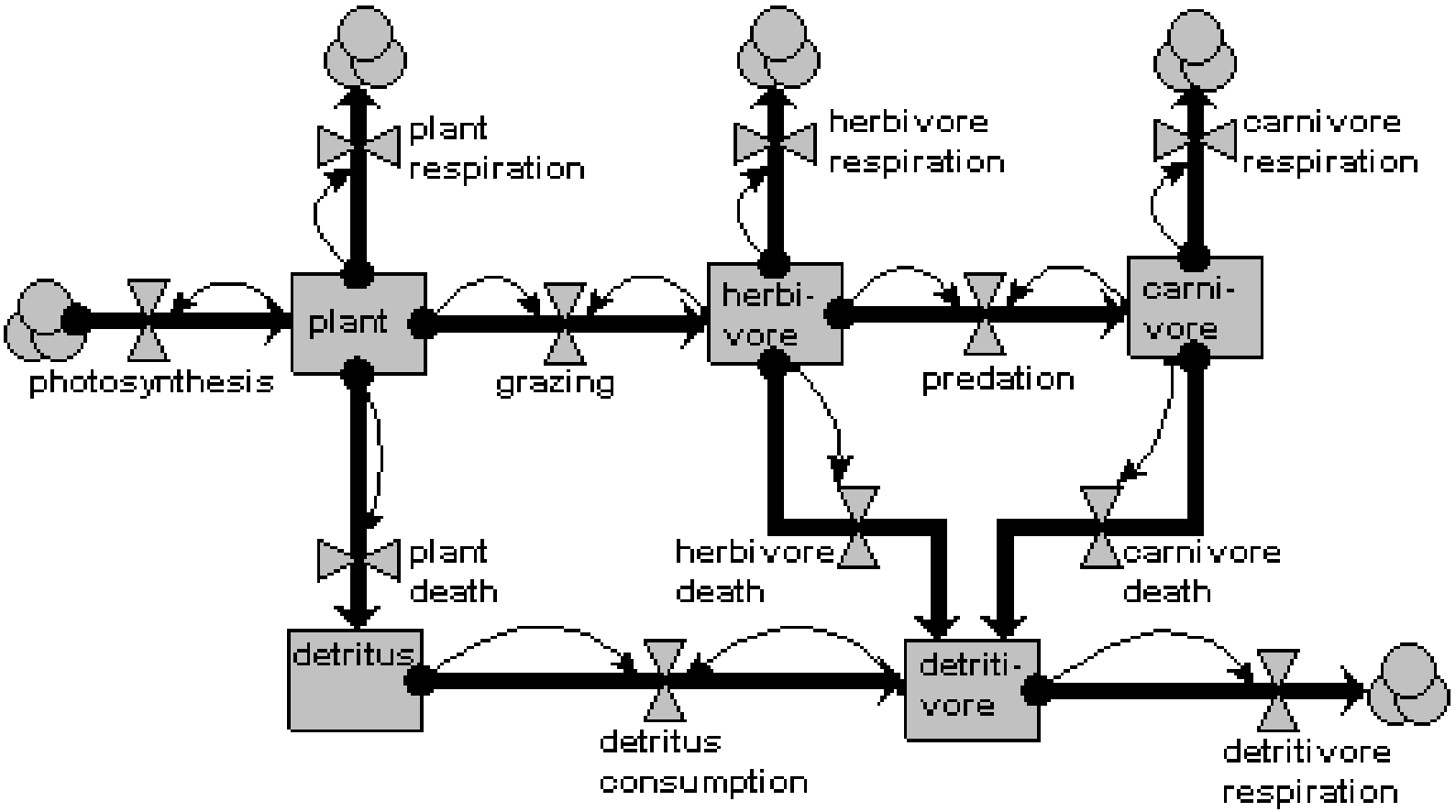
CMGCR

Ecosystem Modelling with System Dynamics

Ecosystem energy flow



System Dynamics Concepts

- Stocks – modified each timestep by flows
- Flows – rate of change
- Auxiliary variables – used for intermediate calculations

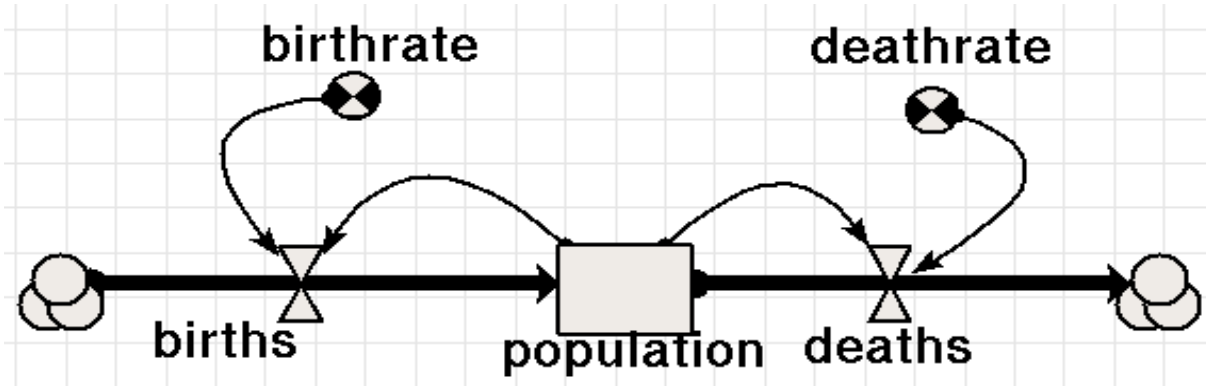
Population Dynamics
simple: statement

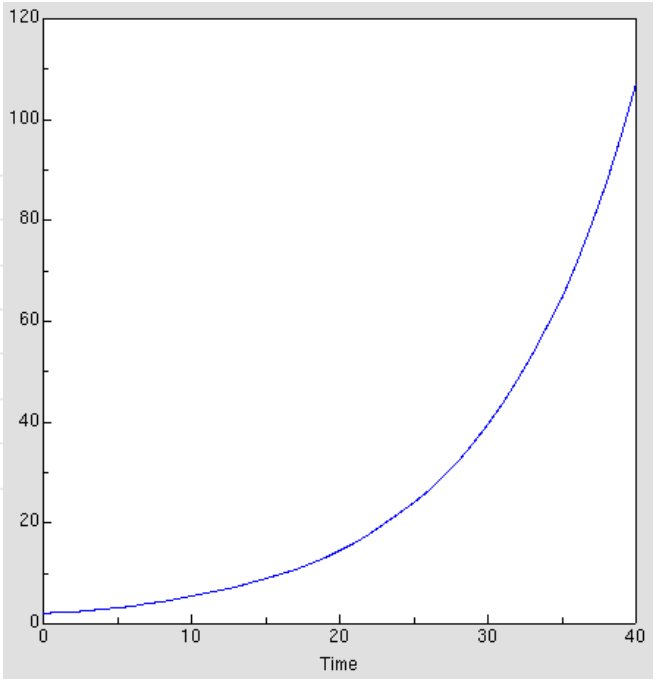
- The population is represented by a single state variable (stock), whose dynamics depend on two flows: a reproduction inflow and a mortality outflow. Both occur at a rate proportional to population size.

