Agent-based modelling:
Are computer simulations useful for archaeologists?

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   b) Human dispersal

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What is agent-based modelling (ABM)?

- Method of computer simulation

- "Agents"

- Individual/group-based rulesets

- Traces aggregate characteristics of a system that emerge from the behaviour of its parts
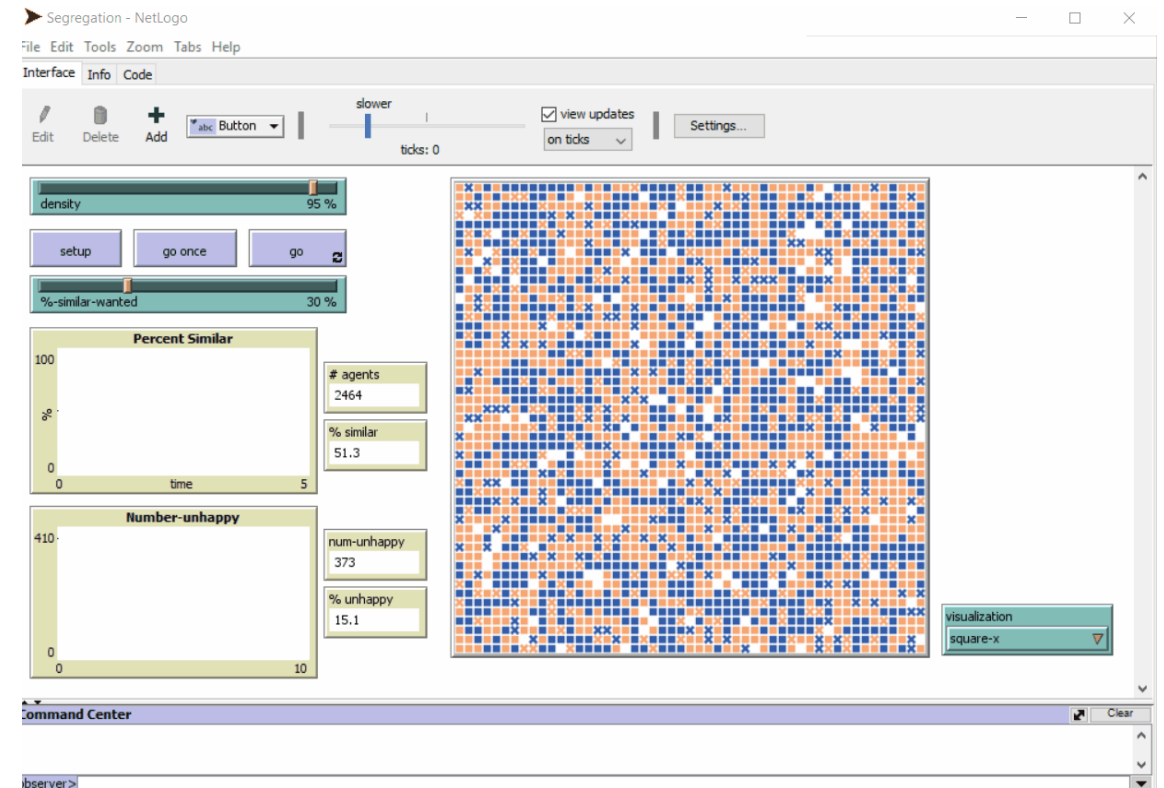
Schelling, T. (1978). *Micromotives and Macrobehavior.* New York: Norton.

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Why model?

- What is a model?
- Three core aspects of models:
  - Representation
  - Simplification
  - Purpose

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Why model?

- **What is a model?**
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Newton's Laws

1. A body will remain at rest, or moving at a constant velocity, unless it is acted on by an unbalanced force.

2. The force experienced by an object is proportional to its mass times the acceleration it experiences:

$$\vec{F} = m\vec{a}$$

3. If two bodies exert a force on one another, the forces are equal in magnitude, but opposite in direction:

$$\vec{F}_{12} = -\vec{F}_{21}$$

Why model?

- **What is a model?**
- Three core aspects of models:
  - Representation
  - Simplification
  - Purpose

"Thus, from the **war of nature**, from famine and death, the most exalted object which we are capable of conceiving, namely, the **production of the higher animals**, directly follows. There is grandeur in this view of life, with its several powers, having been originally breathed into a few forms or into one; and that, whilst this planet has gone cycling on according to the fixed law of gravity, **from so simple a beginning** endless forms most beautiful and most wonderful have been, and are being, **evolved**."
— Charles Darwin, The Origin of Species

The cosmos, plant and animal life, and human society had evolved in that order **from simple, homogenous beginnings** into **increasingly differentiated**, more complexly organised, and more intricately articulated entities. . . . Societies that were more complex and better integrated were able to **prosper** at the expense of less complex ones, just as human individuals and groups who were **better adapted** to social life supplanted those who were less well adapted.
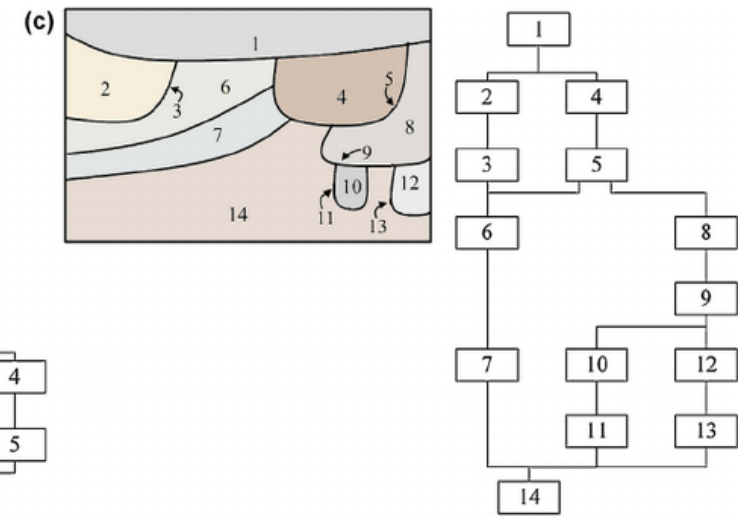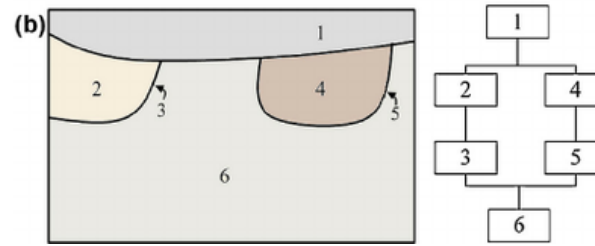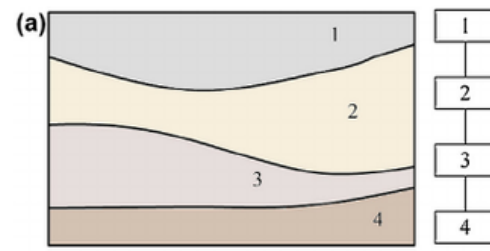— Herbert Spencer, First Principles of a New System of Philosophy

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Why model?

