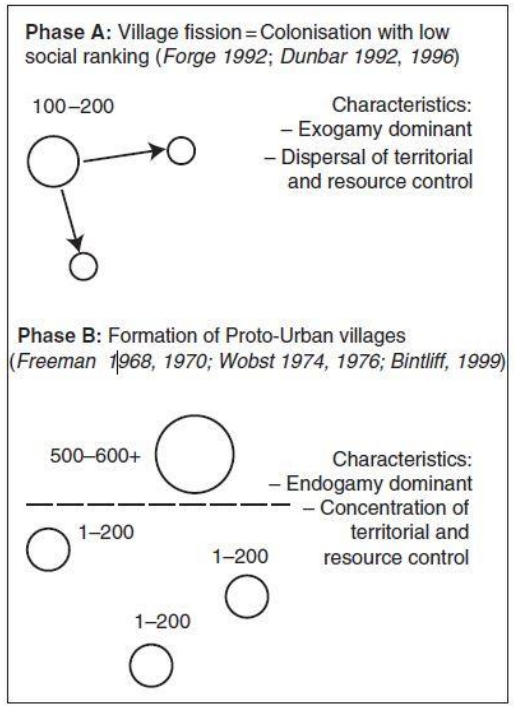
1. Intra-community dynamics
   - Community fission
   - Urban scaling
2. Inter-community dynamics
   - Community fusion
   - Central places and networks

Gonzalez-Perez (2018) Information Modelling for Archaeology and Anthropology.

Conceptual Model: Fusion-Fission Cycles



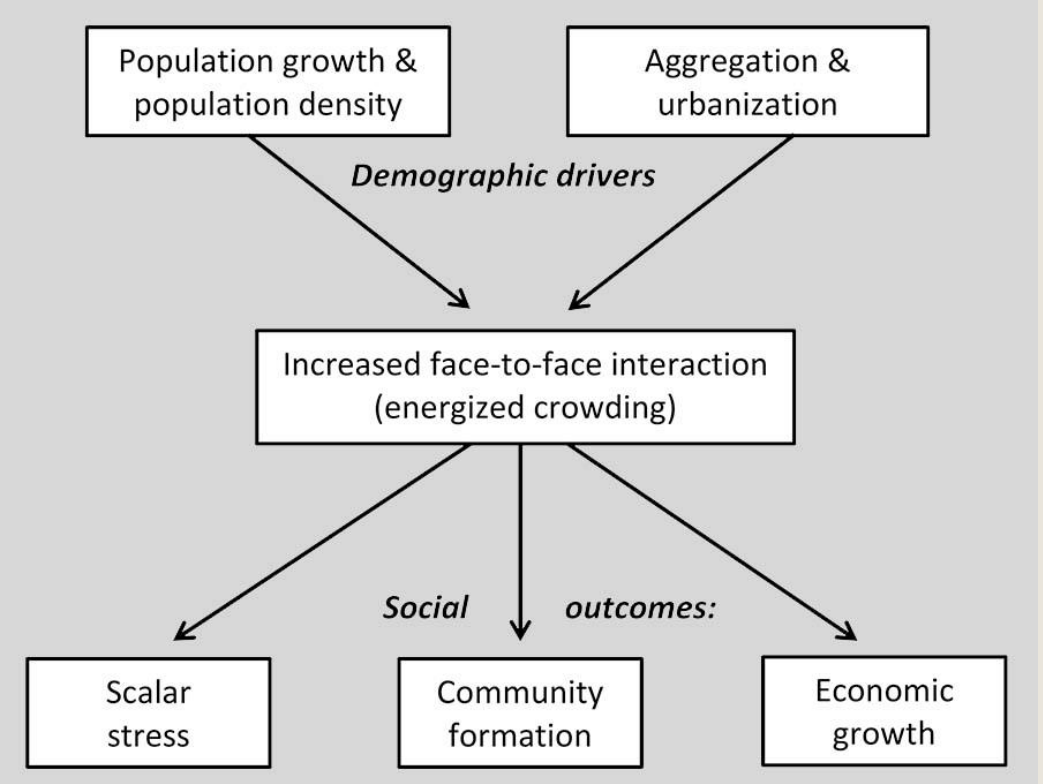




Bintliff (1982) Settlement Patters, land tenure and social structure: a diachronic model.
Bintliff (1994) Territorial behaviour and the natural history of the Greek polis.
Bintliff et al. (2007) Emergent complexity in settlement systems and urban transformations.

