Discrete Intra-Agent Dynamics: Statecharts

Nathaniel Osgood

Using Modeling to Prepare for Changing Healthcare Needs

Duke-NUS

April 16, 2014

Discrete Agent Dynamics

- Frequently we can represent agent behaviour using as transitioning among a set of mutually exclusive and collectively exhaustive states in a “state chart”
- For a given simple statechart, the agent is in exactly one state at a time
- Fixed transitions between states define possible evolution
- The transitions between states occur instantaneously, based on some condition

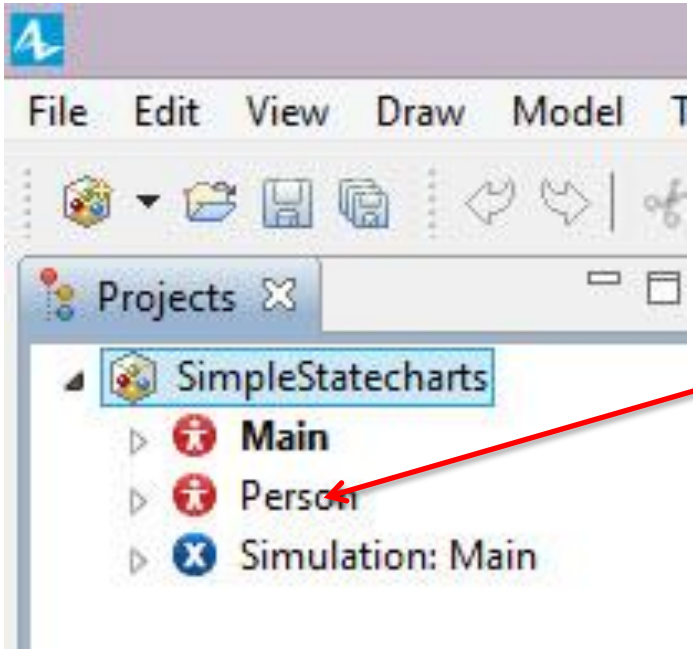
Hands on Model Use Ahead

Load Previous Built [& Provided] Model:

HeterogeneousAgents

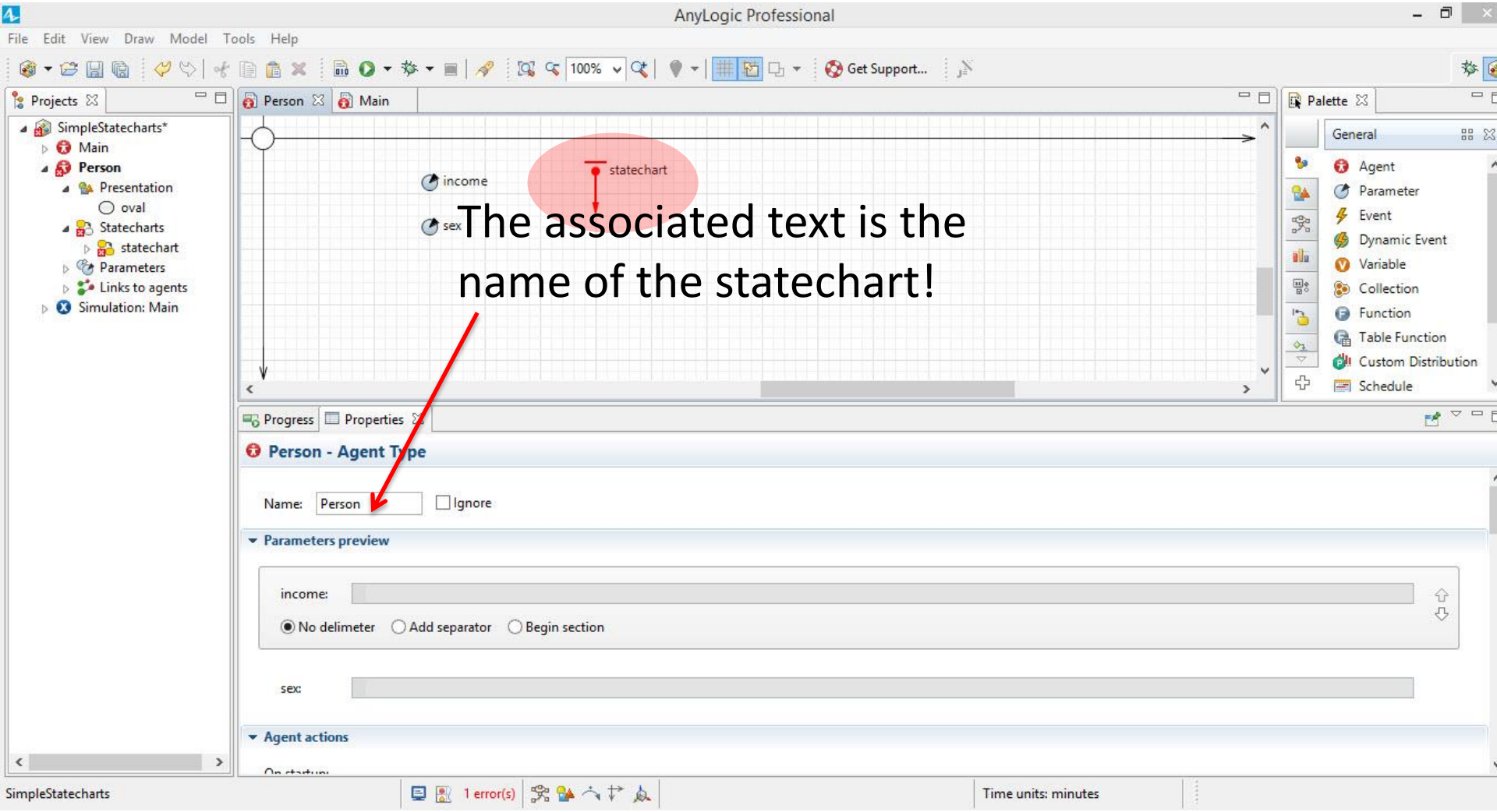
Save as **SimpleStatecharts**

Open Up Canvas for “Person”
(In case it is not already open)