Population Dynamics
simple: components

- stock: population
- flows: births, deaths
- parameters: birthrate, deathrate
- Equations:
  - births = population x birthrate
  - deaths = population x deathrate
- initial conditions: population, birthrate, deathrate

Population Dynamics
simple: model



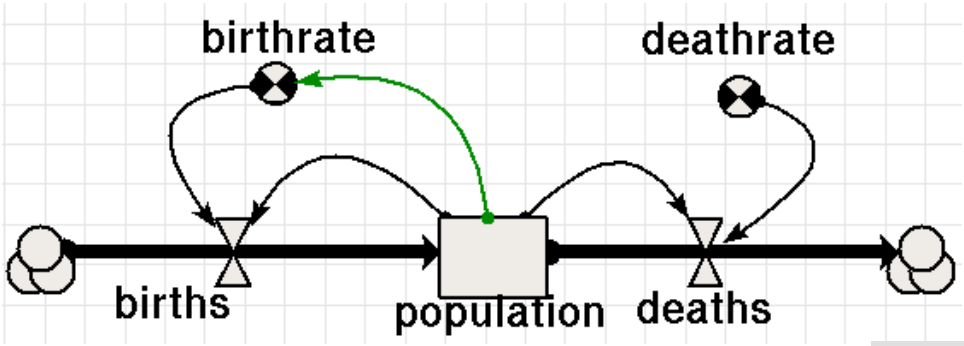


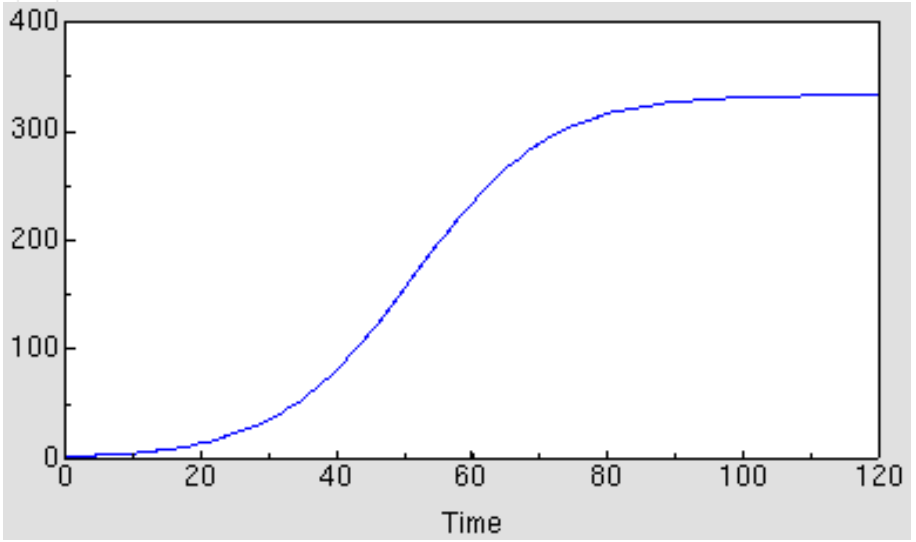
Population Dynamics
declining fertility: statement

- The simple model is modified by making the reproductive rate per individual depend on population size, decreasing as population increases.
- Birthrate =

$$0.3 \times (1000 - \text{population})/1000$$

Population Dynamics
declining fertility: model





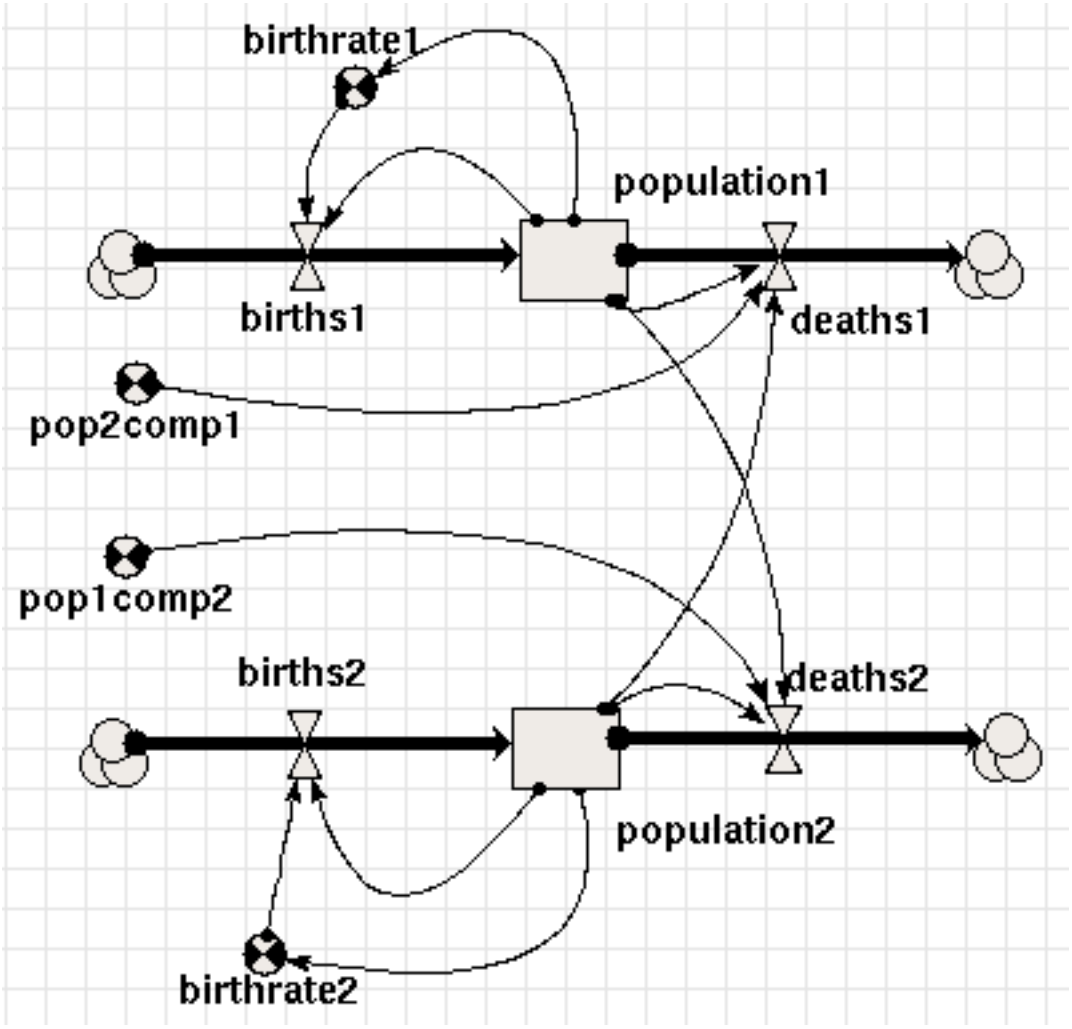
Population Dynamics
competition: statement

- Two-species competition. Each population's growth rate is reduced as its population gets bigger (the *declining-fertility* model). When a competitor is present, then the growth of each population is further reduced by the other. The outcome depends on the relative strength of within- and between-species factors.

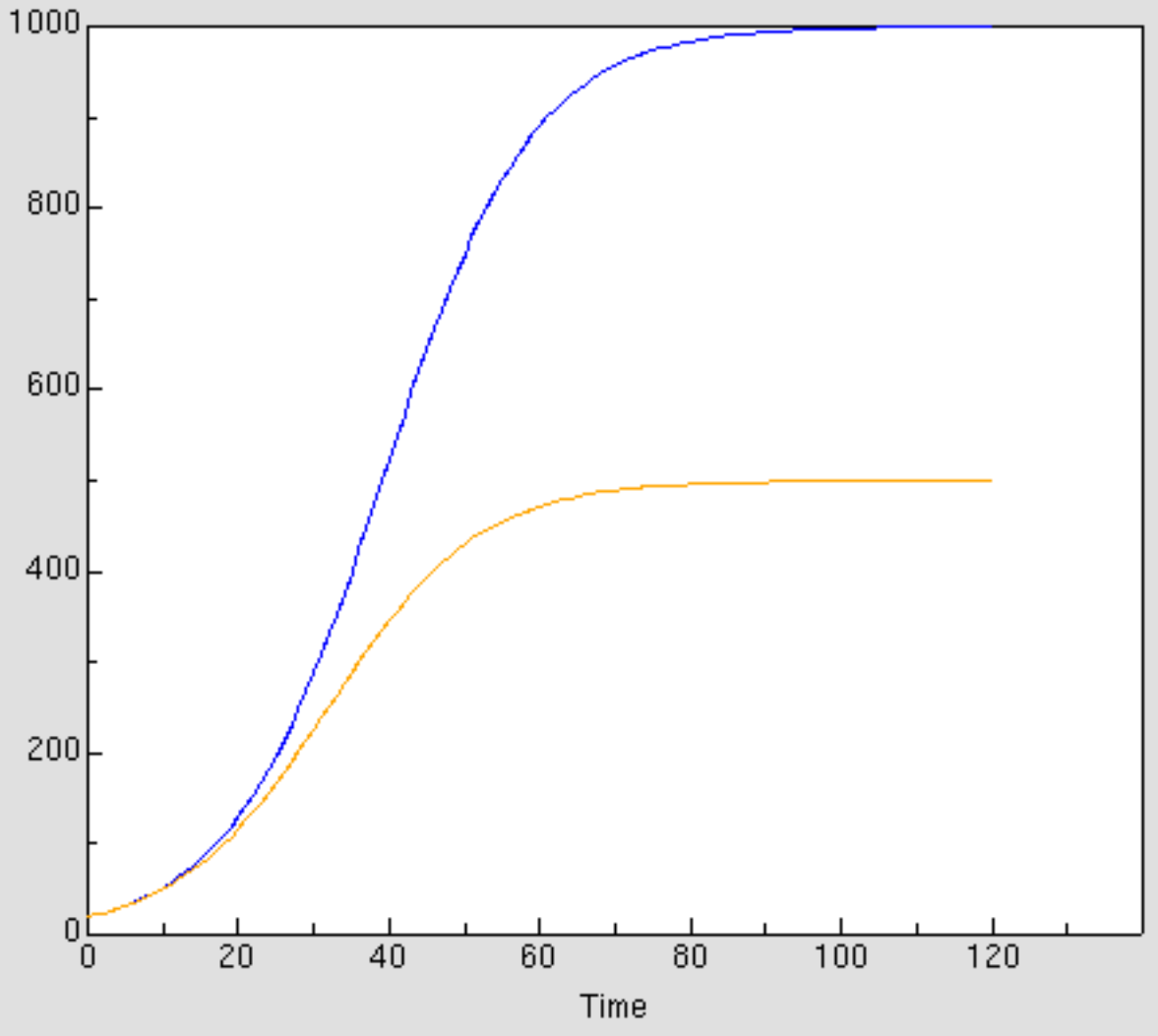
Population Dynamics *competition*: components