- What is a model?
- Three core aspects of models:
  - **Representation**
  - Simplification
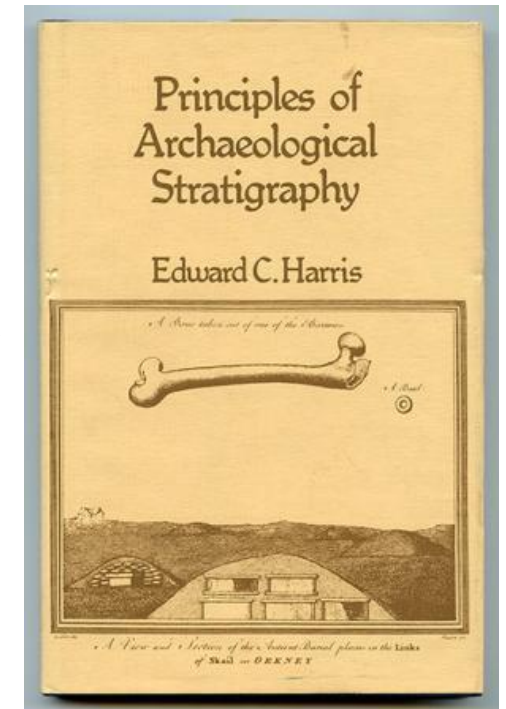 - Purpose

Reality

Model

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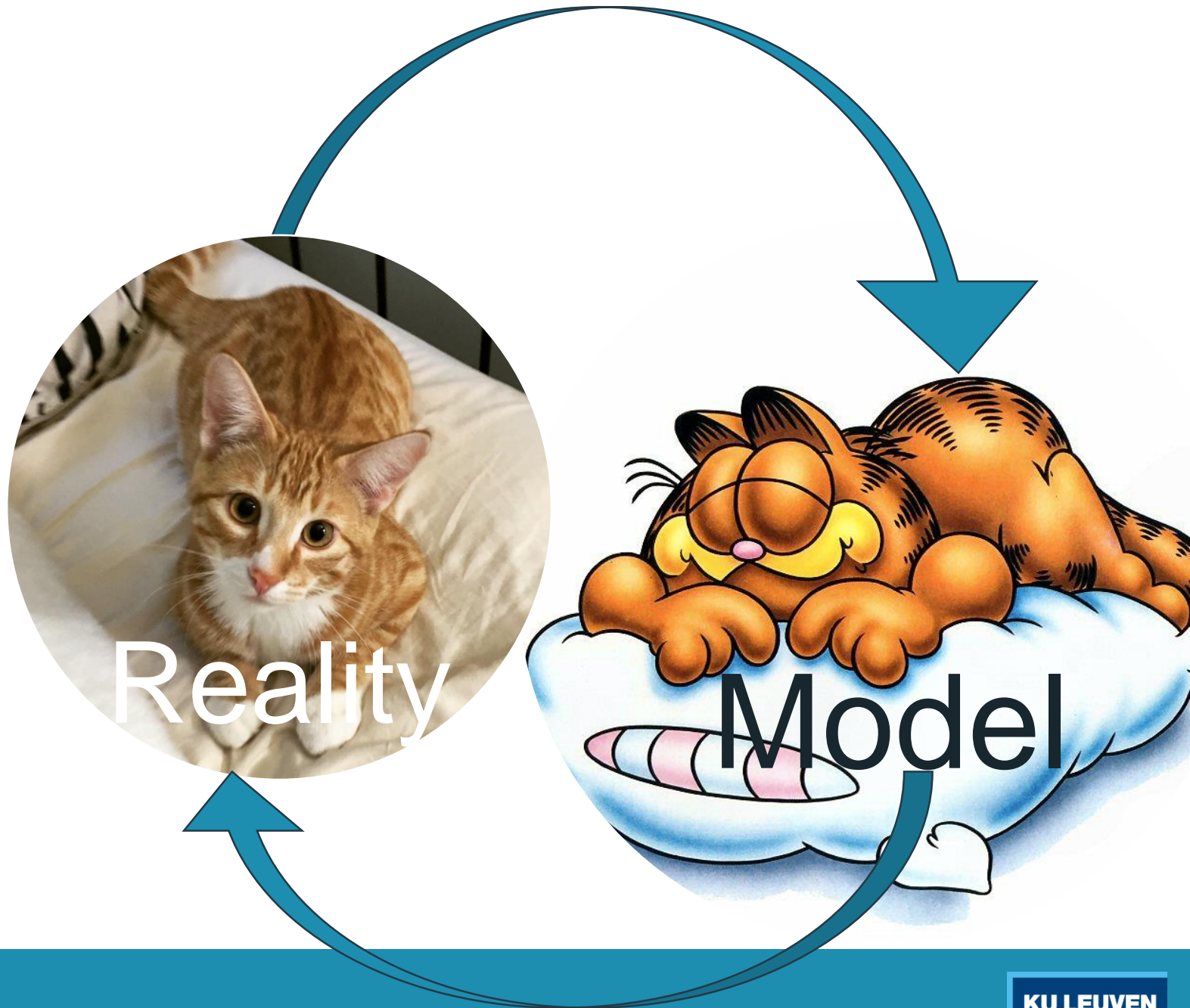
Why model?

- What is a model?
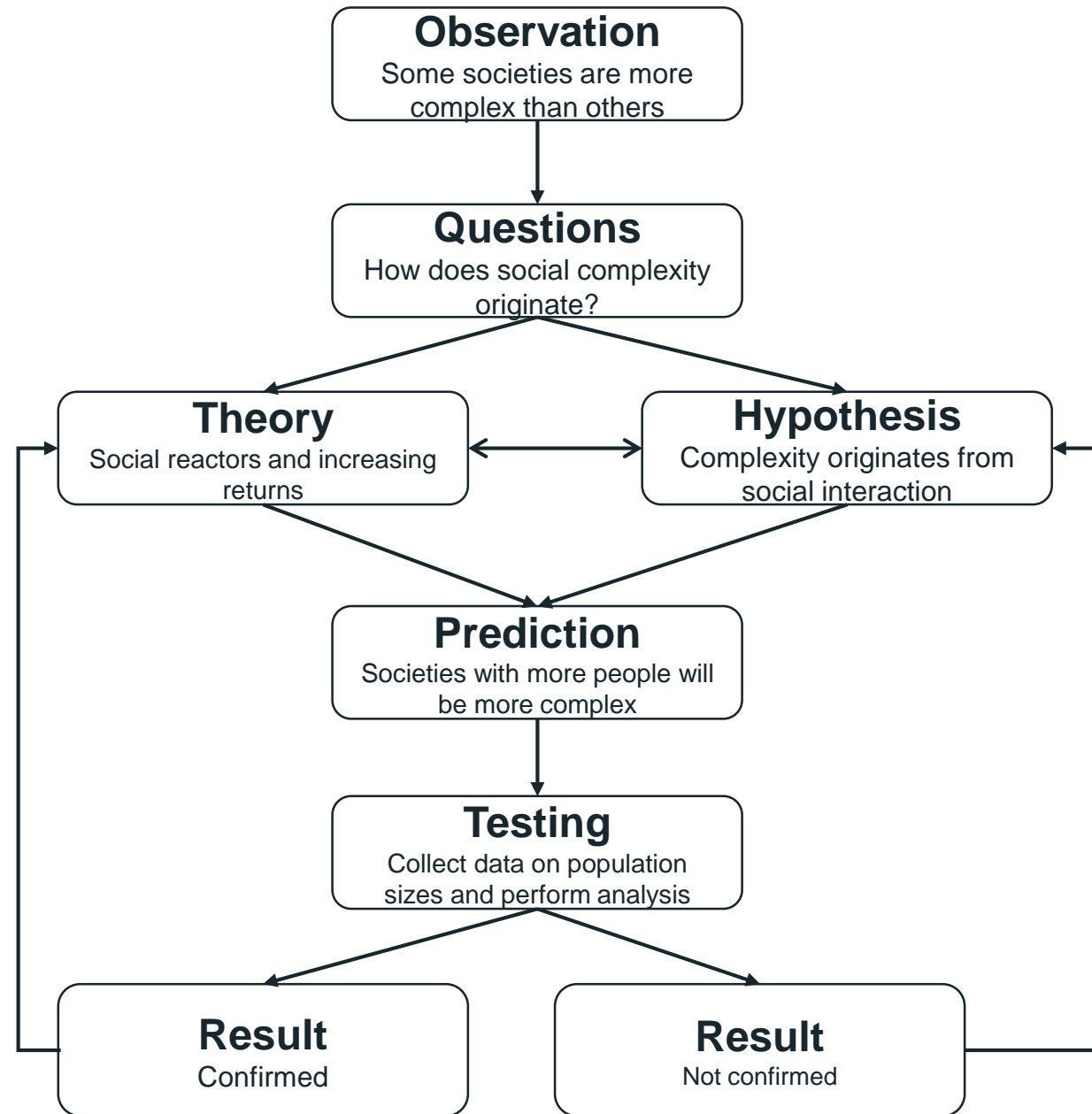- Three core aspects of models:
  - Representation
  - **Simplification**
  - Purpose

1. Law of superposition
2. Law of original horizontality
3. Law of original continuity
4. Law of stratigraphic succession

Principles of Archaeological Stratigraphy

Edward C. Harris

Why model?