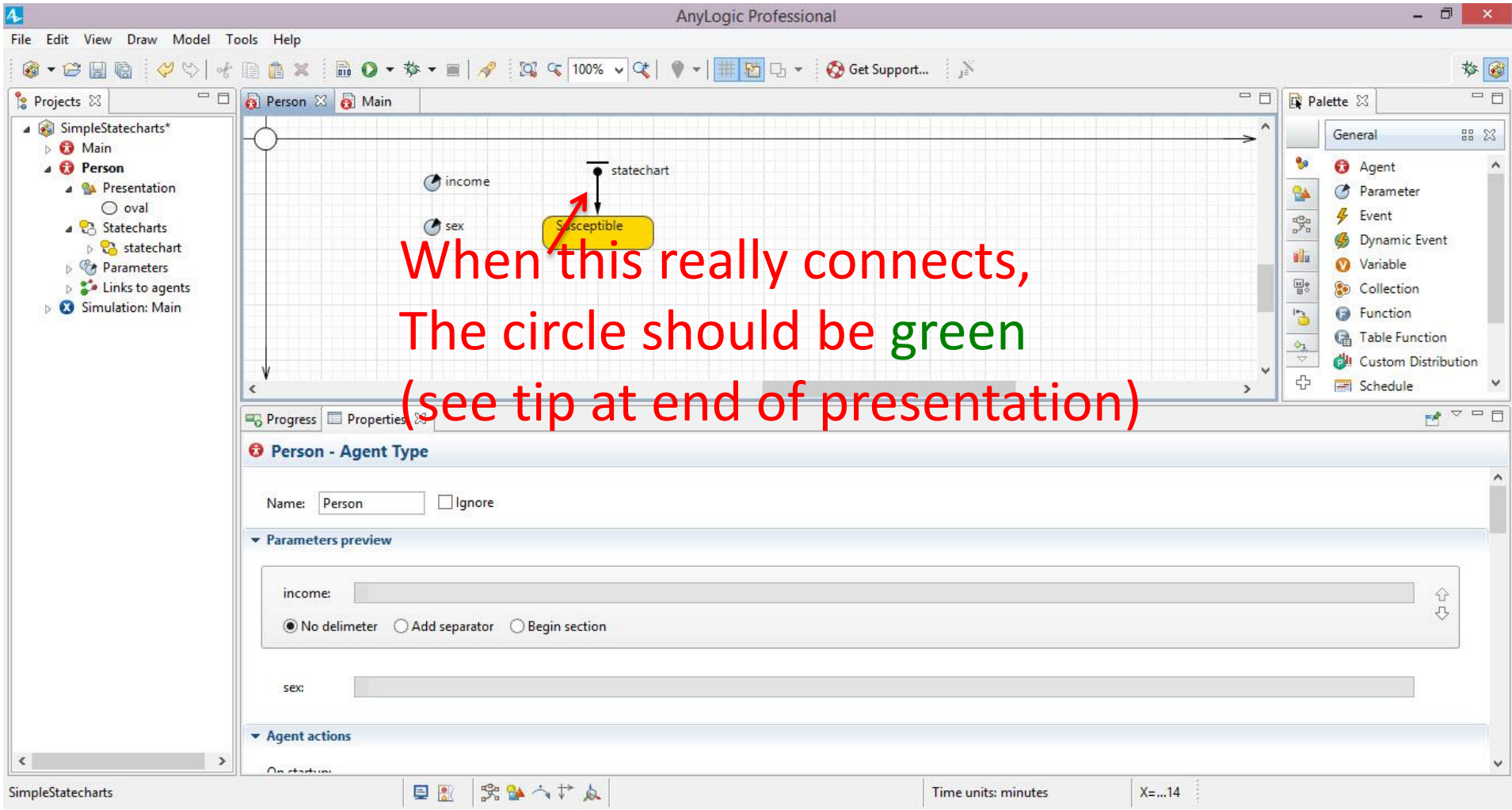


Double Click Here

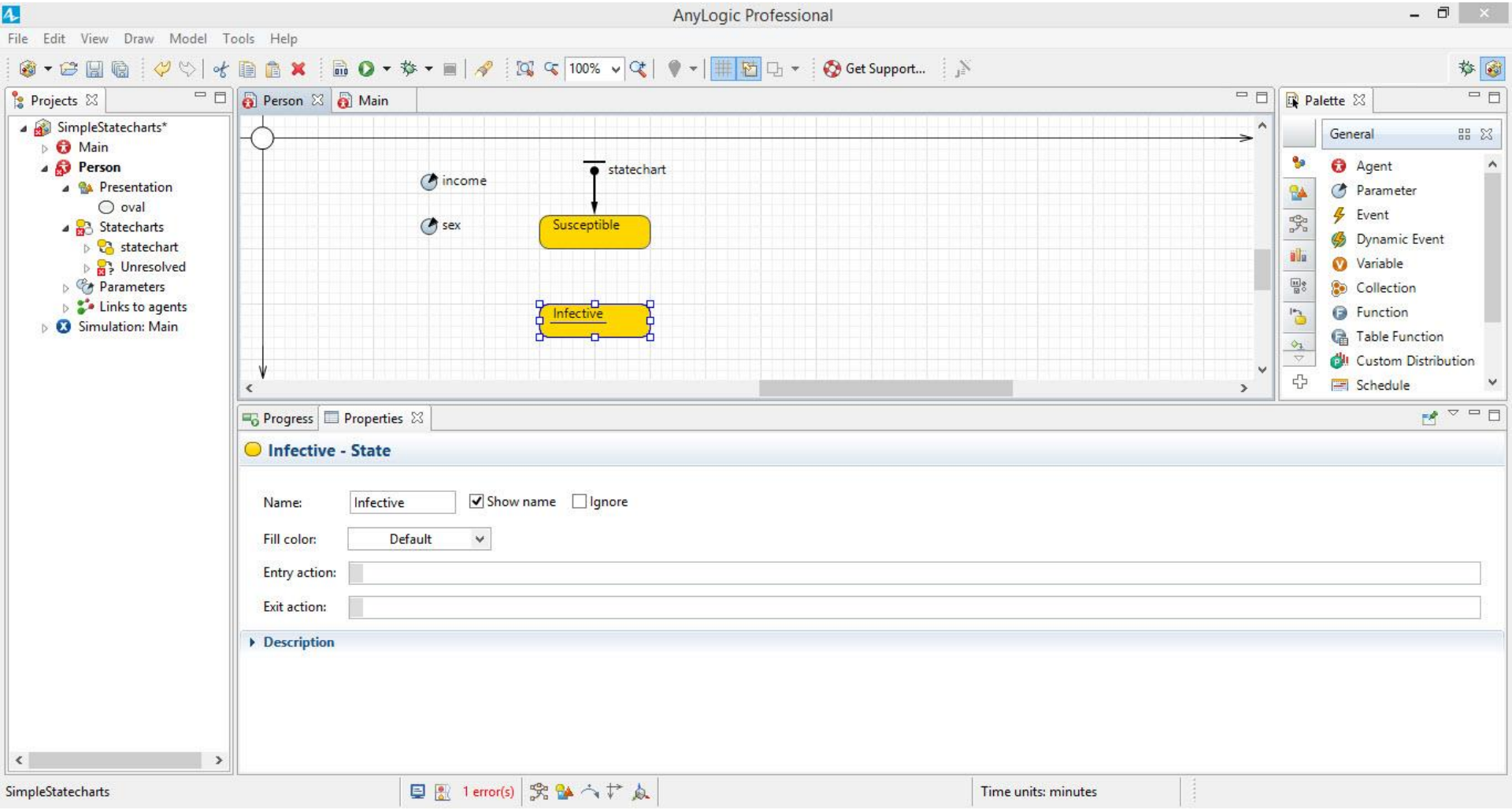
Add a Statechart Entry Point



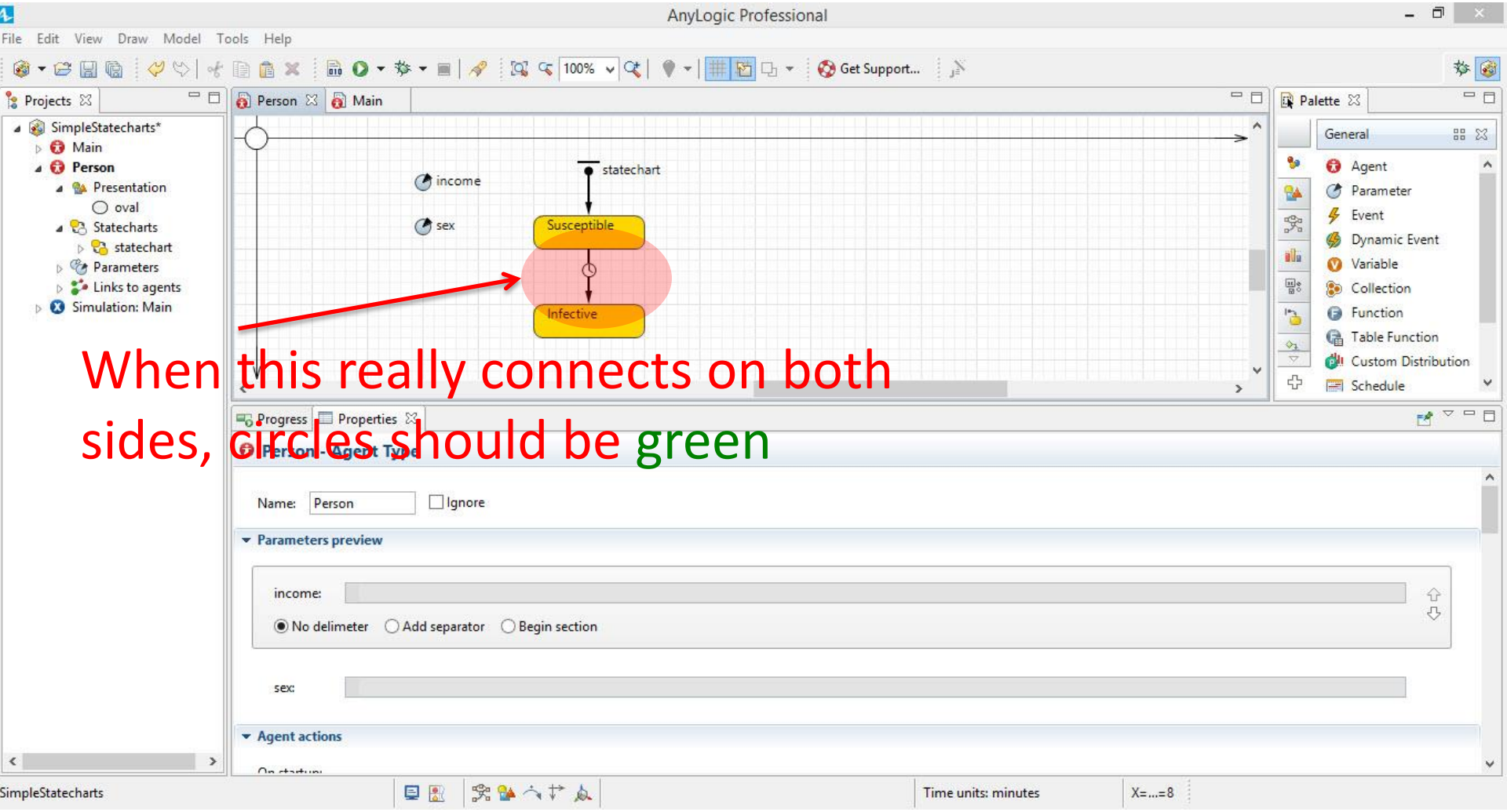
Add a Initial State