Conceptual Model: (Urban) Scaling

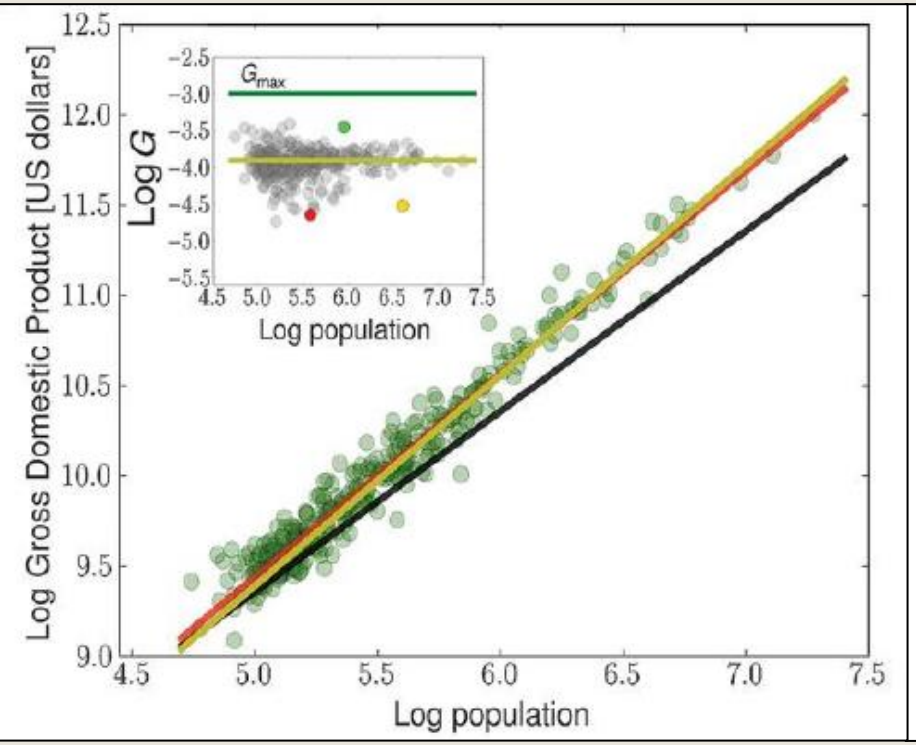
- Population growth and concentration as one of main drivers of societal development
- Face-to-face interaction and information transmission
- Settlements as ‘pockets of interaction’ or ‘social reactors’
- As community sizes increase, ‘social outcomes’ grow as well
- Processes span urban-nonurban divide