- What is a model?

- Three core aspects of models:
  - Representation
  - Simplification
  - **Purpose**

Observation
Some societies are more complex than others

↓

Questions
How does social complexity originate?

Theory
Social reactors and increasing returns

↔

Hypothesis
Complexity originates from social interaction

Prediction
Societies with more people will be more complex

↓

Testing
Collect data on population sizes and perform analysis

Result
Confirmed

Result
Not confirmed

Why model?

Model **purposes**:

1) Explore possible questions

2) Hypothesis testing

3) Theory building

4) Predictive modelling

5) Experimenting
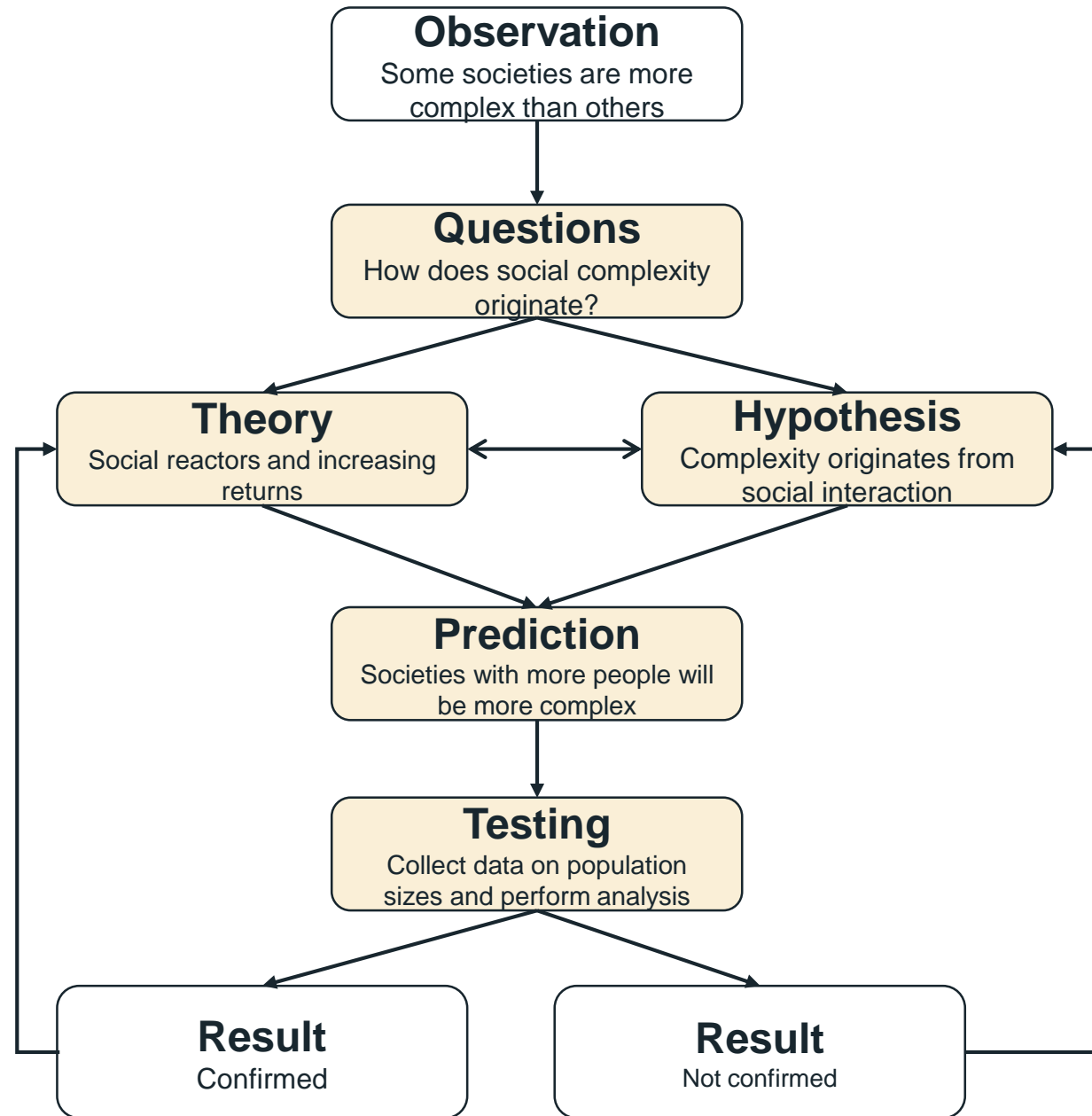
Modelling in archaeology

- How does archaeology generate knowledge?
  - No direct observation of the past
- Inference from material remains
  - Destructive nature of archaeological praxis
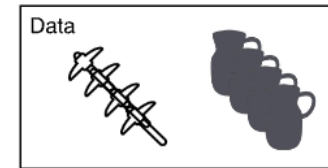 - Patchiness of evidence
  - Preservation biases
  - …

- https://projectmercury.eu/why-model/

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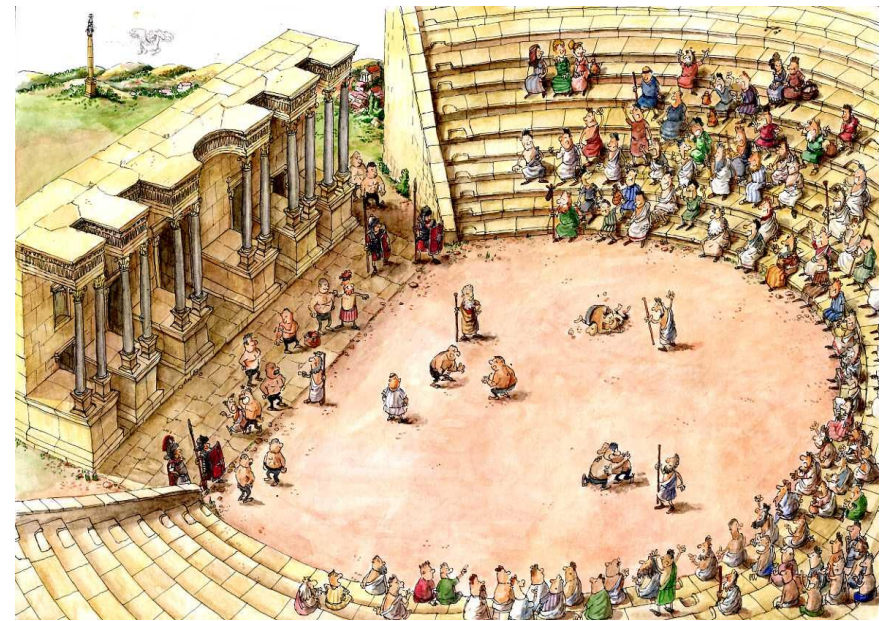
ABM in Archaeology

Models as heuristic devices

ABM as "cultural laboratories"