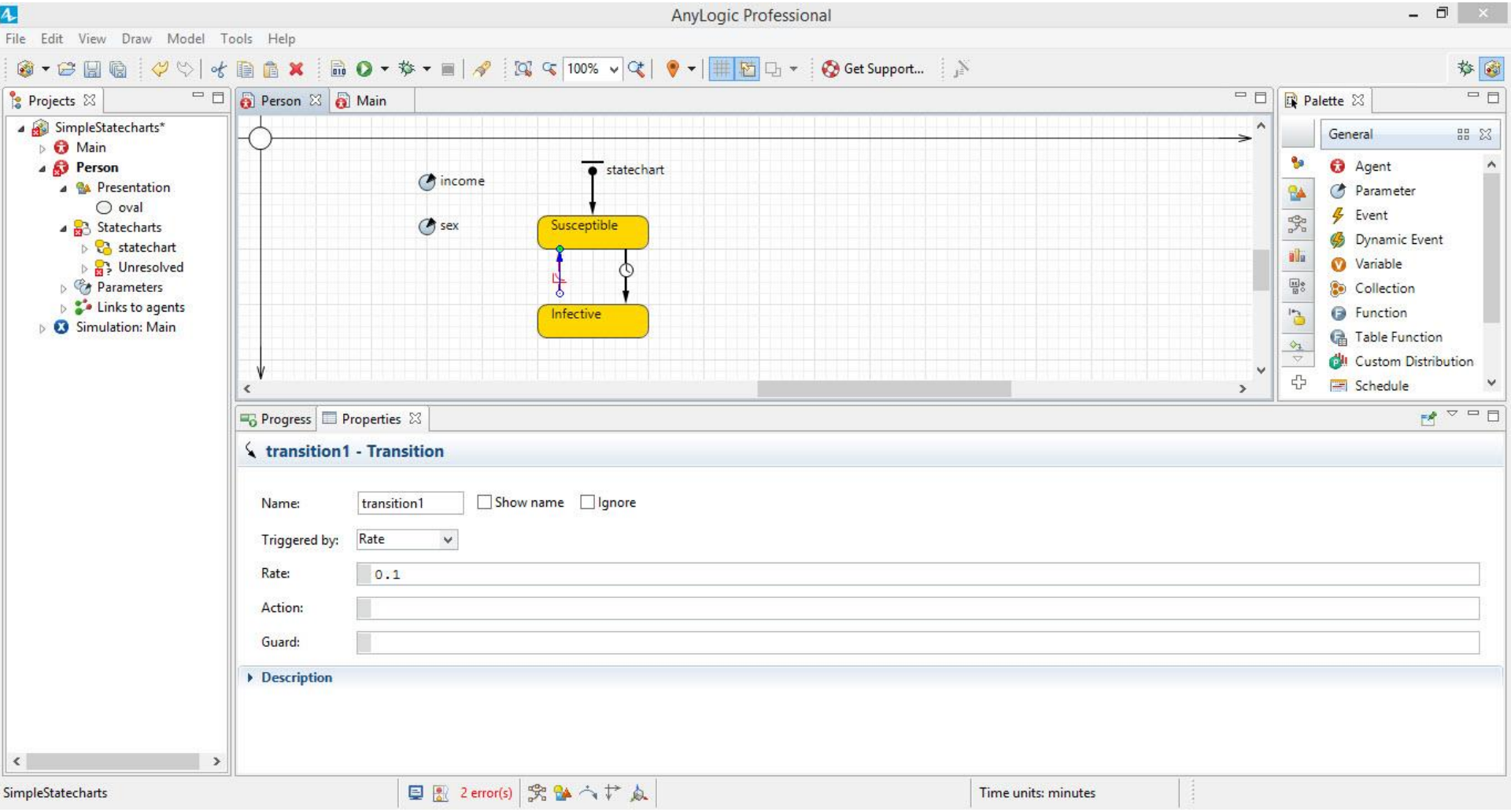
Add a New State



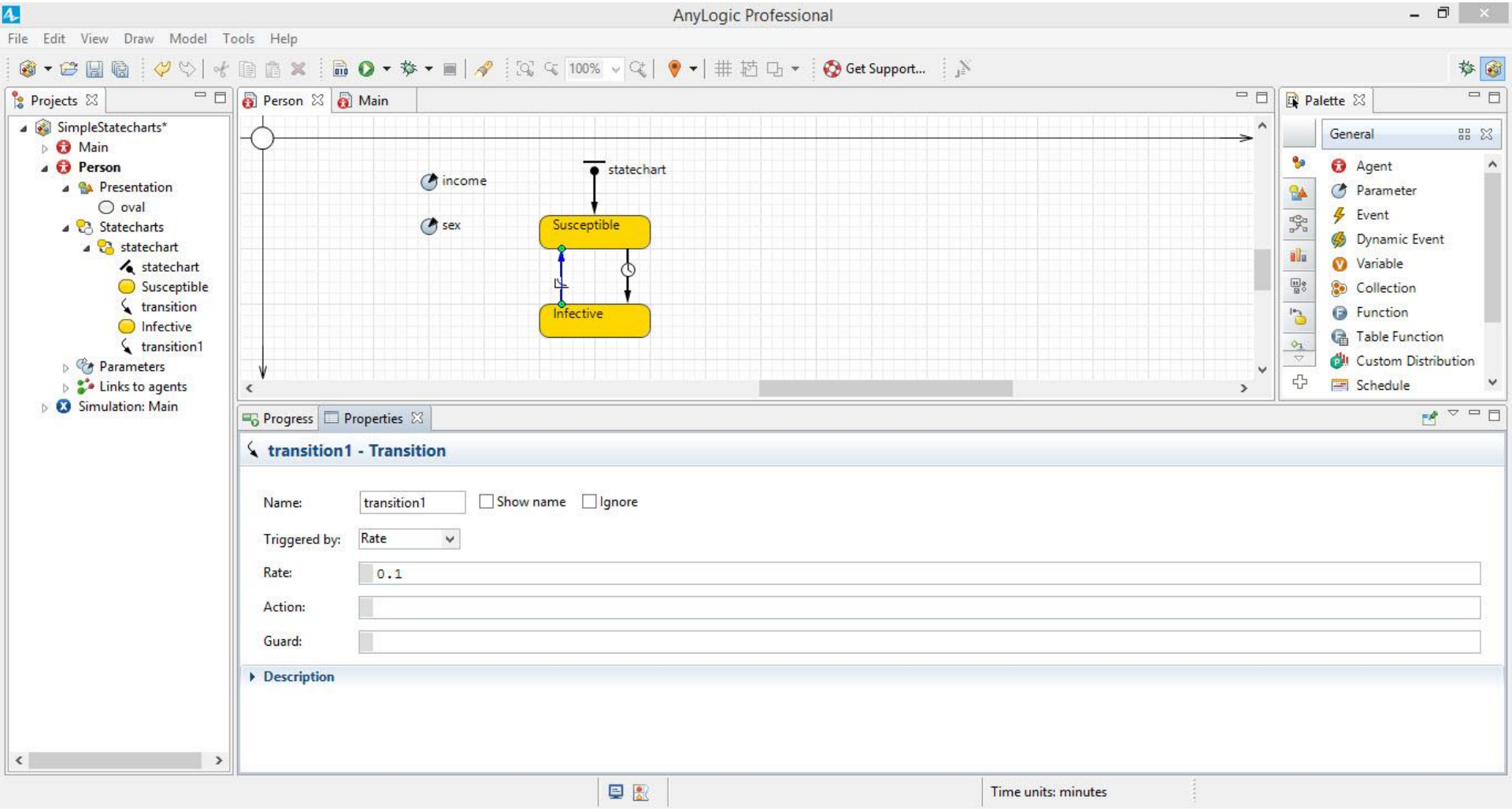
Add a Transition



Tip: Beware Loose Connections

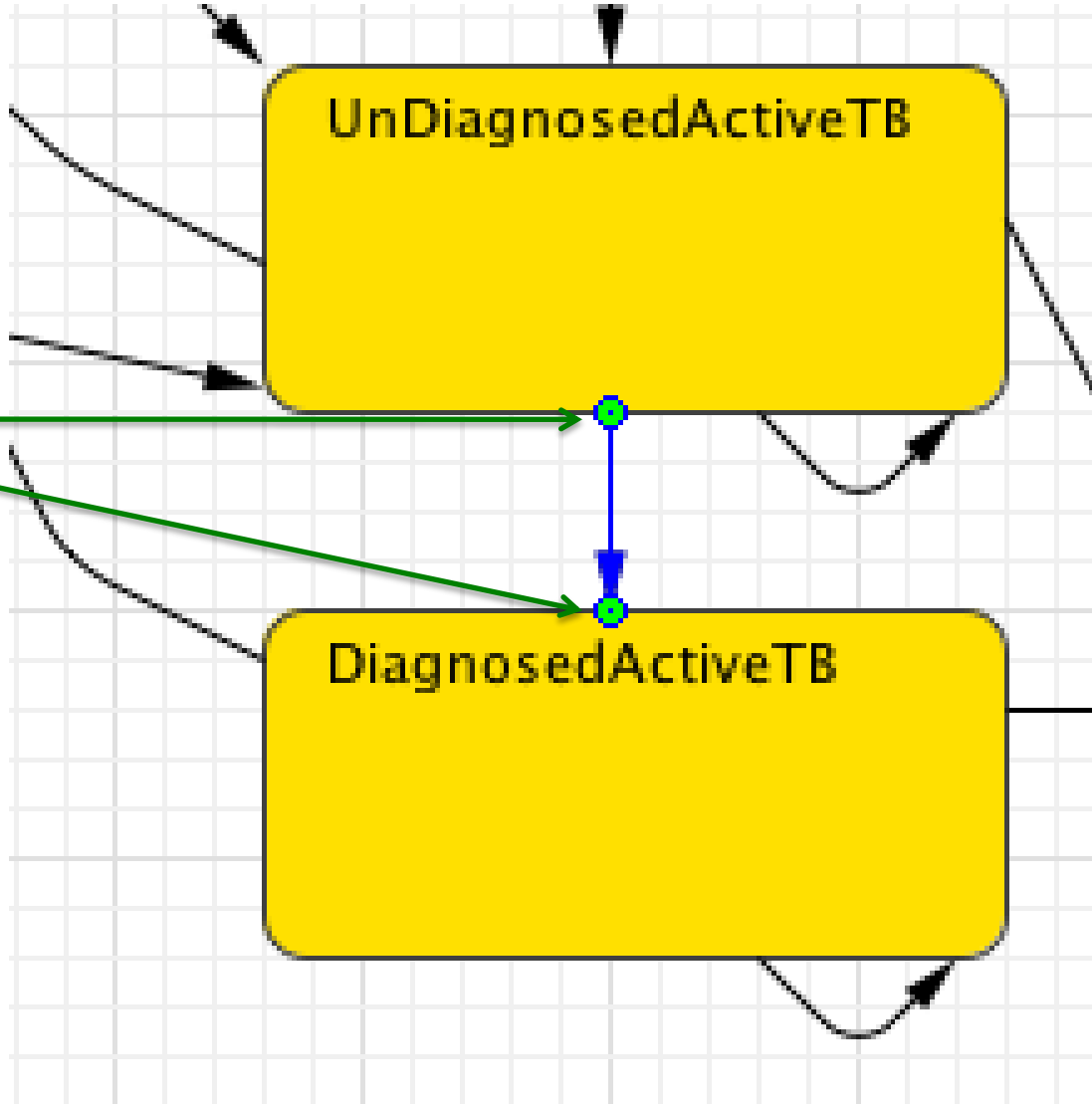


Corrected