- Stocks: population1, population2
- Flows
  - each population as for *declining-fertility*
- Parameters
  - Additional parameters to reflect the increase in deaths due to the other species (alternatives?)

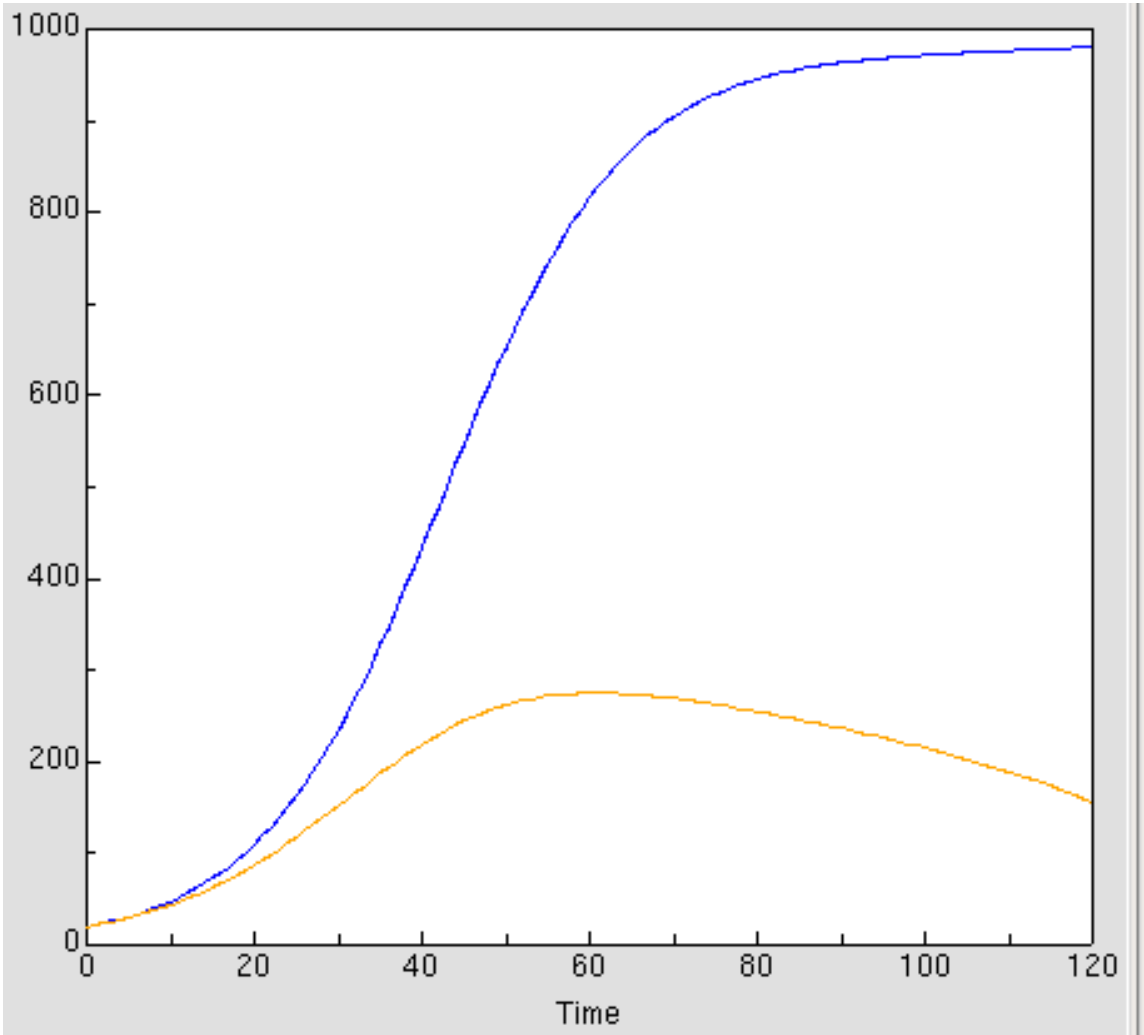
Population Dynamics
competition: model



Population Dynamics
competition: none



Population Dynamics
competition: suppression



Mathematical Formulation *competition*: statement and model

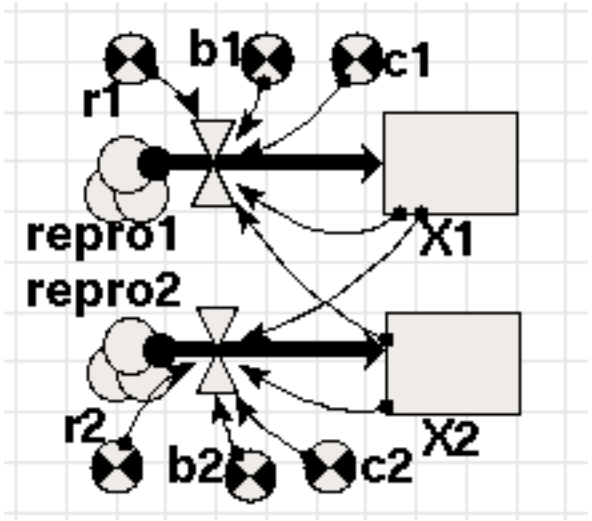
$$dX_1/dt = r_1.X_1.(1-b_1.X_1-c_1.X_2)$$
$$dX_2/dt = r_2.X_2.(1-b_2.X_2-c_2.X_1)$$

X_1, X_2 are the populations sizes of the two species;

r_1, r_2 are the intrinsic rate sof increase of the two species;

b_1, b_2 are the self-inhibition coefficients for the two species;

c_1, c_2 are the competitor's inhibition coefficient for each species.