- Enforcing conceptual clarity
- Understand underlying mechanisms of change
- Infer past dynamic behaviour from static archaeological record
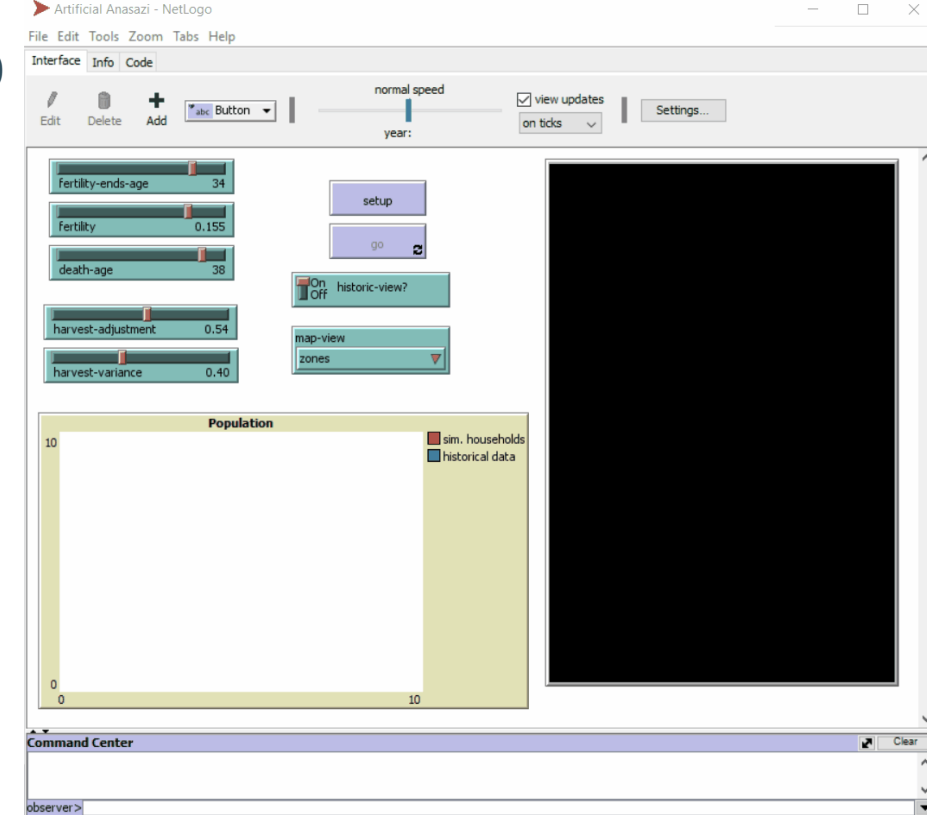- Rigorous hypothesis testing
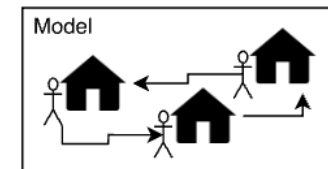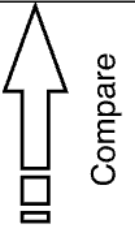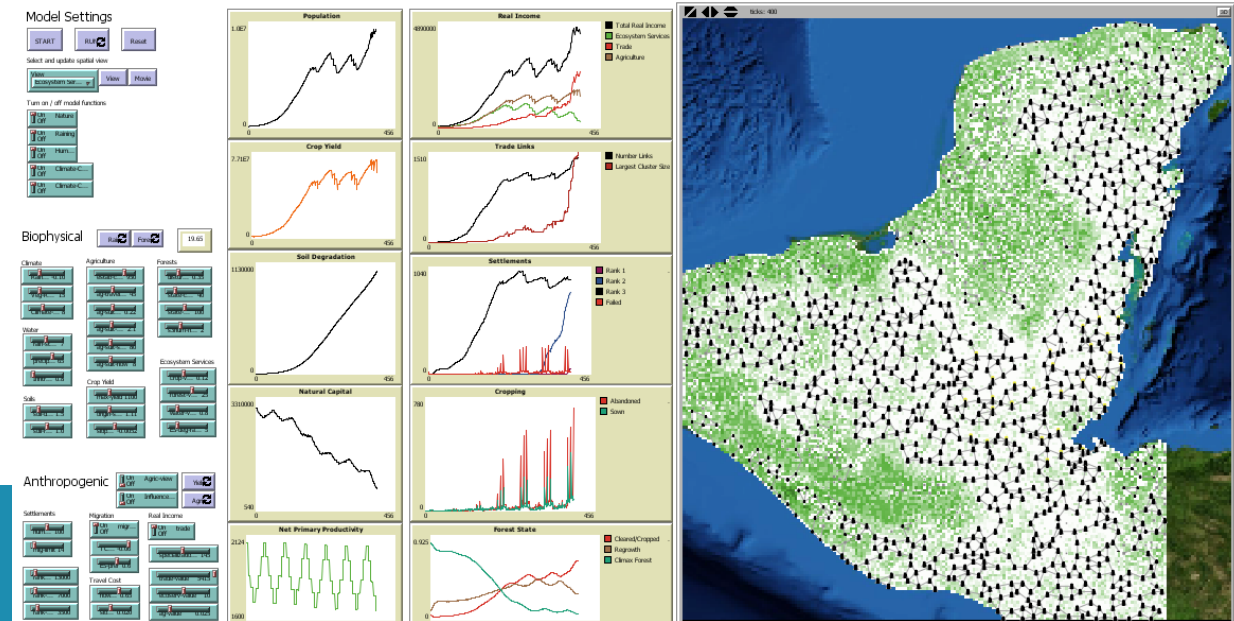

Romanowska (2015) So you think you can model?

ABM in Archaeology

- Human-environment interactions
- Hierarchy development
- Community formation
- Population growth
- Social complexity
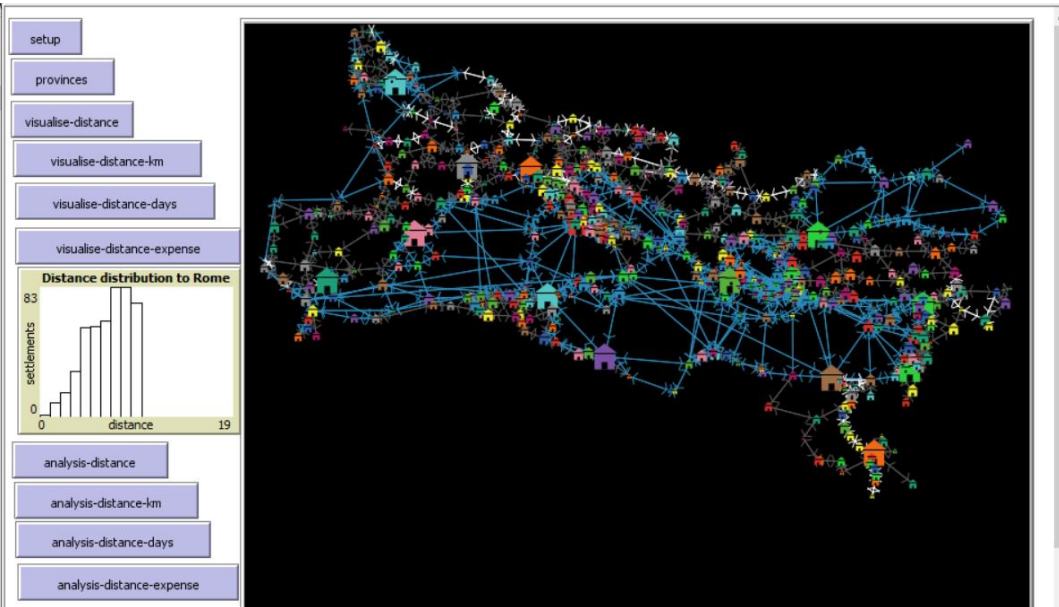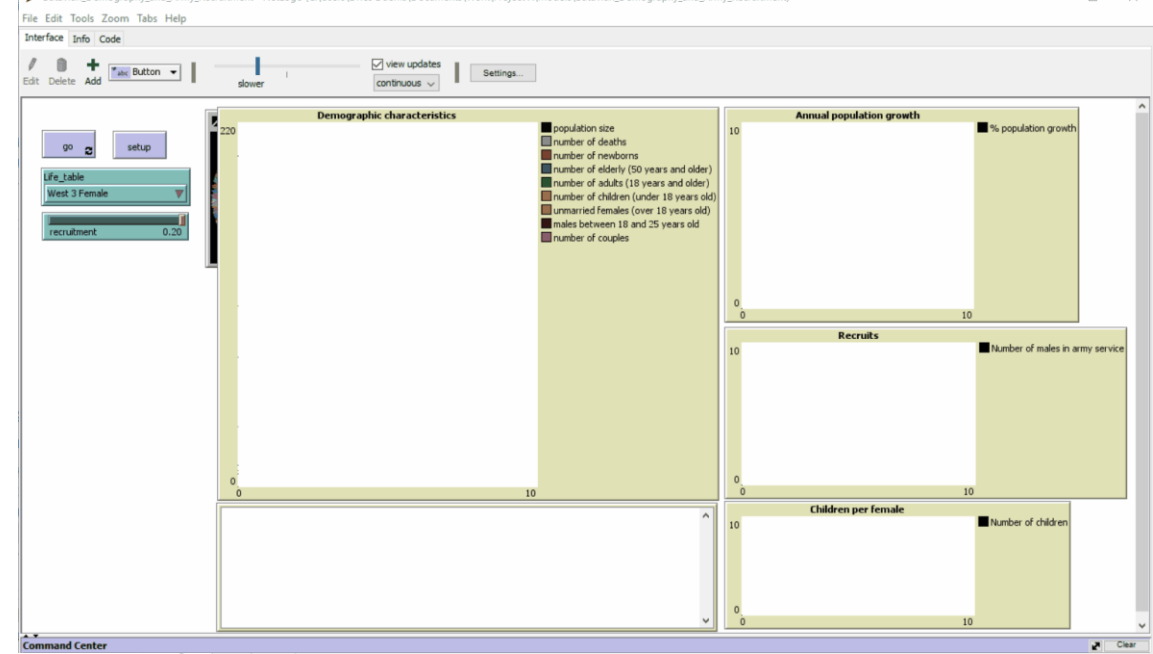- Urbanisation