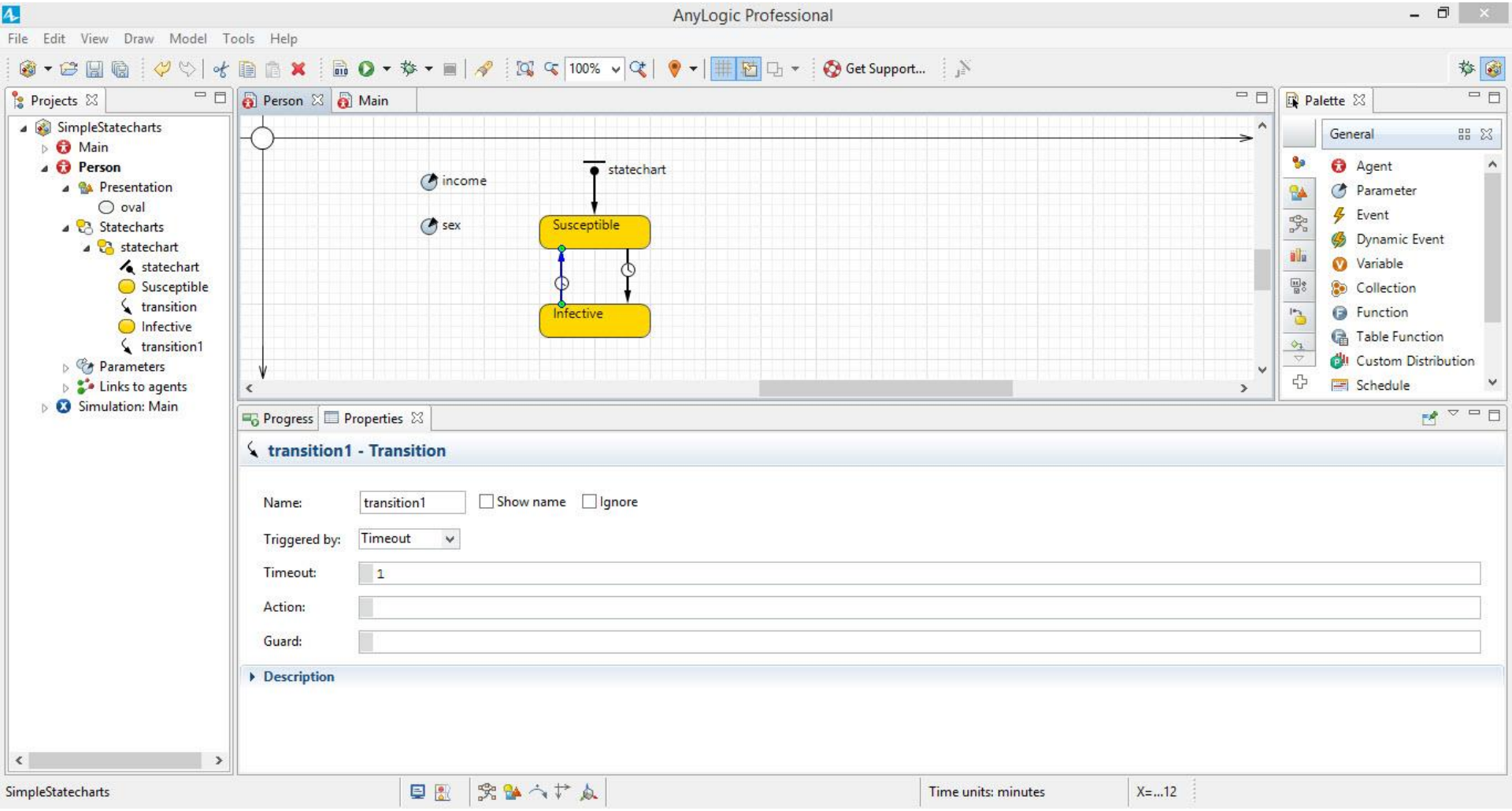

AnyLogic Professional
File Edit View Draw Model Tools Help
Get Support...
Projects
SimpleStatecharts*
Main
Person
Presentation
oval
Statecharts
statechart
statechart
Susceptible
transition
Infective
transition1
Parameters
Links to agents
Simulation: Main
Person
Main
income
sex
statechart
Susceptible
Infective
Palette
General
Agent
Parameter
Event
Dynamic Event
Variable
Collection
Function
Table Function
Custom Distribution
Schedule
Progress
Properties
transition1 - Transition
Name:
transition1
Show name
Ignore
Triggered by:
Rate
Rate:
0.1
Action:
Guard:
Description
Time units: minutes