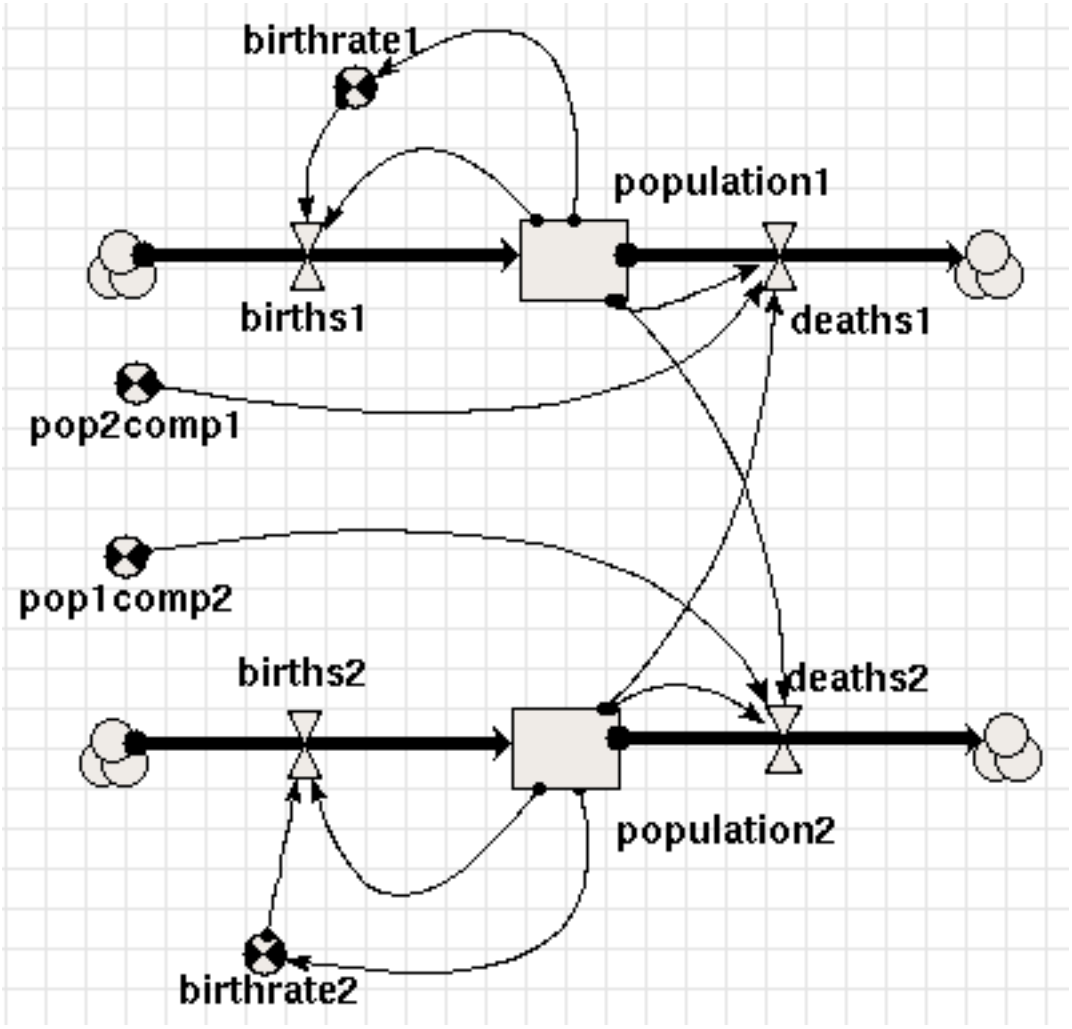
Predator-Prey exercise

- www.simulistics.com/tutorials/predprey
- Look at the first page, try to build your own model
- Then look at the suggested way to model
- ... including the mathematical variant

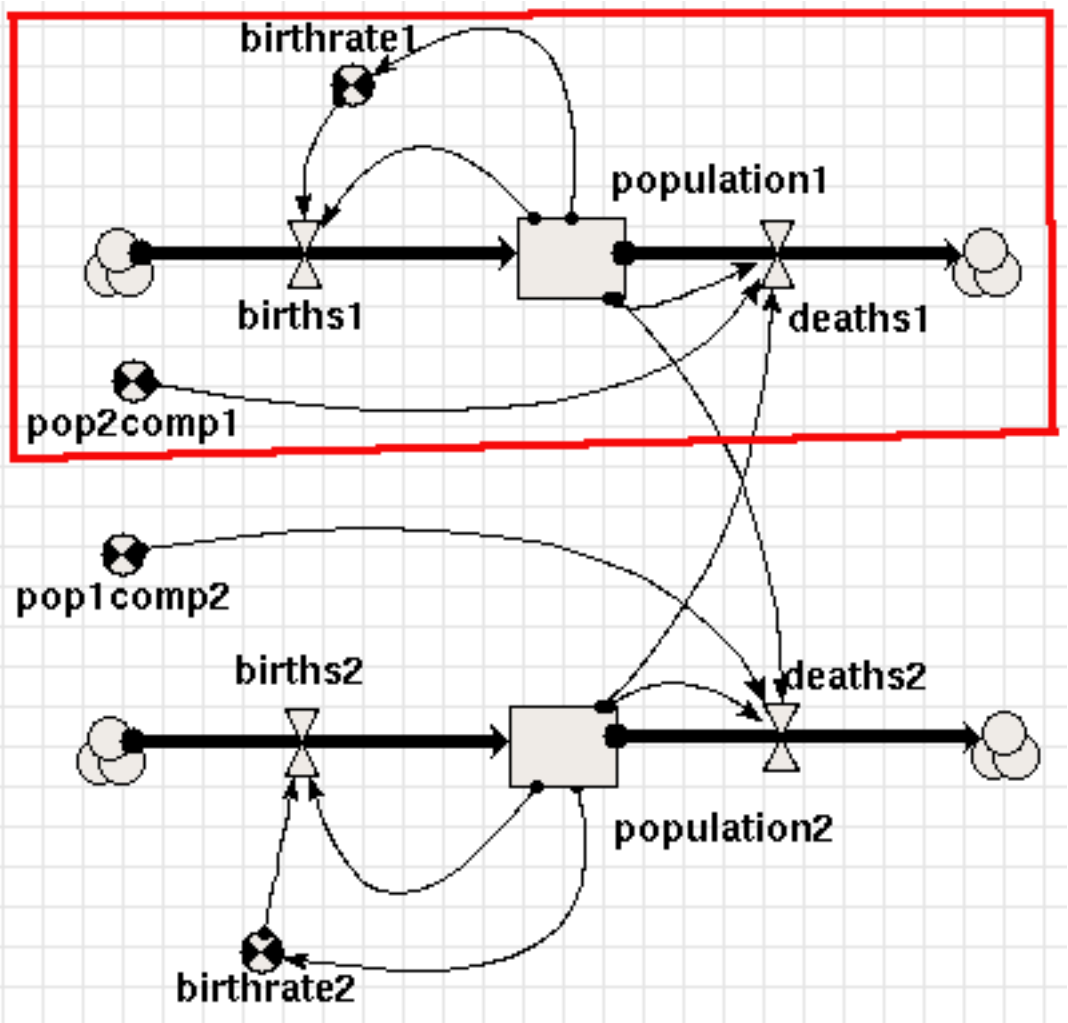
Submodels

- In many real-world situations, things to be modelled are repeated
  - Animals, trees, species, land patches, ...
- Simulators should support the concept of a submodel