Dean et al. 2000
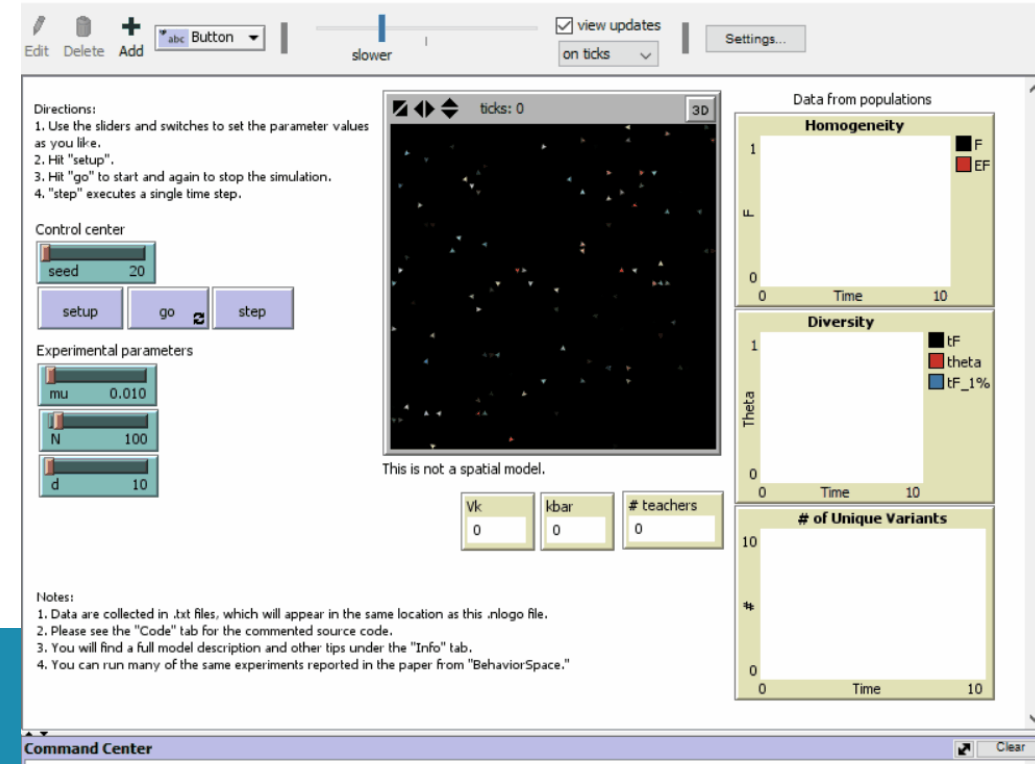Artifical Anasazi

Heckbert
2013
MayaSim

ABM in Archaeology

- Demography
- Cultural diversity
- Trade networks

Verhagen et al. 2019
Limits of the limes

Premo 2014
Cultural transmission
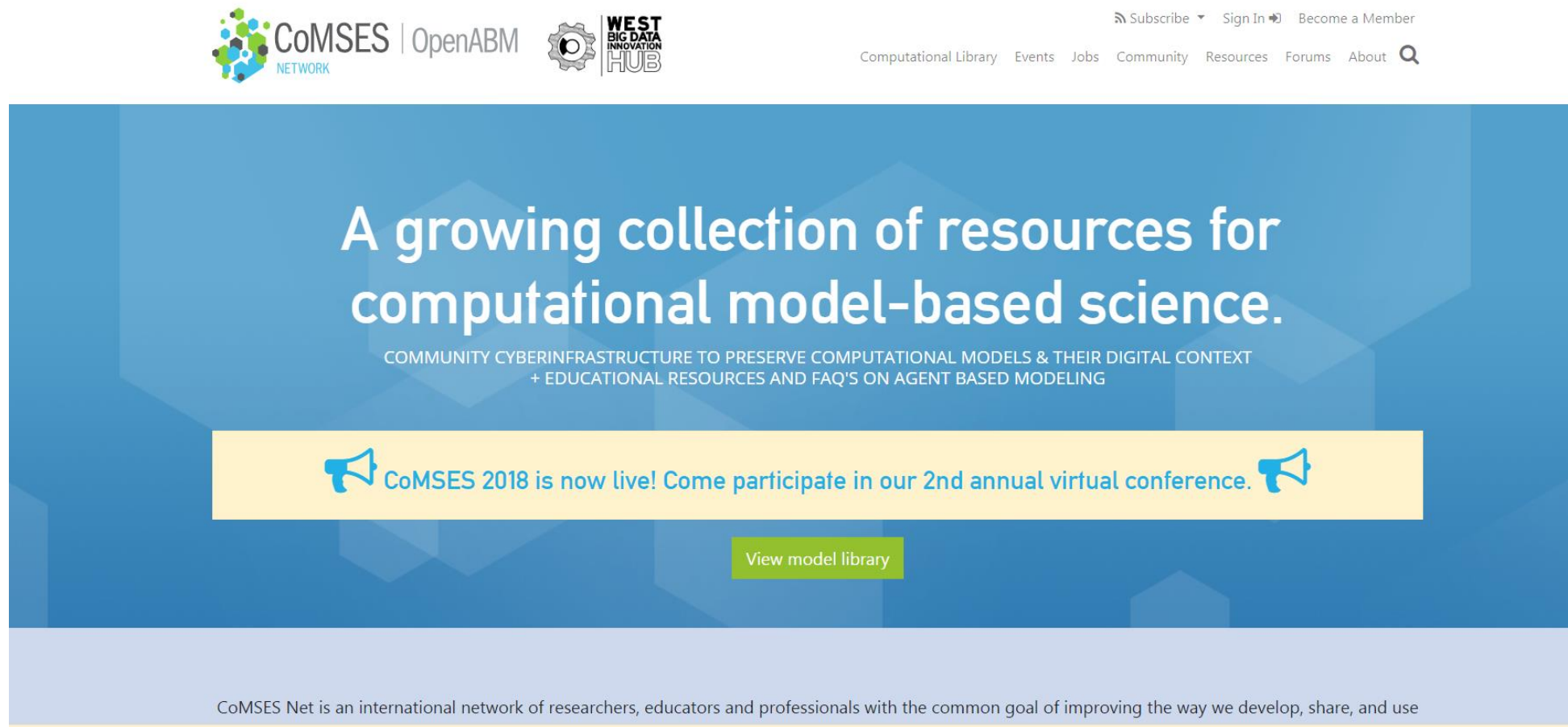
Brughmans 2018

Resources: Tutorials

Tutorials

- Romanowska, I., Crabtree, S.A., Harris, K., Davies, B., 2019. Agent-Based Modeling for Archaeologists: Part 1 of 3. Advances in Archaeological Practice 7, 178–184. https://doi.org/10.1017/aap.2019.6

- Davies, B., Romanowska, I., Harris, K., Crabtree, S.A., 2019. Combining Geographic Information Systems and Agent-Based Models in Archaeology: Part 2 of 3. Advances in Archaeological Practice 7, 185–193. https://doi.org/10.1017/aap.2019.5

- Crabtree, S.A., Harris, K., Davies, B., Romanowska, I., 2019. Outreach in Archaeology with Agent-Based Modeling: Part 3 of 3. Advances in Archaeological Practice 7, 194–202. https://doi.org/10.1017/aap.2019.4

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Resources: Literature

- Chattoe-Brown, E., 2013. Why Sociology Should Use Agent Based Modelling. Sociological Research Online 18, 1–11.