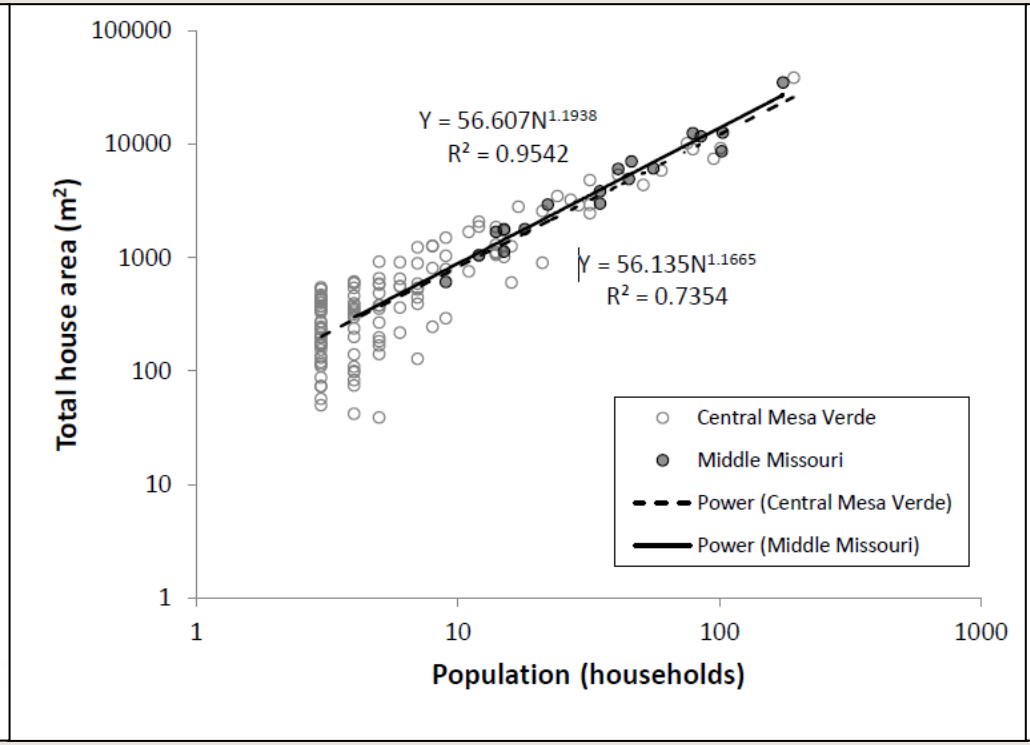


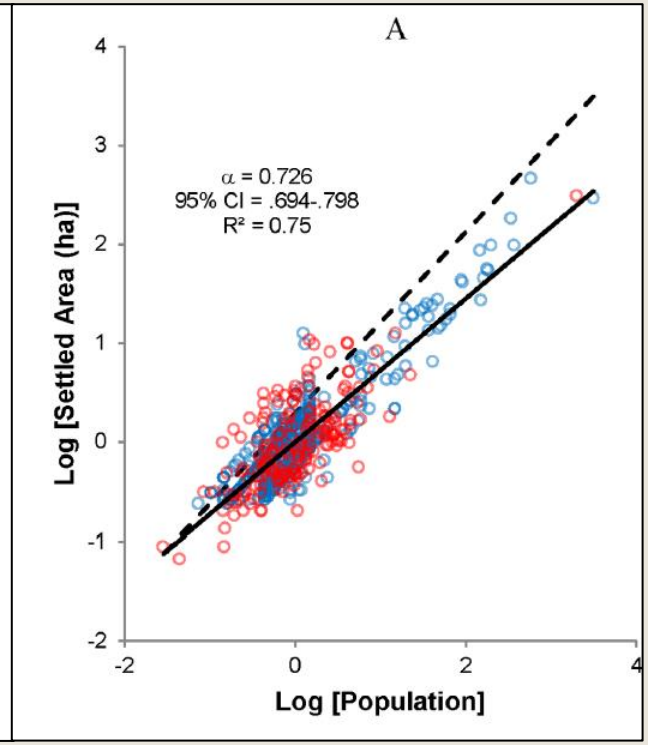
Smith 2019

Bettencourt (2013) The Origins of Scaling in Cities
Ortman and Cofey (2015) Universal Scaling: Evidence from Village-Level Societies.
Smith (2019) Energized Crowding and the Generative Role of Settlement Aggregation and Urbanization

Conceptual Model: (Urban) Scaling





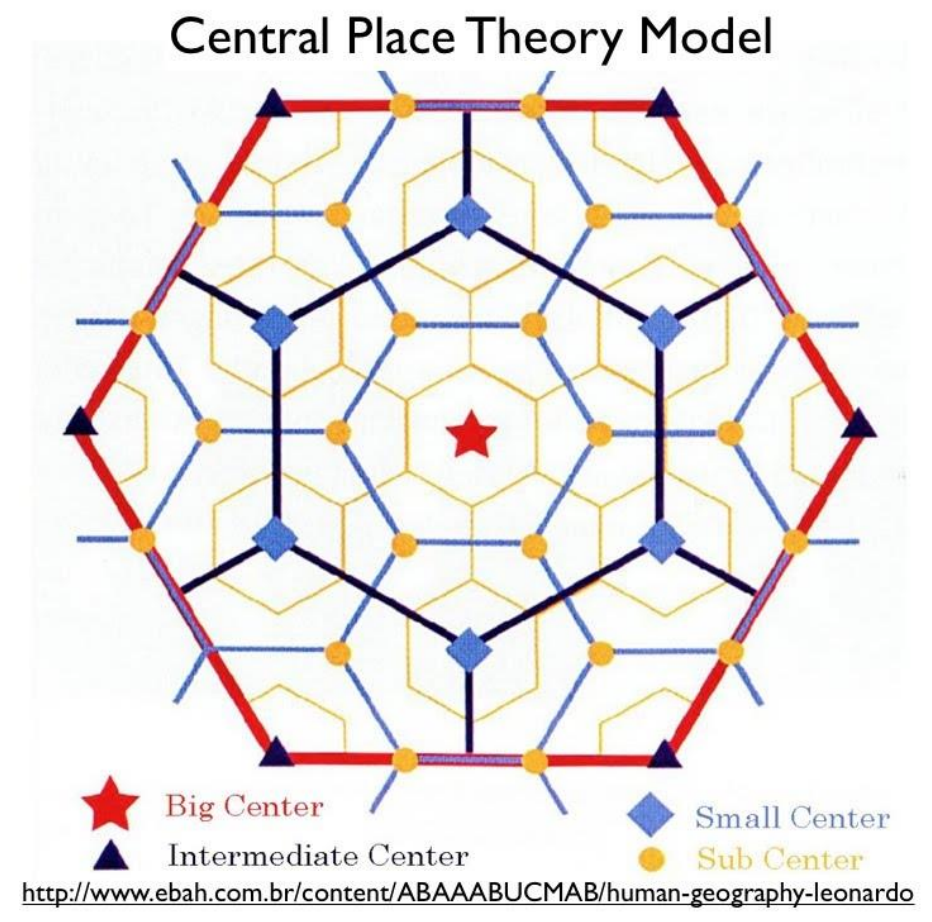


$$X = X_0 N^{\alpha}$$

Bettencourt (2013) The Origins of Scaling in Cities.
Ortman & Cofey (2015) Universal Scaling: Evidence from Village-Level Societies.
Ortman et al. (2014) The Pre-History of Urban Scaling.