Tip: Confirming Transition Connectivity

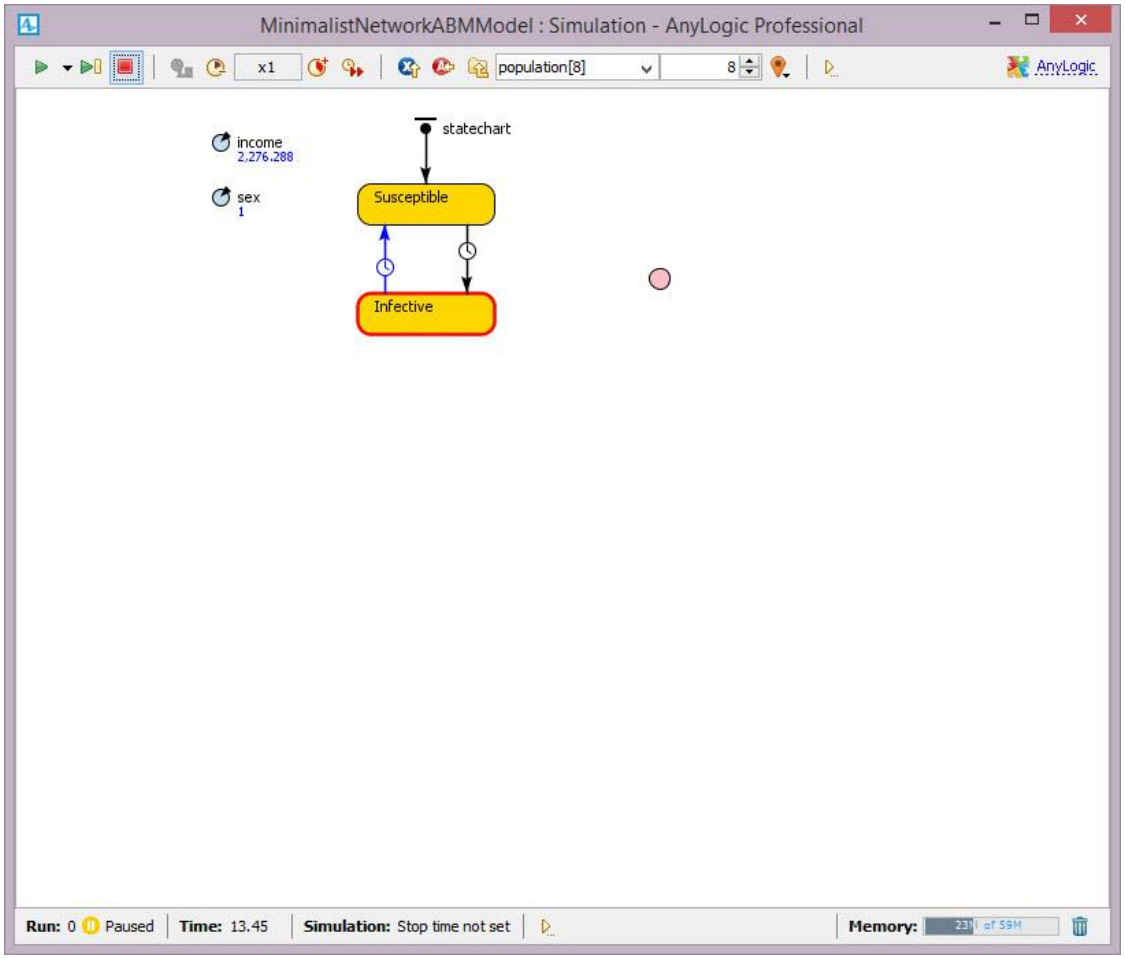
- Ensure that both sides of the transition show green circles when connected
  - Otherwise, may appear connected but will actually be disconnected!



