# ODD: Fission-fusion cycles in *polis* formation

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## 1. Purpose

This model simulates processes of *polis* formation through the manifestation of fission-fusion dynamic in village communities.

## 2. Entities, state variables, and scales

* Two types of entities: persons and communities.
* Temporal resolution: 1 tick = 1 year
* Length of simulation run can be defined by slider which is standard set to 500 years
* Spatial resolution: 201x201 patches. Distances between communities are abstract but assumed to be easily bridgeable and no deterrent for inter-community movement.

State variables:

* People
  + Community-affiliation
  + Information
  + Partner
  + Partnered?
* Communities
  + Community-id
  + Community-size
  + Scalar-stress
  + Community-ideas
  + Status

## 3. Process overview and scheduling

1. Communities are randomly positioned
2. People are assigned to a community
3. People move around and interact within their own communities, exchanging information.
4. People reproduce
5. Growing communities must either undergo fission, subdividing in two village communities, or fusion by absorbing a nearby community and transforming into a *polis* community.

Process:

* Setup
* Move
* Interact
* Innovate
* Reproduce
* Fission
* Fusion

## 4. Design concepts

*Basic principles:* The model is based on the principles of settlement scaling studies, which posit that communities can be considered as social reactors, meaning that they amplify the increasing returns of social interaction. The effects of these interactions can be both positive and negative, resulting in community formation and socio-economic growth (growing communities) on the one hand, and scalar stress (splitting communities) on the other. These dynamics originate in social interactions on an intra-community level, but also have emergent effects on an inter-community level resulting in changing settlement patterns. A suitable framework to study these emergent effects on an inter-community level is the fusion-fission cycle approach.

*Emergence*: Fusion-fission dynamics on the community level are modeled as emergent outcomes of social interactions on the individual level. They therefore constitute an emergent phenomenon driven by intra-community dynamics, but manifesting on the inter-community level.

*Adaptation*: Communities adapt and set new properties when transforming from villages into polis communities, including scalar thresholds and territorial requirements

*Objectives*: The interactions between individuals increase the total amount of novel information generated in a community, however, this is not an explicit objective of the interaction processes. The intention is for the community-level processes to emerge out of the interactions without being hard-coded in the model.

*Learning:* No learning dynamics are included in the model.

*Prediction*:Agents do not predict future dynamics. Some degree of (bounded) knowledge of the environment is incorporated to facilitate interaction processes.

*Sensing*: Communities sense ‘scalar stress’ if their population size grows too much relative to the degree of social organization.

*Interaction:* People interact directly and exchange information with other people within the community. Interactions consist of an ‘encounter’ where two individuals recognize each other as an interaction partner, and the initiation of an information transfer, where packaged of information are exchanged and stored in each agent’s information list.

*Stochasticity*: Stochasticity is involved in:

1. The assignment of the number of people to a community
2. Random movement of persons
3. Selection of ideas from idea list to be exchanged during interaction
4. Generating innovation
5. Reproduction
6. Probabilities of fission events
7. Probabilities of fusion events

*Collectives*:Individuals aggregate in collective communities.

*Observation*. The data that are be collected from the ABM for further testing and analysis are population sizes and settlement patterns (in the form of rank-size distributions) that will be collected at the end of the simulation run.

## 5. Initialization

A number of sliders are initialized on the interface with following settings:

* Time limit with standard setting on 500
* 10 communities created
  + For each community, a population is created, based on a normal distribution with a mean of 100 set by the slider and standard deviation of 1/3 of the slider setting
* Scalar threshold for village communities is 200 persons
* Scalar threshold for polis communities is 1000 persons
* Population growth 10%
* Buffer zone for village communities 20 patches
* Buffer zone for polis communities 40 patches
* Fission and fusion probabilities both on 50%
* Innovation rate set to 10%
* Each community starts with:
  + scalar stress set to 0
  + an empty list for community-ideas
  + status “village”
* People are initialized with:
  + Partnered? Set to false and partner set to *nobody* 🡪 empty slate to initiate interaction
  + one unit of information represented by a random value between 0 and the total number of people of that community, added to the *information* list
* Patches and persons are assigned to a community as its, respectively, territory and population by calculating the closest community.

## 6. Input data

No external input data is used.

## 7. Submodels

* Setup
  + Create communities
  + Create population
  + Assign patches to
  + Assign people to communities
* Move
  + People move randomly within the community boundaries
* Interact
  + If people encounter each other (i.e. are in proximity), then:
  + Initiate contact
  + Exchange information
    - A virtual coin is tossed to decide whether the package of information of each participant in the interaction is transferred to the other
    - If yes: added to information list with a probability of mutation (i.e. the development of new ideas)
  + Update total information per community
    - Count of unique information values among population of a community
* Innovate
  + Percentage of total population across all communities is given chance to generate new ideas
* Reproduce based on limits set by scalar thresholds and population growth parameter
* Fission
  + If population < fission threshold, initiate new round of interactions
  + If population > fission threshold: probabilistic fission event
    - If space available: fission divides community and creates a new community elsewhere
* Fusion
  + If neighboring communities within buffer zone and with smaller population size: attempt to incorporate other community