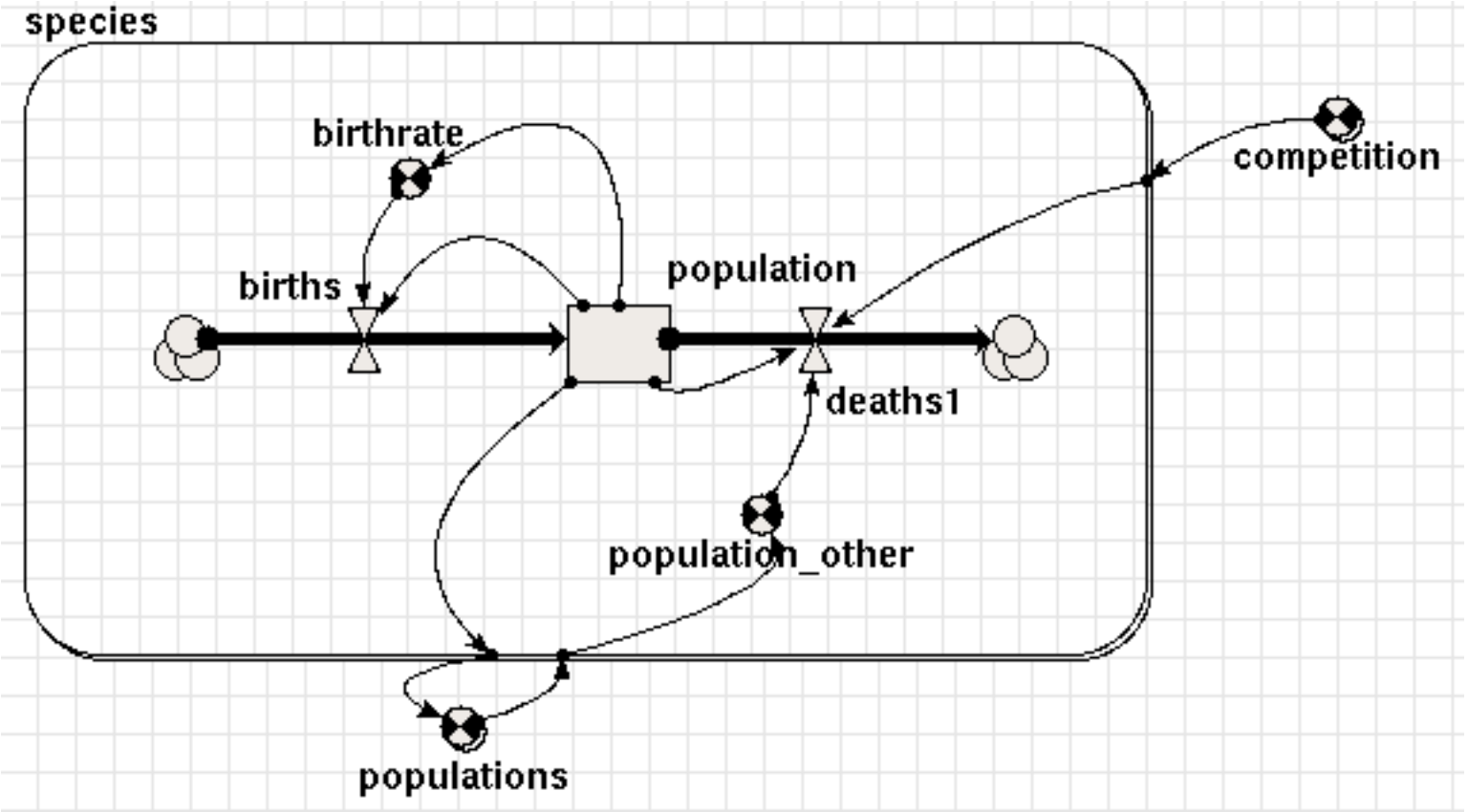
Population Dynamics
competition: model



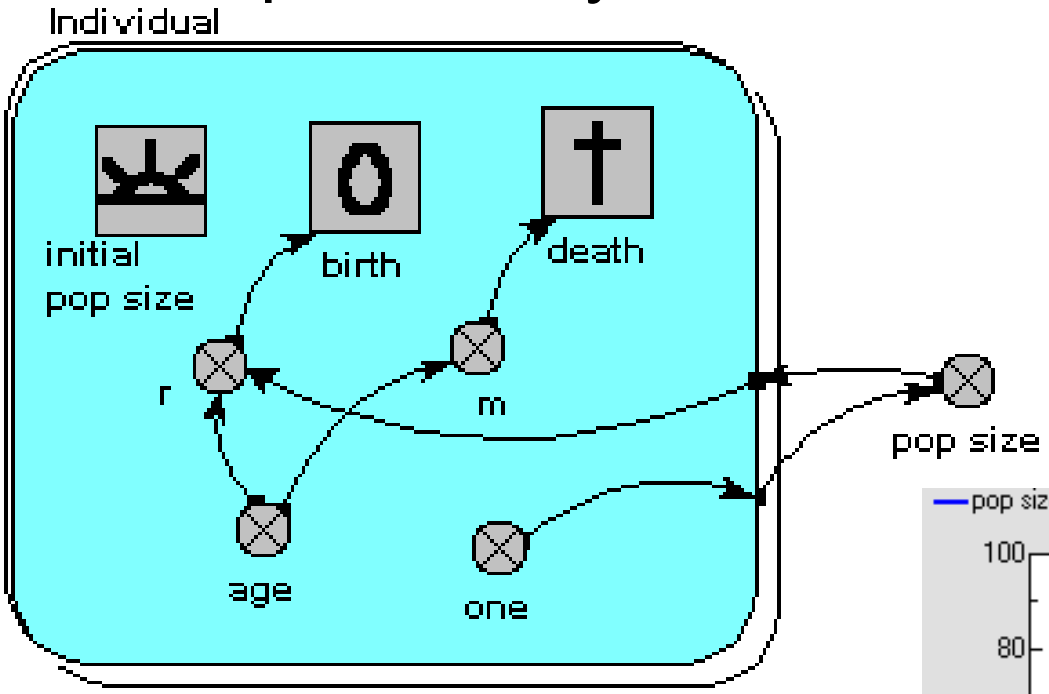
Population Dynamics
competition: model

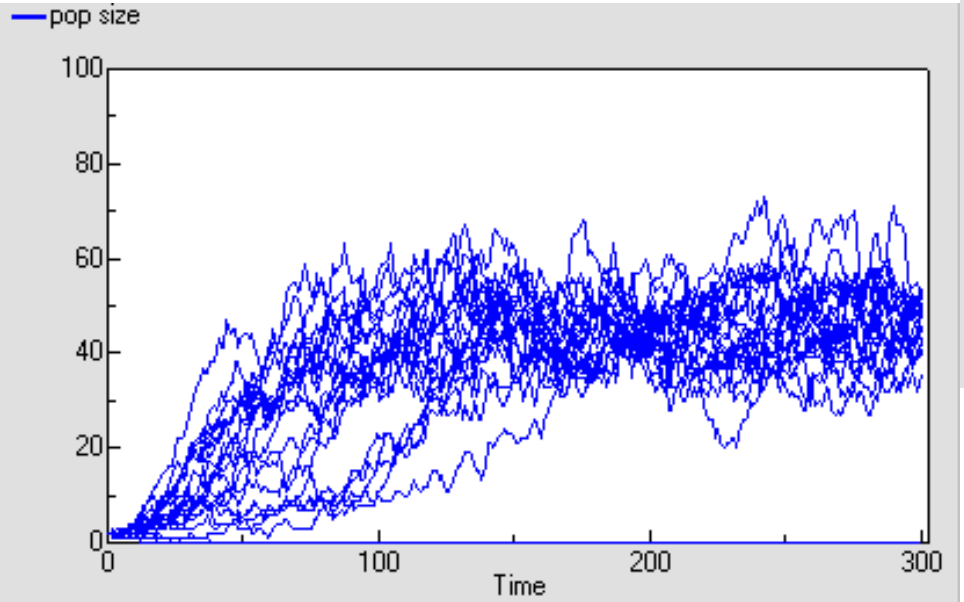


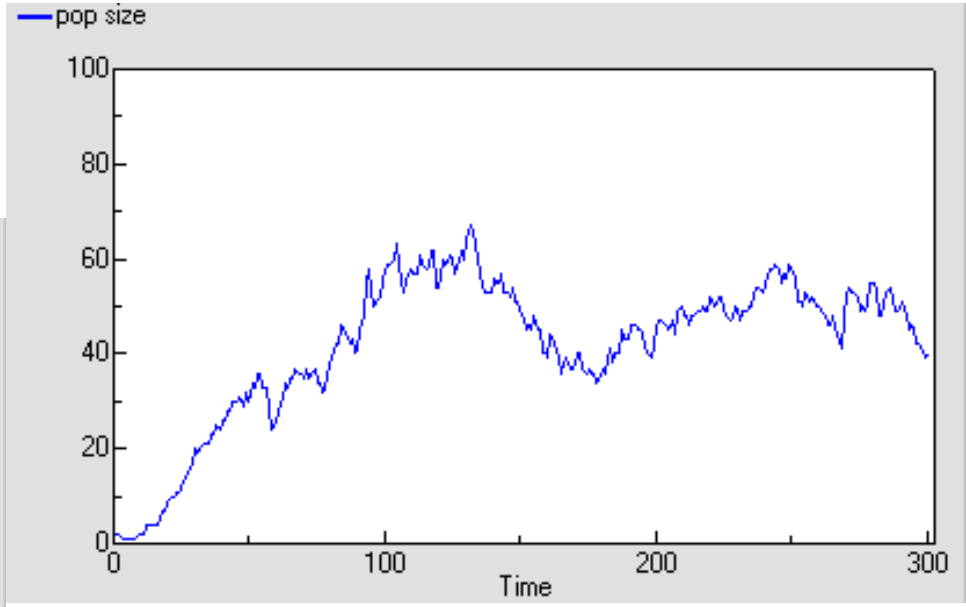
Population Dynamics
competition: submodel