- Cioffi-Revilla, C., 2014. Introduction to Computational Social Science. Springer.

- Edmonds, B., et al. 2019. Different Modelling Purposes. JASSS 22, 6.

- Epstein, J.M., 2007. Generative Social Science: Studies in Agent-Based Computational Modeling. Princeton.

- Epstein, J.M., Axtell, R., 1996. Growing Artificial Societies: Social Science from the Bottom Up. Brookings Institution Press.

- Grimm, V., et al. 2010. The ODD protocol: A review and first update. Ecological Modelling 221, 2760–2768.

- Kohler, T.A., Gumerman, G.G. (Eds.), 2000. Dynamics in Human and Primate Societies: Agent-Based Modeling of Social and Spatial Processes. Oxford University Press, New York.

- Premo, L. 2006. Agent-based models as behavioral laboratories for evolutionary anthropological research. Ariz. Anthrop.17, 91–113.

- Railsback, S.F., Grimm, V., 2011. Agent-Based and Individual-Based Modeling: A Practical Introduction, Princeton.

- Romanowska, I., 2015. So You Think You Can Model? A Guide to Building and Evaluating Archaeological Simulation Models of Dispersals. Hum. Biol. 87, 169–192.

- Van Der Leeuw, S., 2004. Why Model? Cybernetics and Systems 35, 117–128.

- Wurzer, G., Kowarik, K., Reschreiter, H. (Eds.), 2015. Agent-based Modeling and Simulation in Archaeology, Advances in Geographic Information Science. Springer International Publishing.

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Resources: Model repositories

https://www.comses.net/

Now let's get to it!

- Tutorial 1:

Neutral stone procurement model

- Tutorial 2:

Human dispersal model

https://github.com/driesdaems10/CAA-NAFL2019
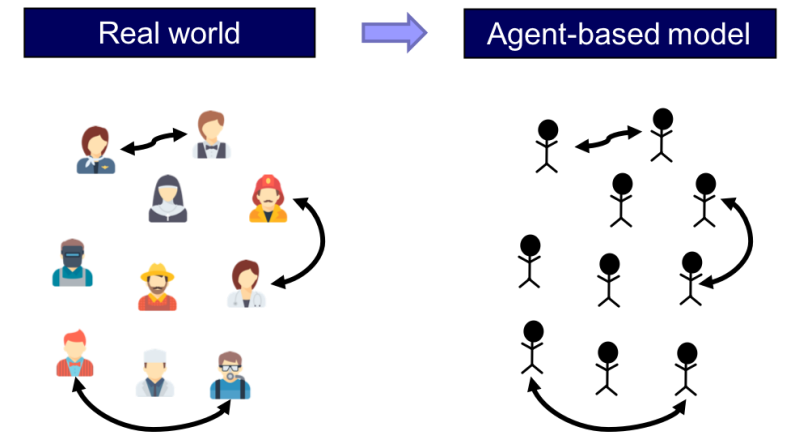
ABM software

- Netlogo
  - Easy to learn
  - High performance
  - Models library!

- Version 6.0.1

- https://ccl.northwestern.edu/netlogo/download.shtml
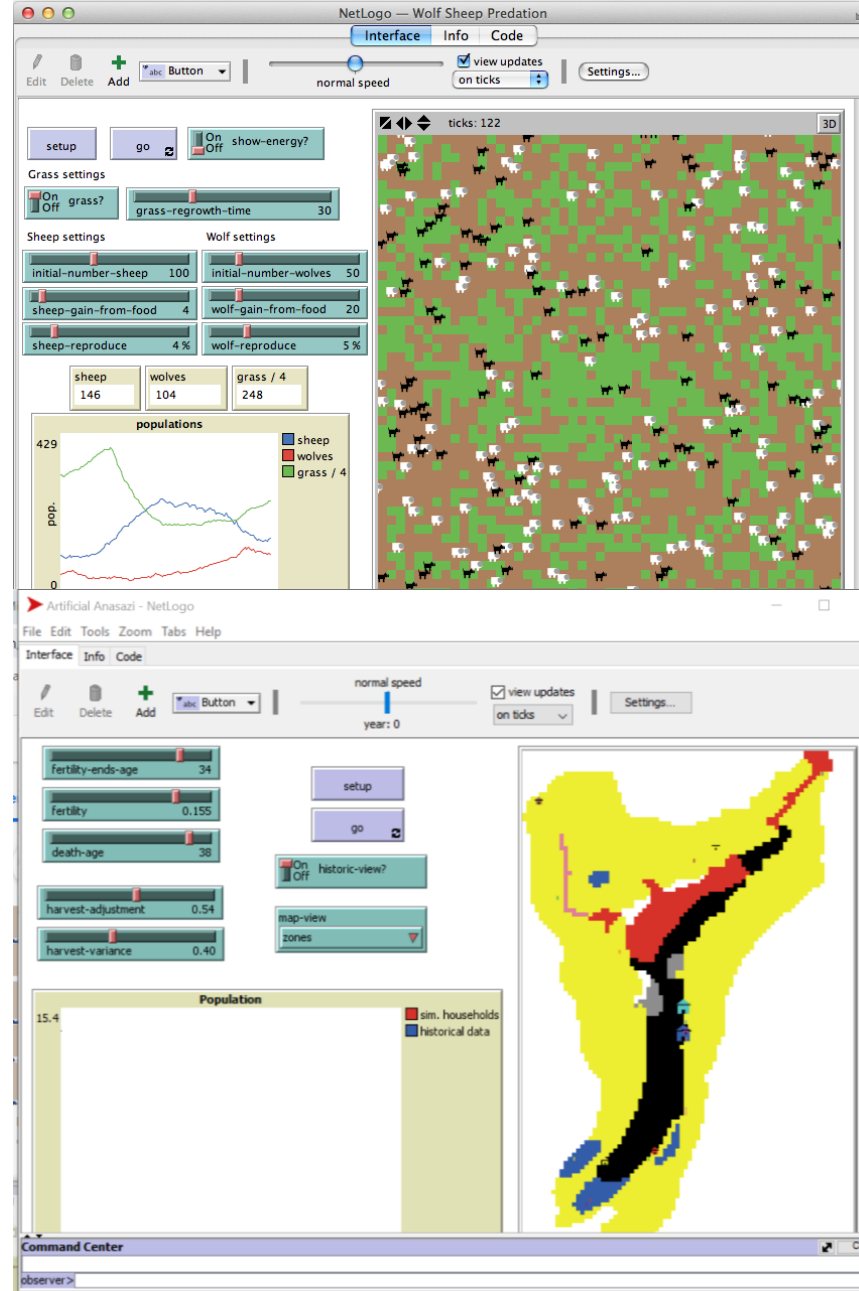
Wolf-sheep predation model (Netlogo Models Library)

Artificial Anasazi model (Netlogo Models Library)