Conceptual Model: Central Places

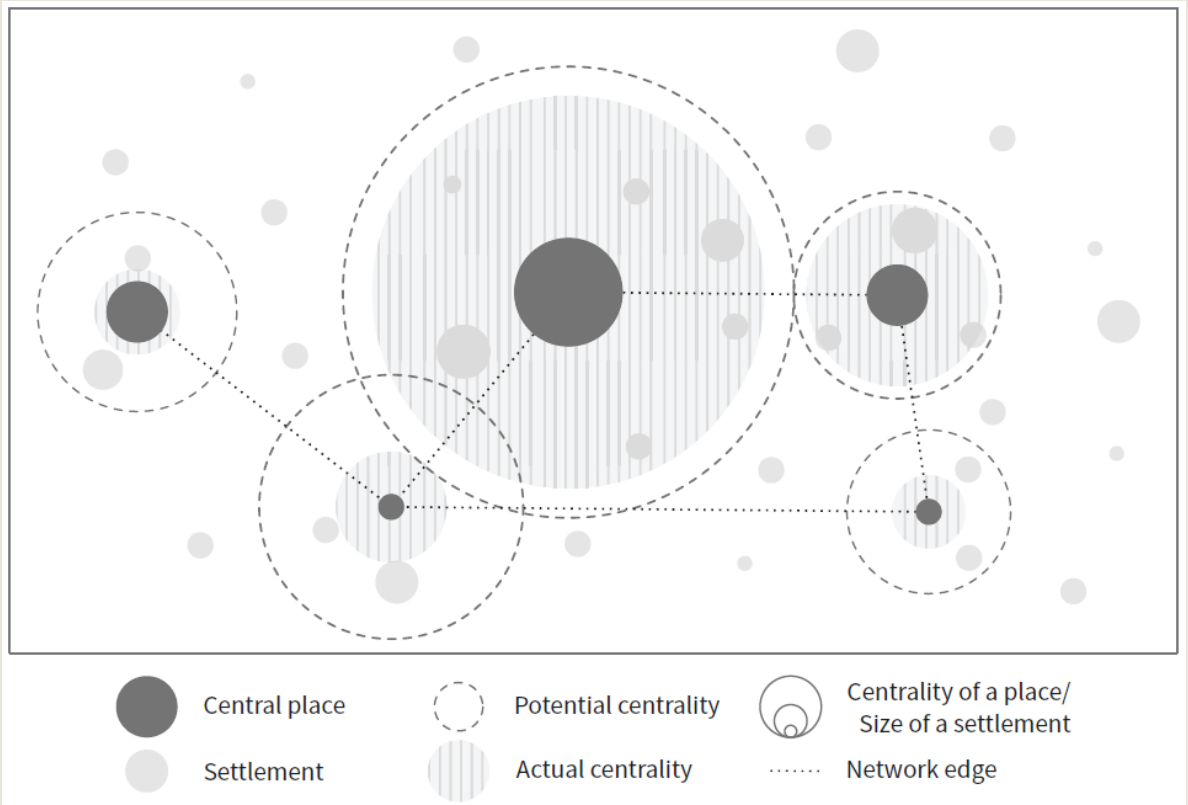
- Larger community ~ more diversity in activities/functions (Hanson et al. 2017)
- Spatial concentration of functions in settlement systems (Christaller 1933)
- Centrality in network hierarchies:
  - Qualitative and quantitative
  - (1) administration; (2) security; (3) craft and industry; (4) trade; and (5) cult (Gringmuth-Dallmer 1996)



Christaller (1933) Die Zentralen Orte in Süddeutschland
Gringmuth-Dallmer (1996) Kulturlandschaftsmuster und Siedlungssysteme.
Hanson et al. (2017) Urbanism and the division of labour in the Roman Empire

Conceptual Model: Central Places

- "Relative concentration of interaction"
  - Network approach: Places and flows
- Pulling factors for *potential* centrality
  - Population size, natural resources, strategic location, administrative institutions, cultural functions, high carrying capacity, ritual features, etc. (Knitter and Nakoins 2018)



Knitter & Nakoinz (2018) The Relative Concentration of Interaction

Computational Model: Simulations

Conceptual phase

1. Identifying research questions
2. Finding most suitable method
3. General framework and resolution of simulation
4. Entities and rules of interactions

Technical phase

5. Coding and testing
6. Parameterising simulation
7. Running simulation
8. Analysis and recontextualization of results

Dissemination phase

9. Disseminate findings

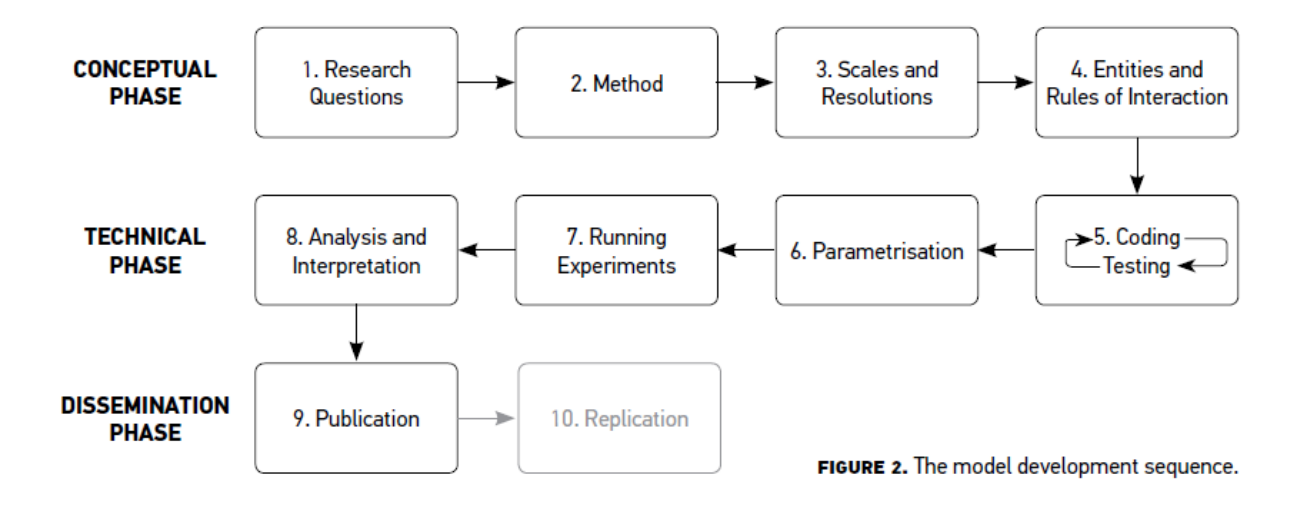


FIGURE 2. The model development sequence.