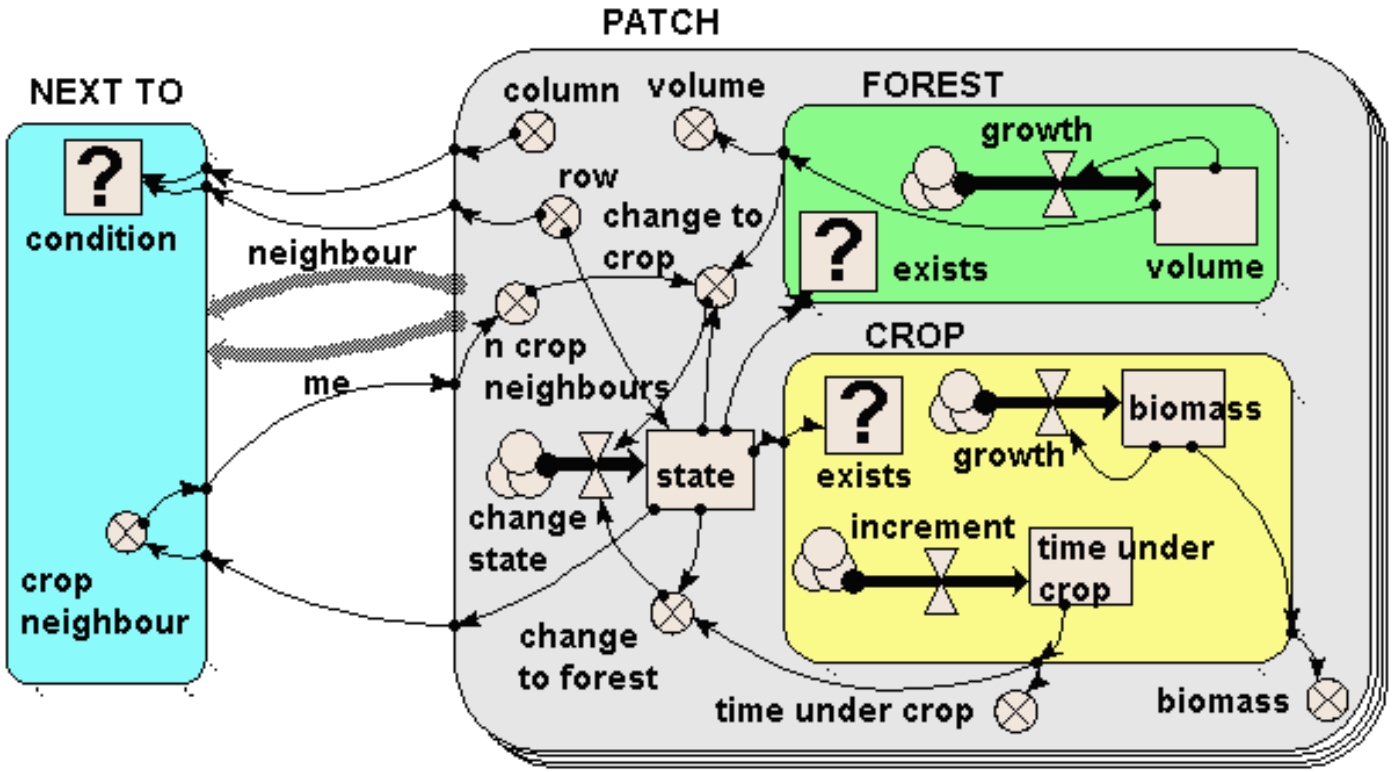


Population dynamics: individual-based

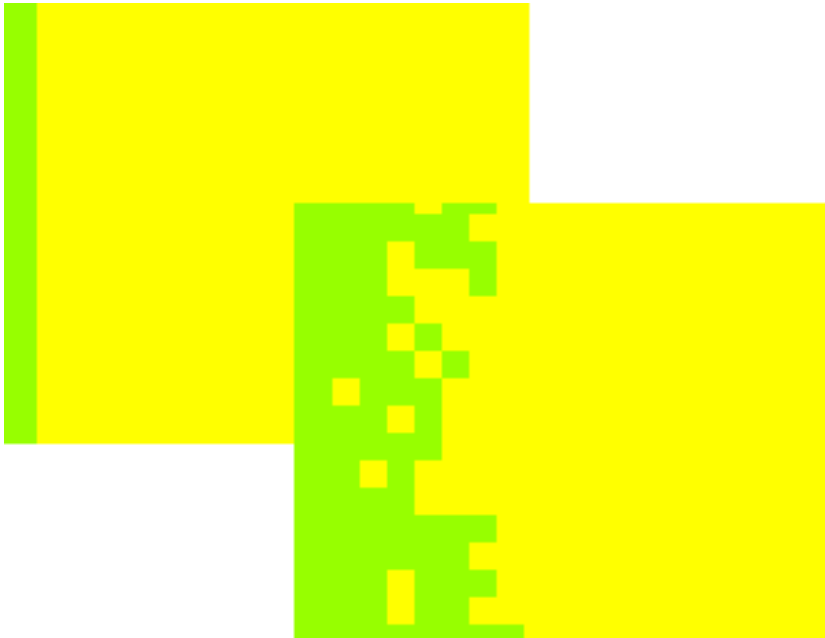




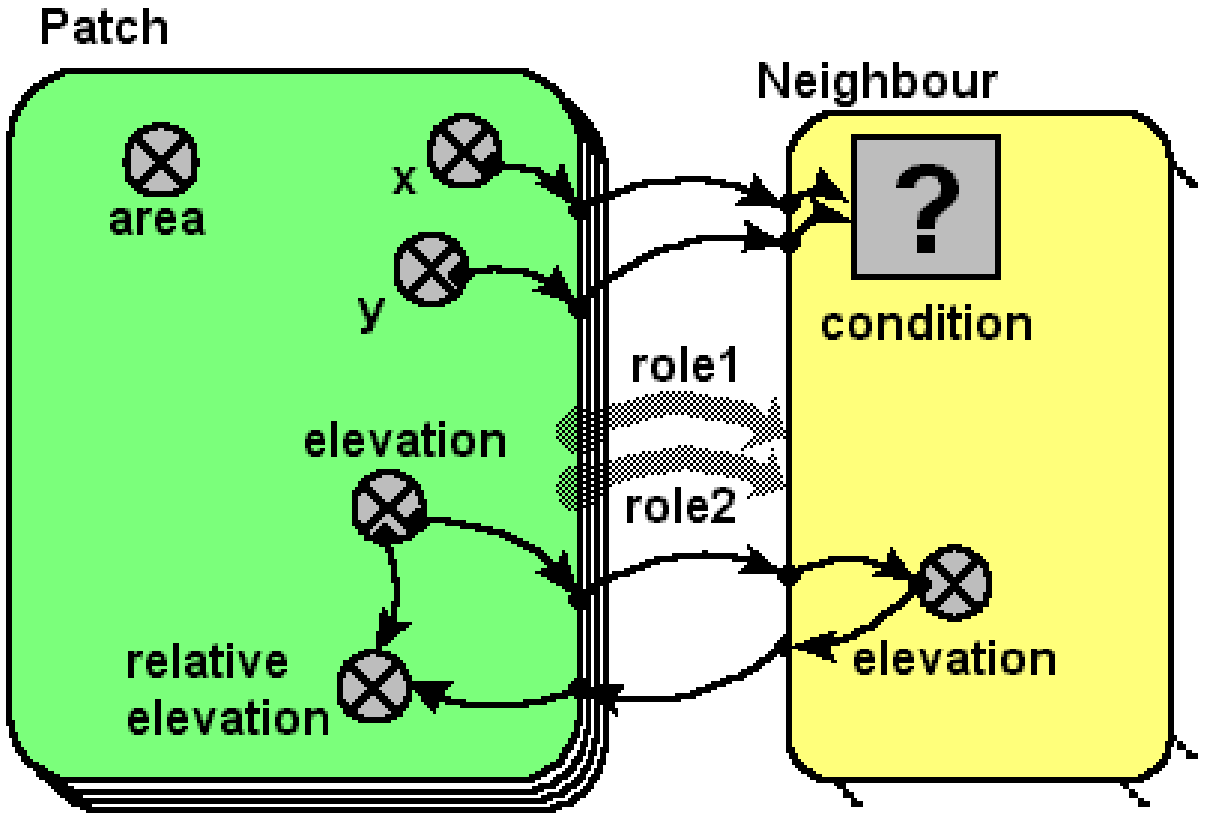




Modelling land-use change at the forest margin

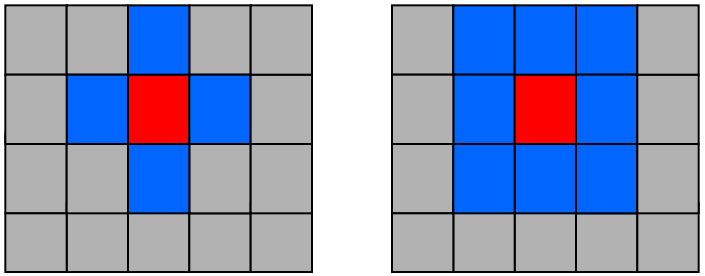


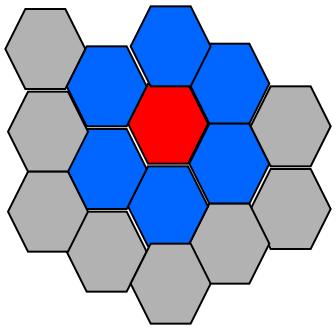