ABM software

- Netlogo
  - Easy to learn
  - High computing power
  - Models library!
- Version 6.0.1
- https://ccl.northwestern.edu/netl ogo/download.shtml

Tutorial 1: Raw material procurement

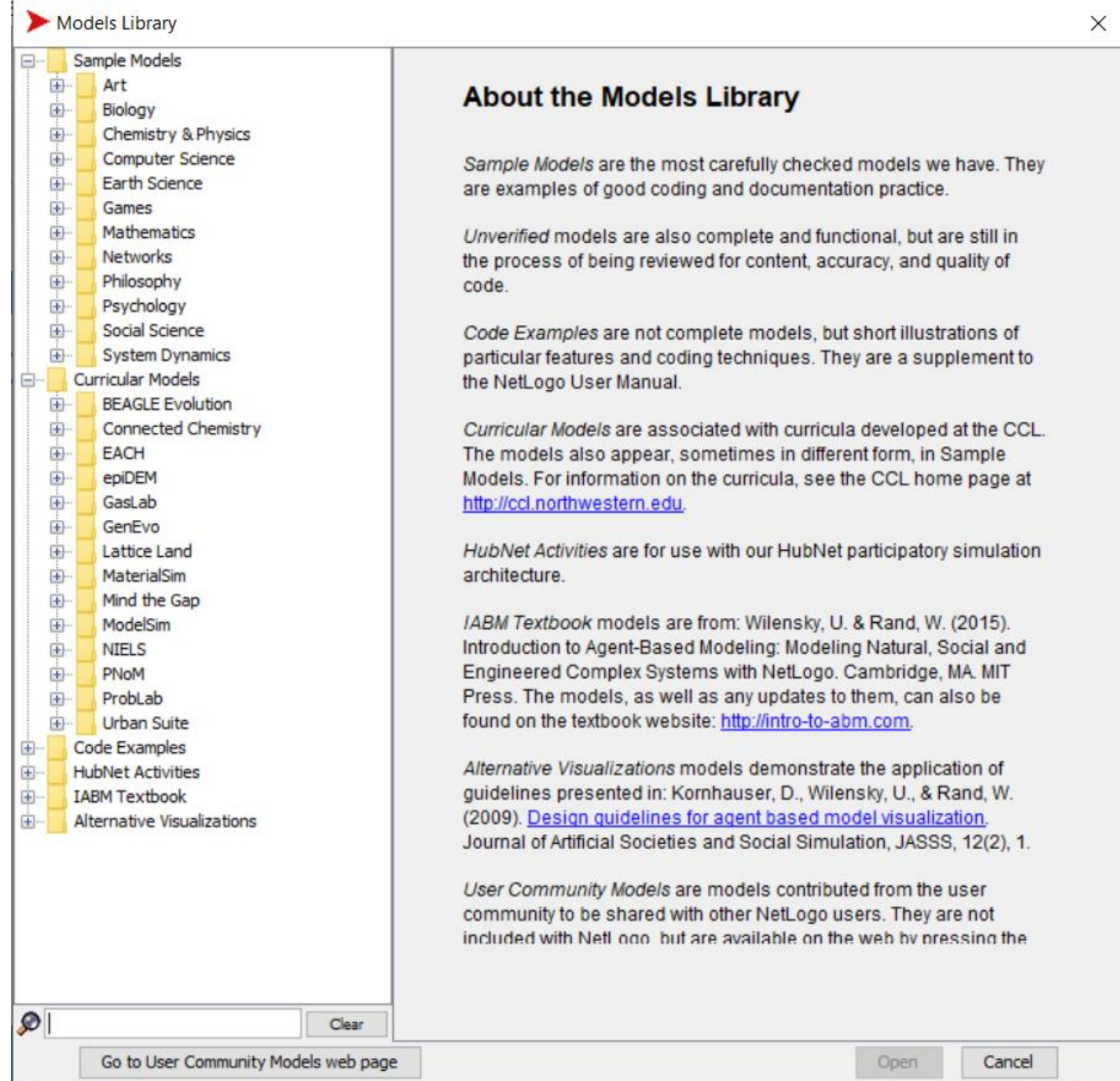- Model based on Brantingham (2003) Neutral Model of Stone Raw Material Procurement. *American Antiquity* 68(3), pp. 487-509.

- Model random raw material exploitation

- Romanowska, I., B. Davies, S. Crabtree and K. Harris. in press. "Agent-based Modeling for Archaeologists. A step-by-step guide for using agent-based modeling in archaeological research (Part I of III)." *Advances in Archaeological Practice.*
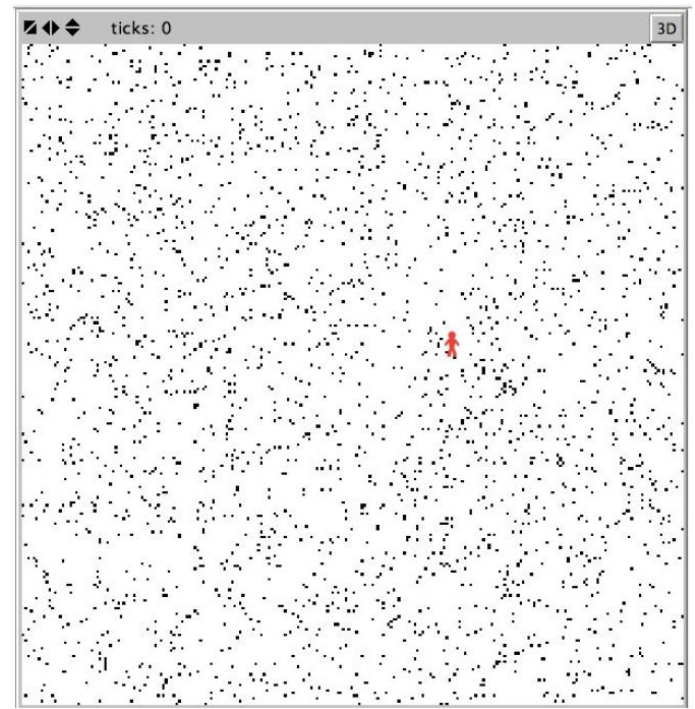

A NEUTRAL MODEL OF STONE RAW MATERIAL PROCUREMENT

P. Jeffrey Brantingham

Stone tool assemblage variability is considered a reliable proxy measure of adaptive variability. Raw material richness, transport distances, and the character of transported technologies are thought to signal (1) variation in raw material selectivity based on material quality and abundance, (2) optimization of time and energy costs associated with procurement of stone from spatially dispersed sources, (3) planning depth that weaves raw material procurement forays into foraging activities, and (4) risk minimization that sees materials transported in quantities and forms that are energetically economical and least likely to fail. This paper dispenses with assumptions that raw material type and abundance play any role in the organization of mobility and raw material procurement strategies. Rather, a behaviorally neutral agent-based model is developed involving a forager engaged in a random walk within a uniform environment. Raw material procurement in the model is dependent only upon random encounters with stone sources and the amount of available space in the mobile toolkit. Simulated richness-sample size relationships, frequencies of raw material transfers as a function of distance from source, and both quantity-distance and reduction intensity-distance relationships are qualitatively similar to commonly observed archaeological patterns. In some archaeological cases it may be difficult to reject the neutral model. At best, failure to reject the neutral model may mean that intervening processes (e.g., depositional time-averaging) have erased high-frequency adaptive signals in the data. At worst, we may have to admit the possibility that Paleolithic behavioral adaptations were sometimes not responsive to differences between stone raw material types in the ways implied by current archaeological theory.