Romanowska (2015) So You Think You Can Model?

Computational Model: Documentation

ODD protocol: standardize the published descriptions of individual-based and agent-based models (Grimm et al. 2010)

Iterated process

- Structure thoughts
- Think through construction of the model

Purpose:

- Study the emergence of *polis* communities out of fusion-fission dynamics and urban scaling processes; and trace their development into central places through network formation
- "Agent-based models make possible the study of nonlinear cultural dynamics that emerge from the historically contingent actions of heterogeneous agents interacting in space" (Premo 2006)

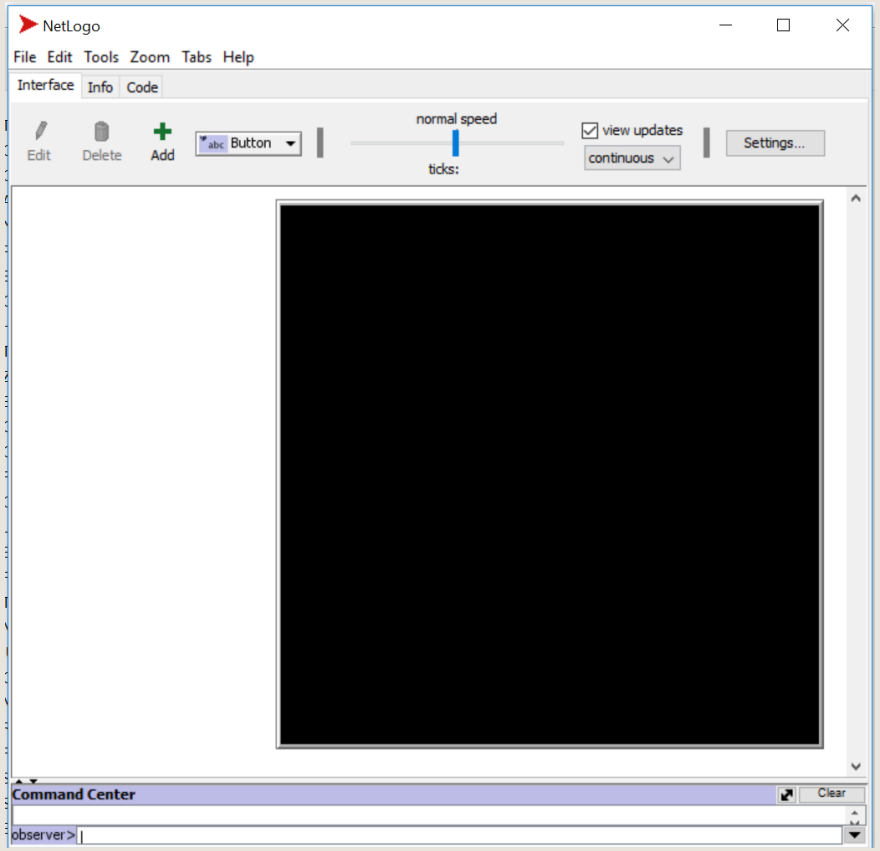
Grimm et al. (2010) The ODD protocol: A review and first update
Premo (2006) Agent-based models as behavioral laboratories

Elements of the updated ODD protocol

1. Purpose
2. Entities, state variables, and scales
3. Process overview and scheduling
4. Design concepts
   - Basic principles
   - Emergence
   - Adaptation
   - Objectives
   - Learning
   - Prediction
   - Sensing
   - Interaction
   - Stochasticity
   - Collectives
   - Observation
5. Initialization
6. Input data
7. Submodels

ABM: Polis Formation

- Software: NetLogo (Wilensky 1999)
- From conceptual to detailed design:
  - Translating the conceptualised system into a set of entities and rules of interaction
  - Input and output information per component
  - Scale and resolution
- Operational design
  - Pseudo-code
  - Coding