Spatial modelling: defining neighbour associations



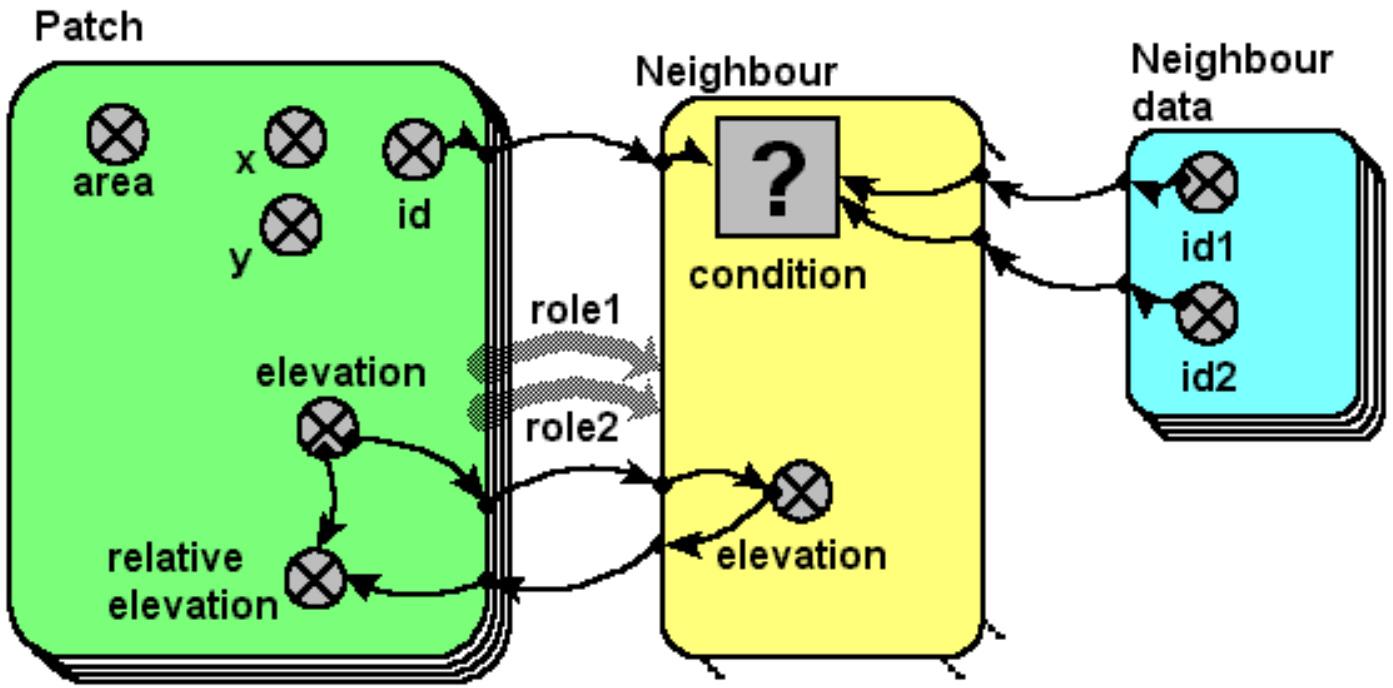
What type of neighbour association? Could be anything that can be inferred from x,y coordinates.

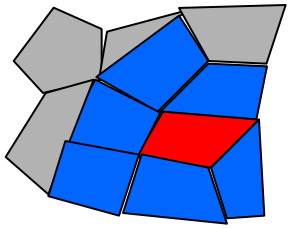
E.g. grid (4-nearest, 8 nearest), hexagon...