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Tutorial 2: Human Dispersal Model

- Model based on Young & Bettinger (1995) The Numic Spread: A Computer Simulation, *American Antiquity* 57(1), pp. 85-99

- Model human movement across the globe

- Romanowska, I., C. Wren & S. Crabtree (In Preparation) 'Agent-based modelling for Archaeologists."
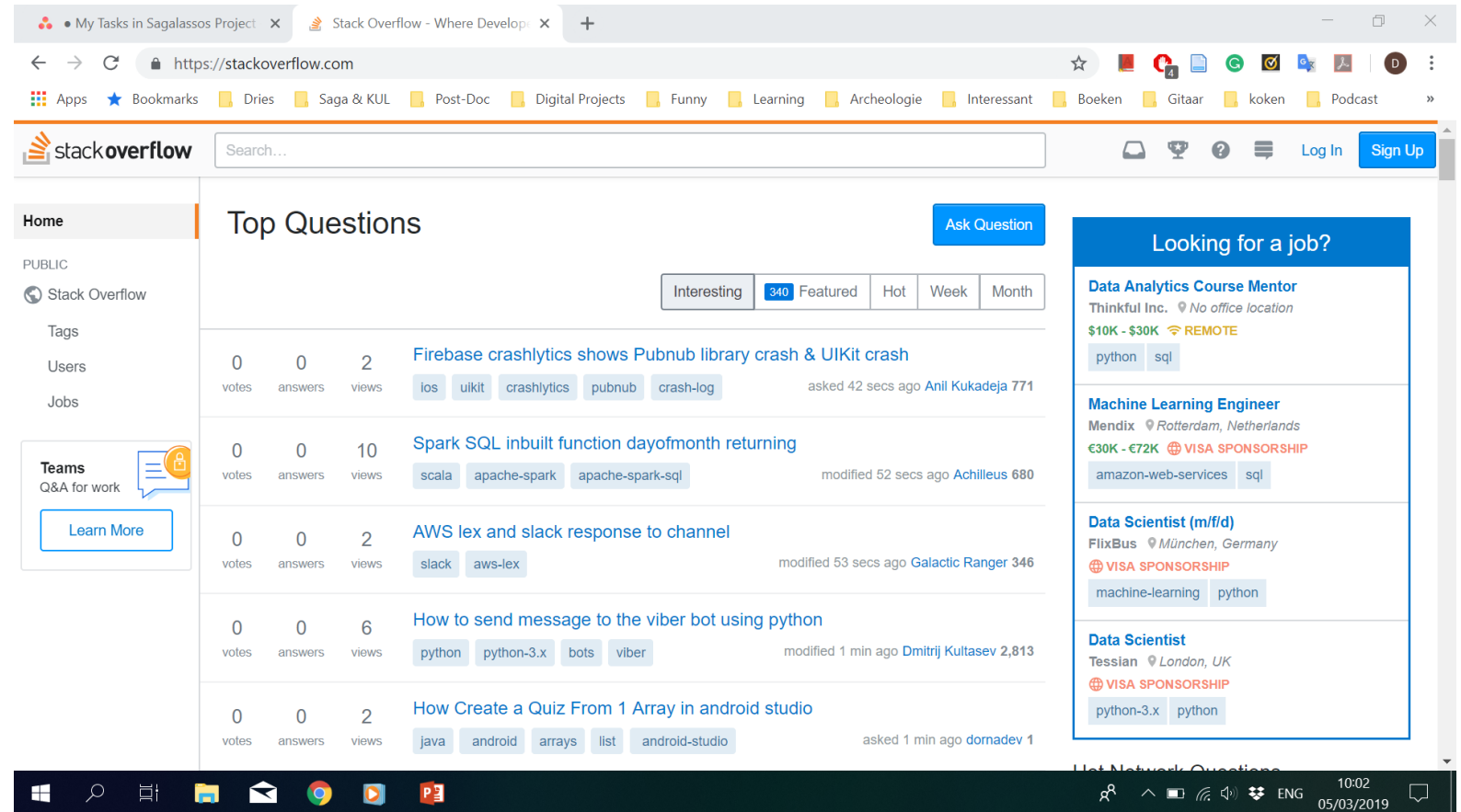
The problem

http://smbc-comics.com/comic/2013-07-18
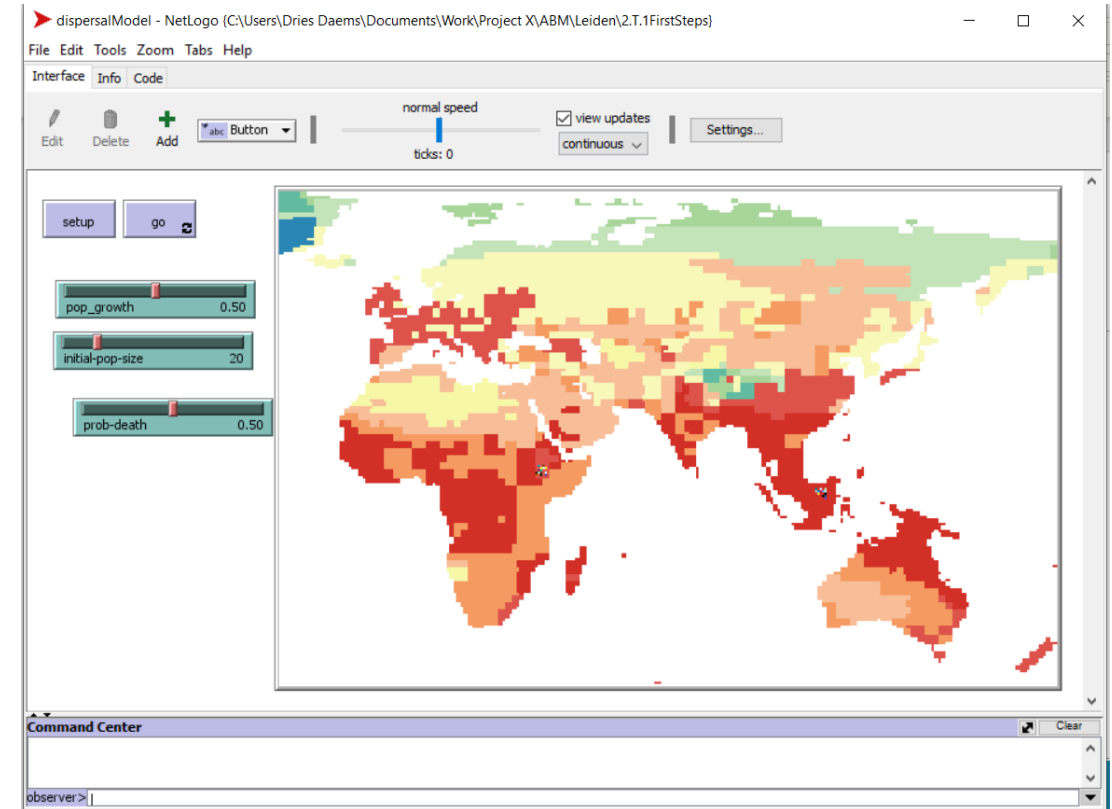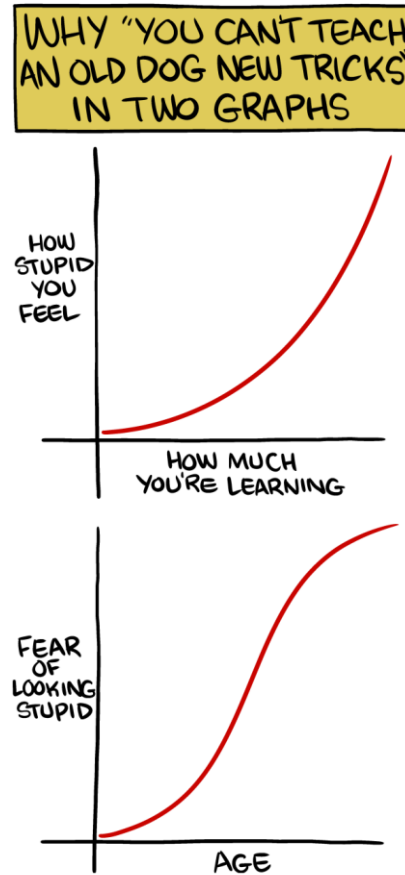
The solution

ASK!!

The secret

- Know where to ask!
  - Peers
  - Google it!
    - StackOverflow
  - Instructors/teachers

https://stackoverflow.com/

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Good luck!
Have fun!!
Questions? ASK!