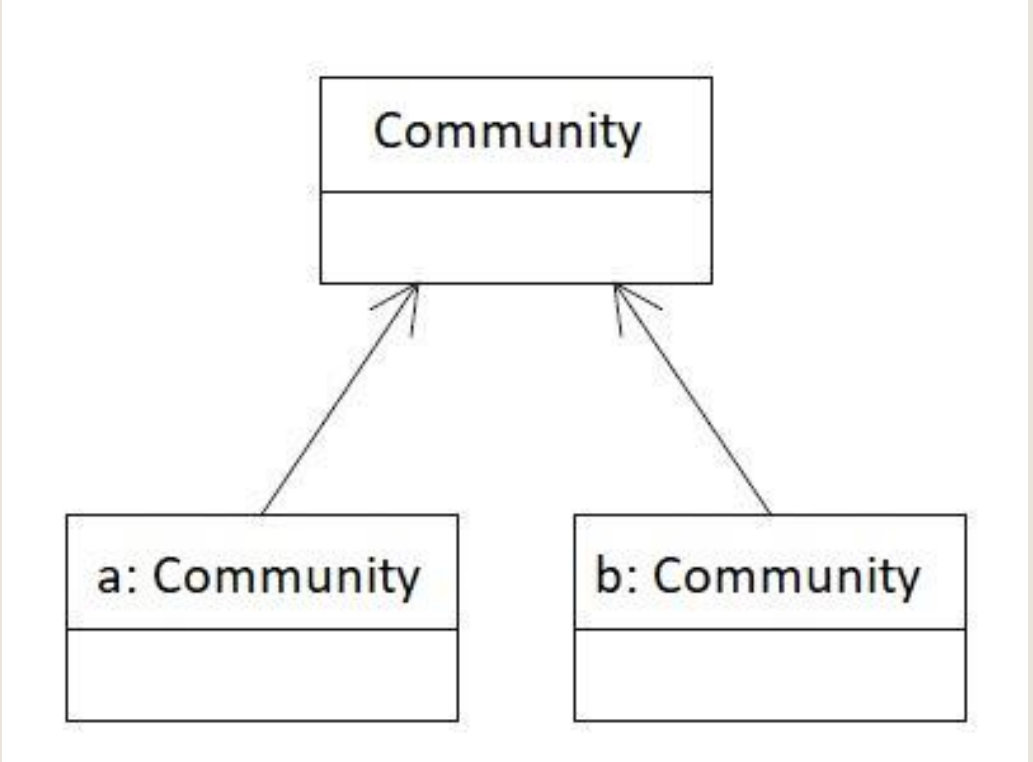


Edmonds and Meyer (2013) *Simulating Social Complexity*
Gonzalez-Perez (2018) *Information Modelling for Archaeology and Anthropology*
Wilensky (1999) NetLogo. http://ccl.northwestern.edu/netlogo/.

Simulation Design

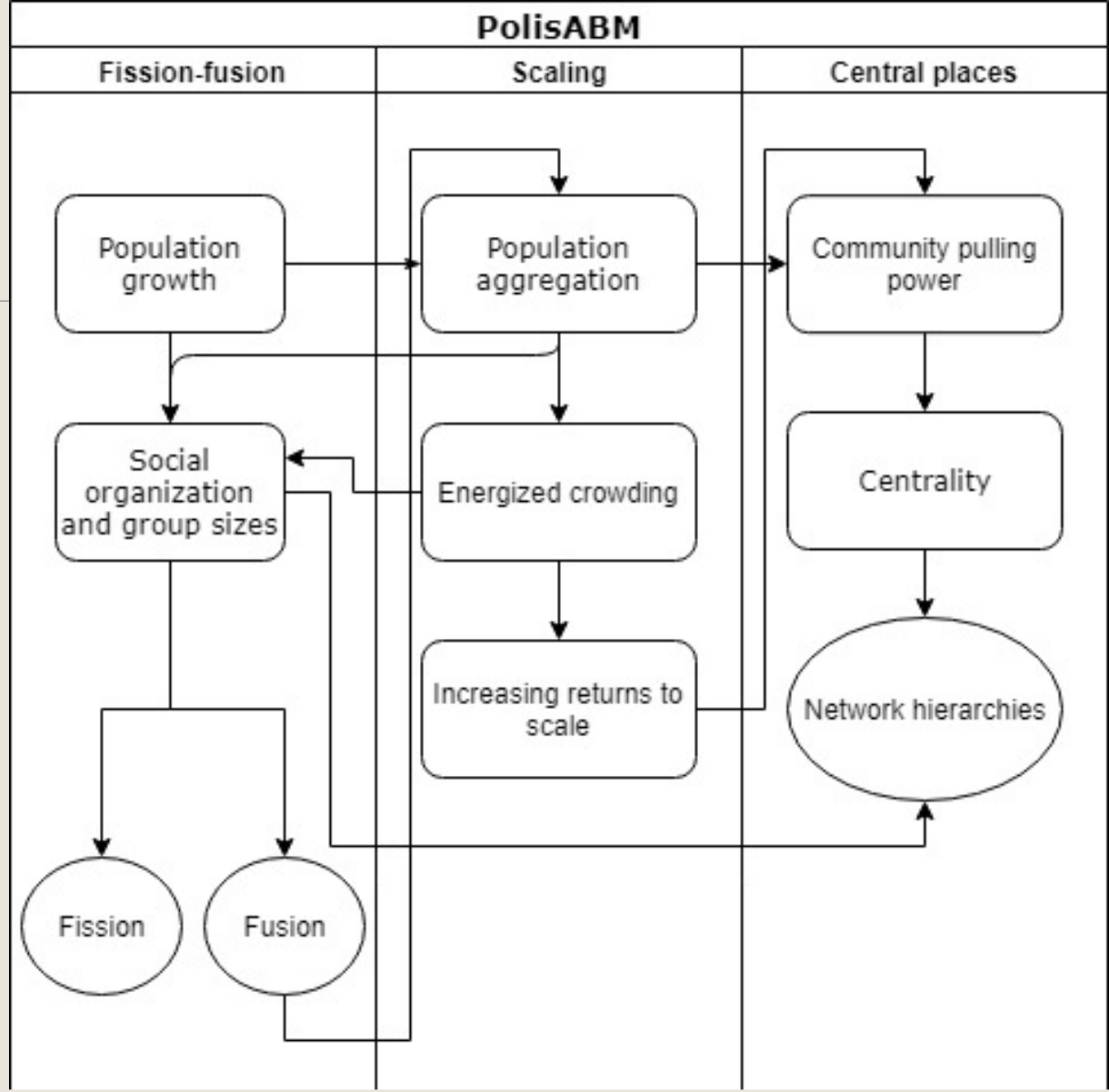
Class: community

a: community		
Attribute name	*Cardinality*	*Type*
Population	1	Number
Territory	1	Number
Output	1	Number
Connections	0..*	Number