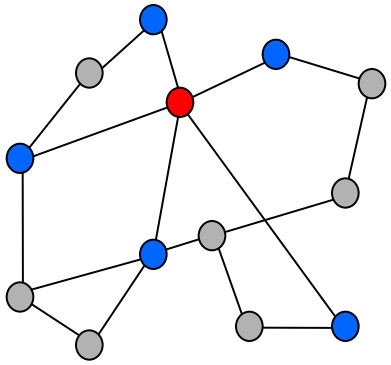




Spatial modelling: explicit listing of neighbours

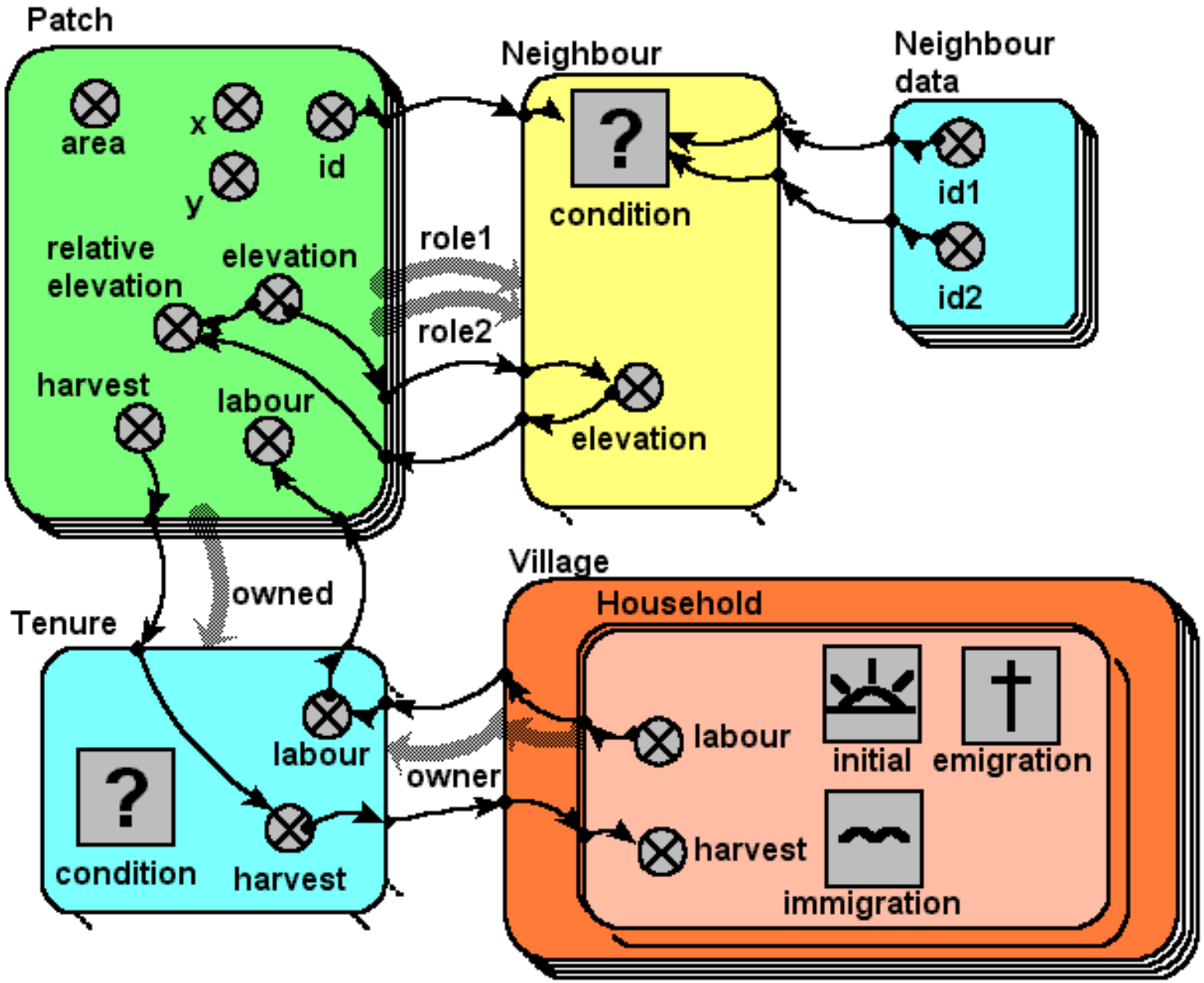




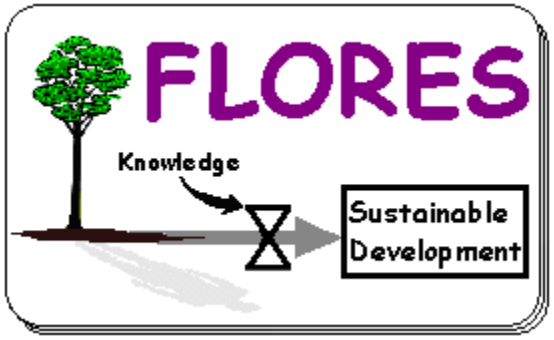


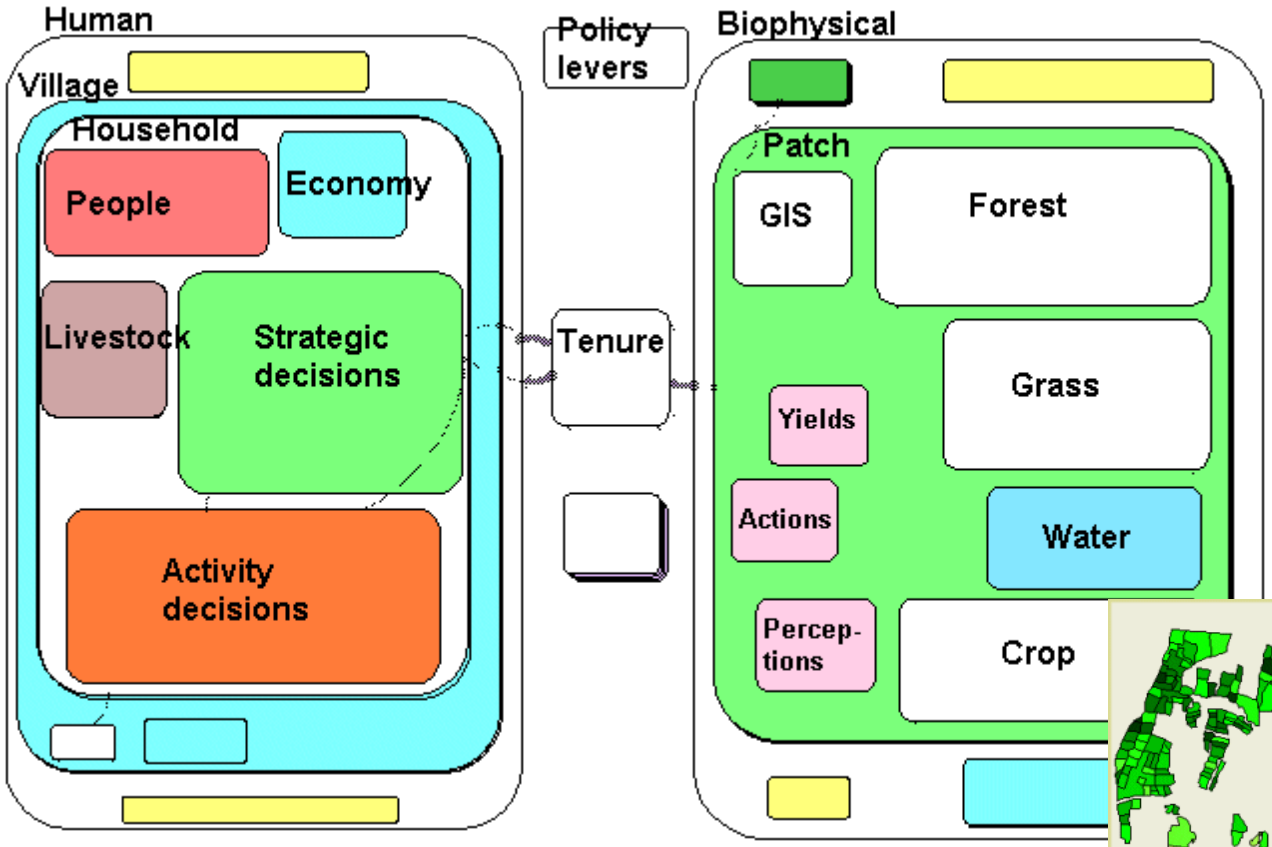
This could represent polygons (vector GIS), or networks.

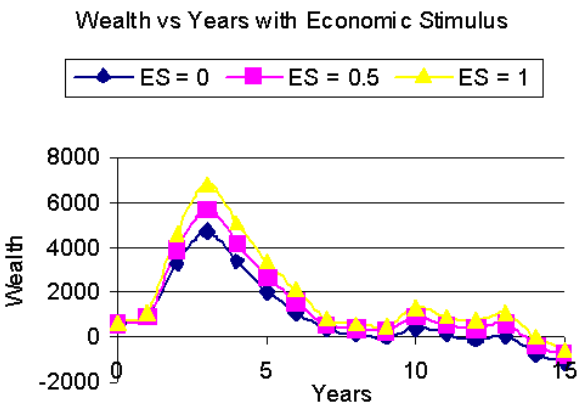
Including the human dimension

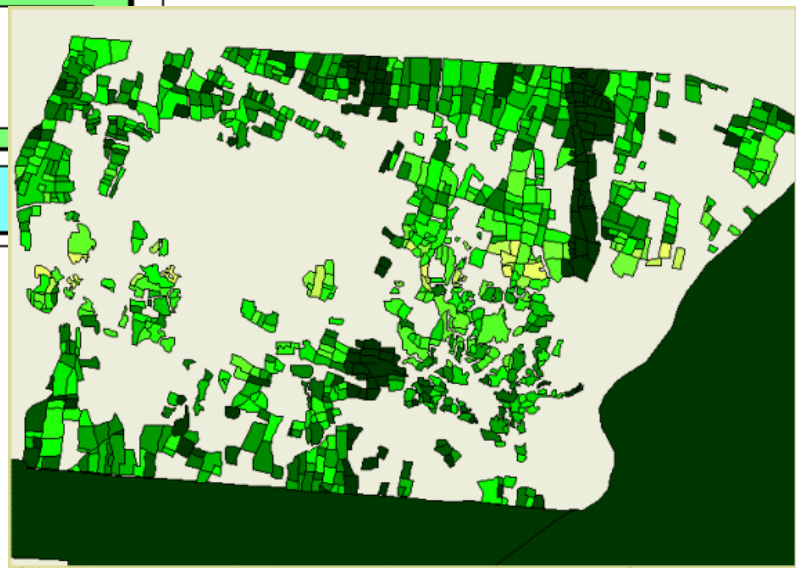


FLORES: modelling sustainable livelihoods at the forest margin









Tree Growth exercise

- www.simulistics.com/tutorials/trees
- Work through the tutorial