Process overview

- Settlement dynamics
  - A. Fission-fusion
  - B. Energized crowding
  - C. Centrality and network formation



Simulating Fission-Fusion Cycles

- Polities expand in size over time due to population growth
- Group fission occurs with certain chance once population threshold is reached and empty space is available
- If no space for expansion
  - Fusion process
  - 'Conquest'
- Fusion can occur when adjacent polities of similar size come into conflict when no empty land separating them remained for expansion

Population growth:

$$\frac{\delta N}{\delta t} = rN\left(1 - \frac{N}{K}\right) + W$$

- N = population size
- r = population growth rate
- K = carrying capacity
- W = settlement pulling force

Griffin (2011) Emergence of fusion/fission cycling

Simulating Scaling

Original social reactor model:

- Number of people over a settled area
- Energetic constraints and costs of travel distance
- Probabilities they will encounter other people
- Average output or productivity per person

(Bettencourt 2013; Smith 2019)

Parameters:

- Number of people
- Size settlement/territory
- Average settlement output

$A(N) = aN^{\alpha}$

- A = settled area
- a = constant for benefit interaction / cost per unit time & space
- N = population size
- α = scaling exponent (2/3 for sublinear output)

$X = xN^{\beta}$

- X = aggregate of socio-economic output
- N = population size
- β = scaling exponent (7/6 for superlinear output)

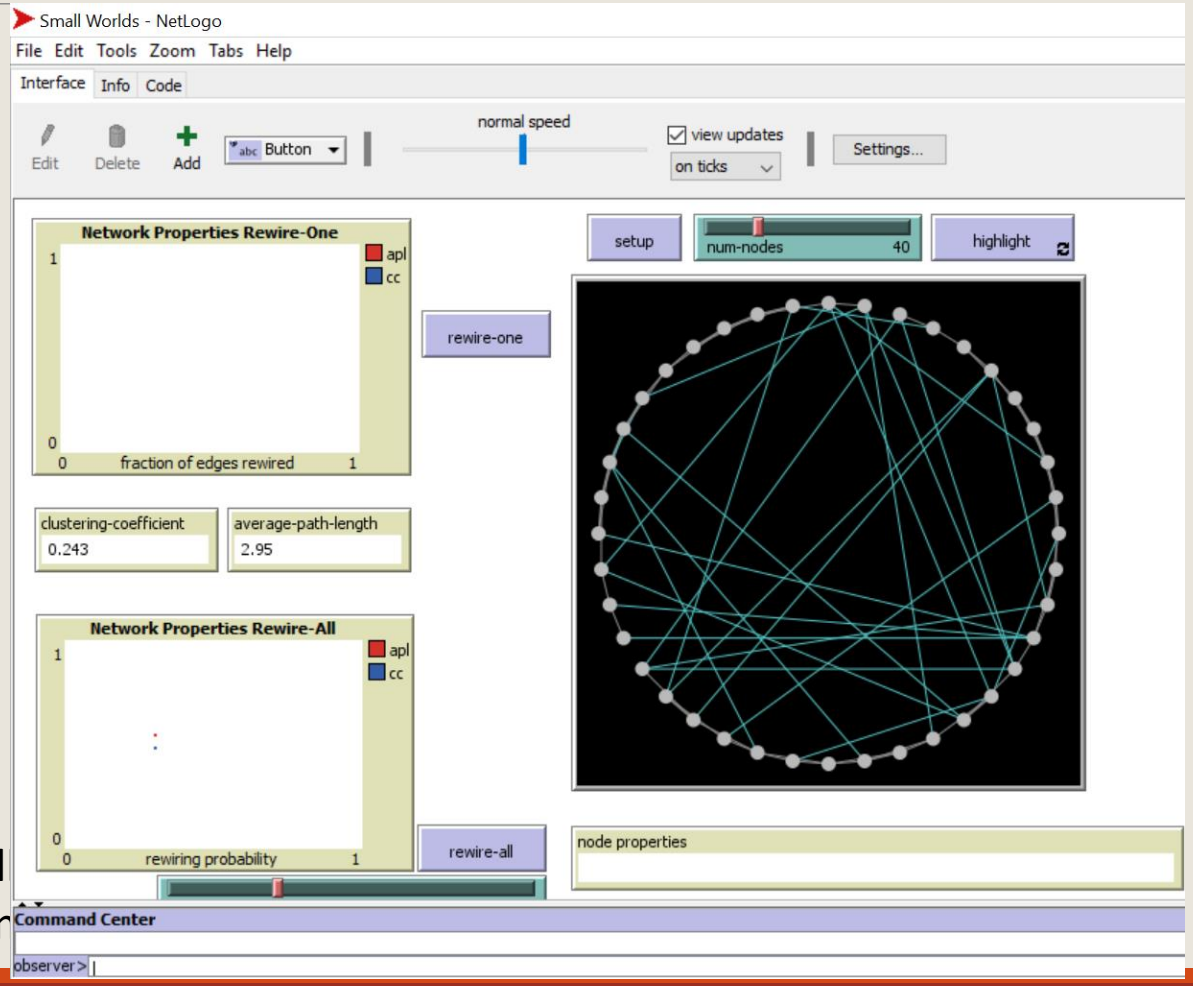
Simulating Central Places and Networks

Pulling forces of a community (Wilson and Rihll 1987)

- Population size: larger communities exercise bigger influence
- 'Weight' of community

Network formation

- Neighbouring ties
- Production output as 'capital' to initiate long-distance connections and increase pulling power over other communities



Watts and Strogatz (1998) Collective dynamics of 'smal

Wilson, A. G., & Rihll, T. E. (1987). Spatial Interaction ar

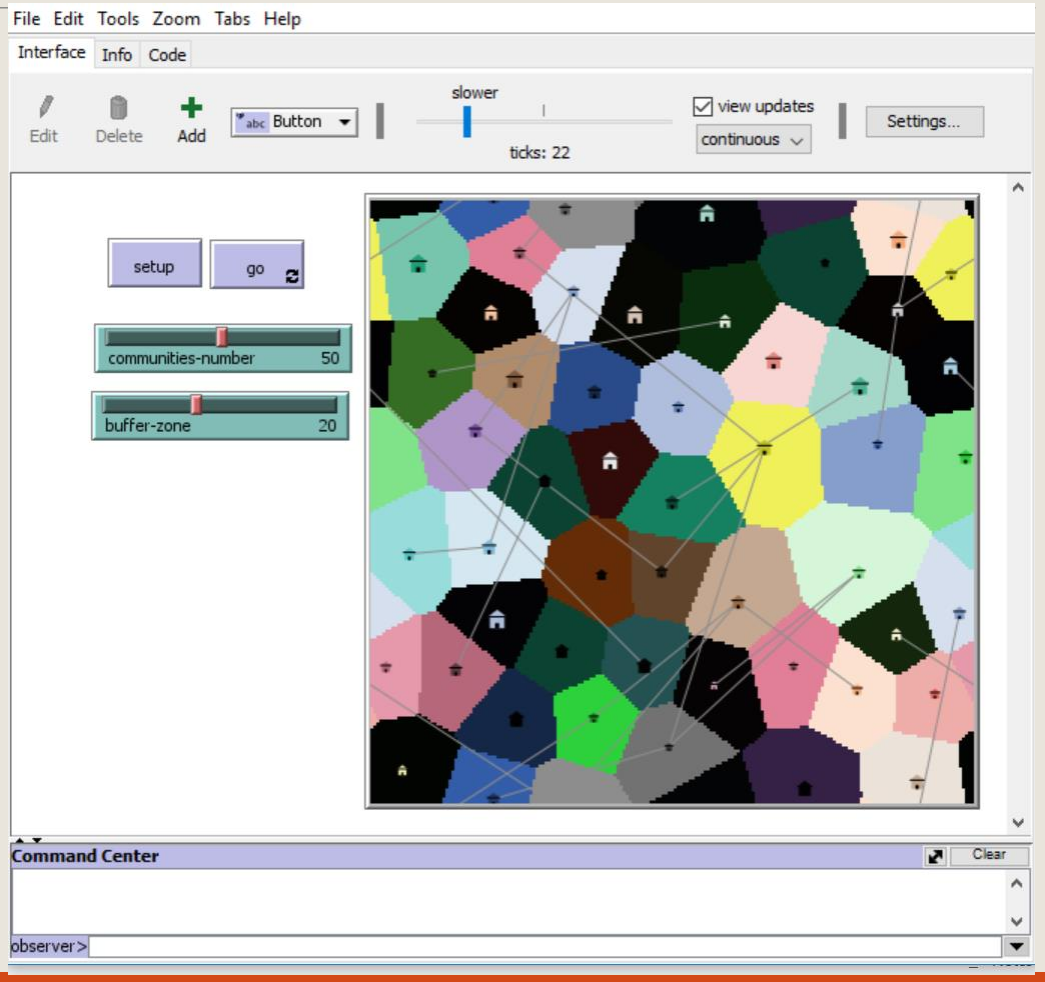
Initialising Simulation

Entities = (corporate) communities

Initial state variables:

- Number of polities = 50
- Population size: Random in 250-750 range
- Territory: Voronoi Diagrams
- Connections = FALSE

- Scale
  - Patch size: 1km²
  - World size: 100x100 km
  - Time step: 1 year
- Network formation



Potential Future Development

Starting point for future development to extend/refine model:

- Micro-scale dynamics:
  - Generate energized crowding output from social interactions
  - Implement fission/fusion cycles according to scaling parameters
- Macro-scale dynamics
  - Royal policy stimuli
- Human-environment interactions
  - Energy capture and expenditure
  - Settlement chambers
- Code and documentation will be made available: https://github.com/driesdaems10/PolisABM

Thank you for your attention!

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