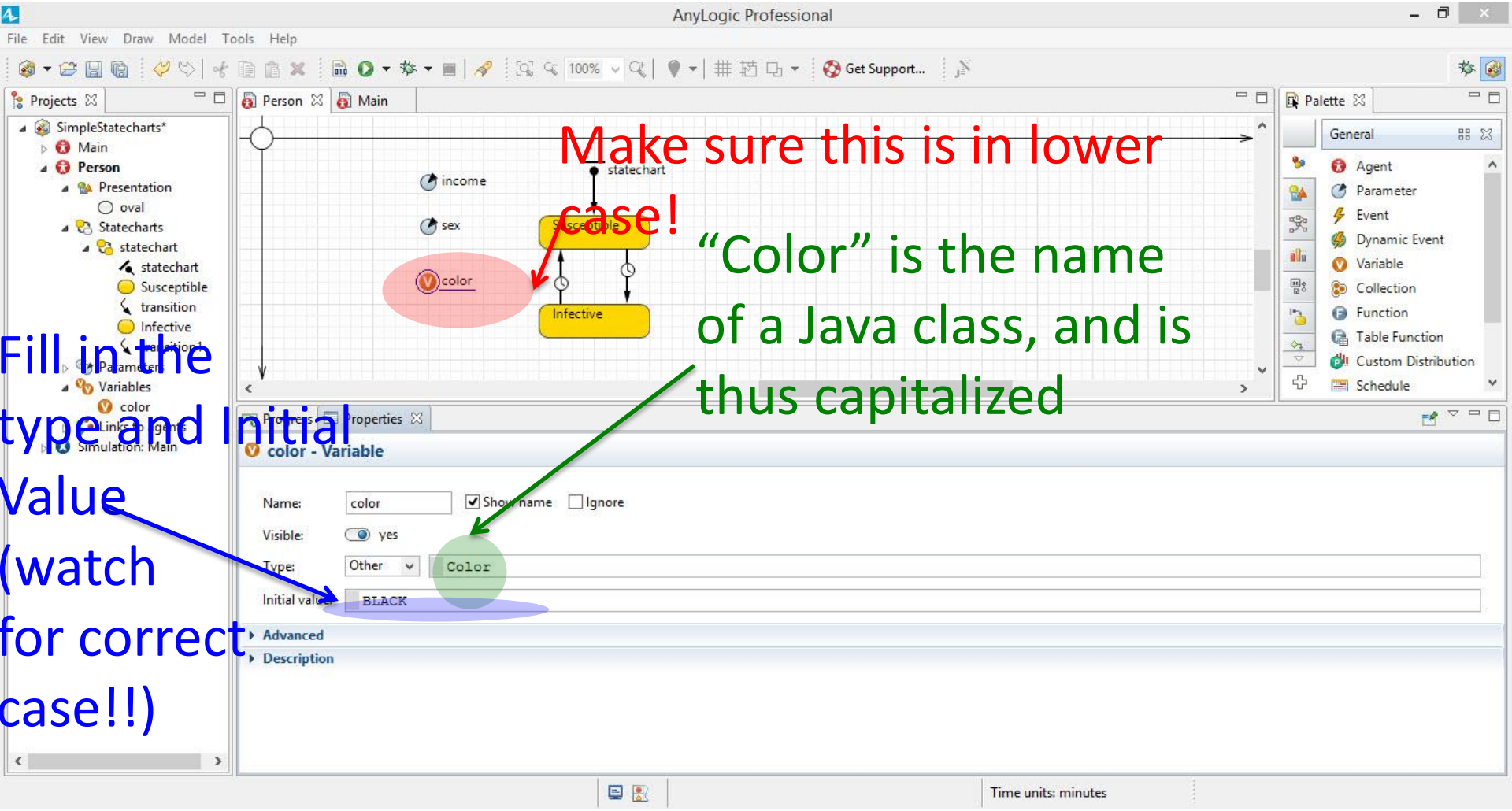
Add a Recovery Transition



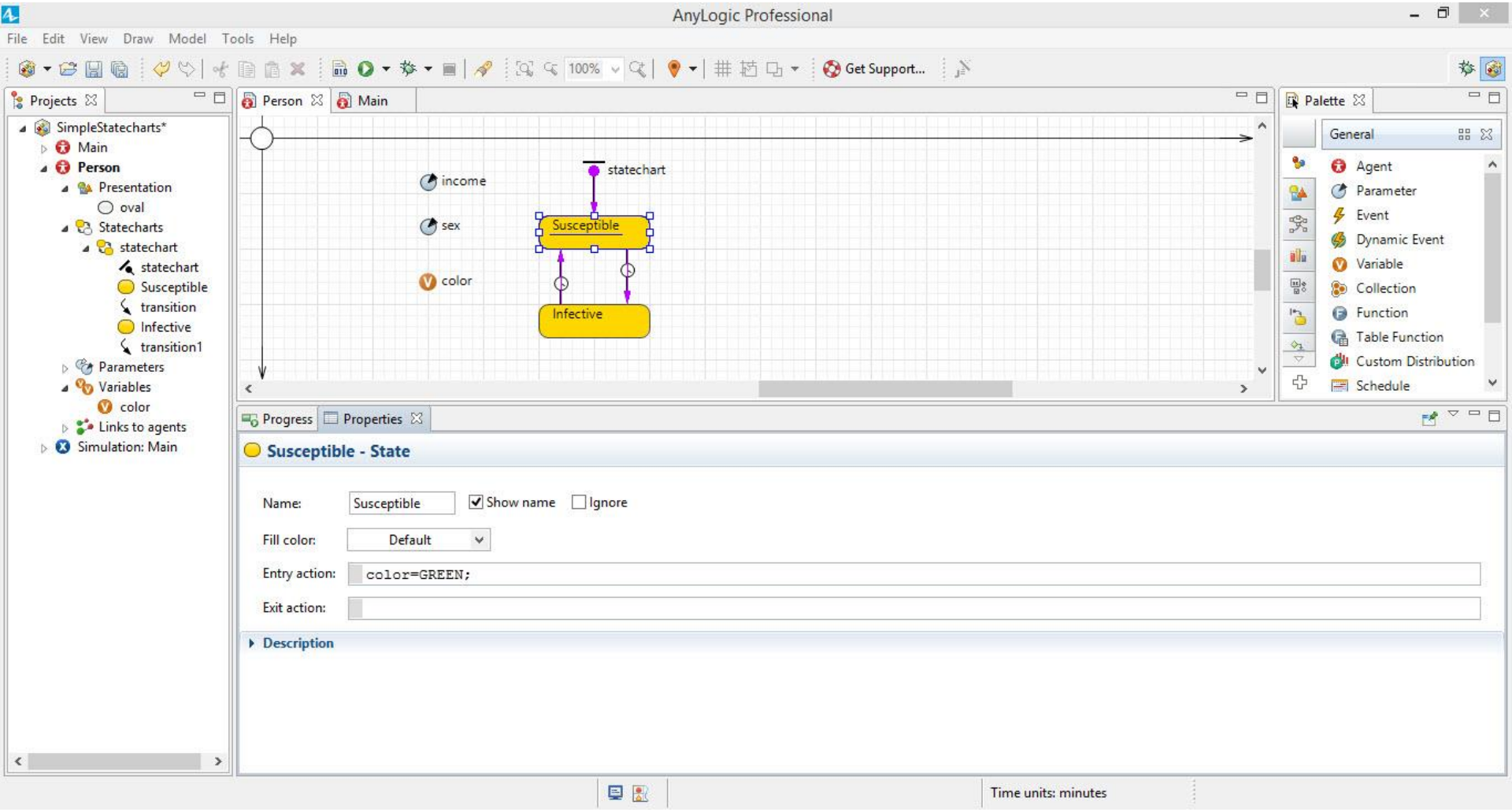
Agent State Changes over Time



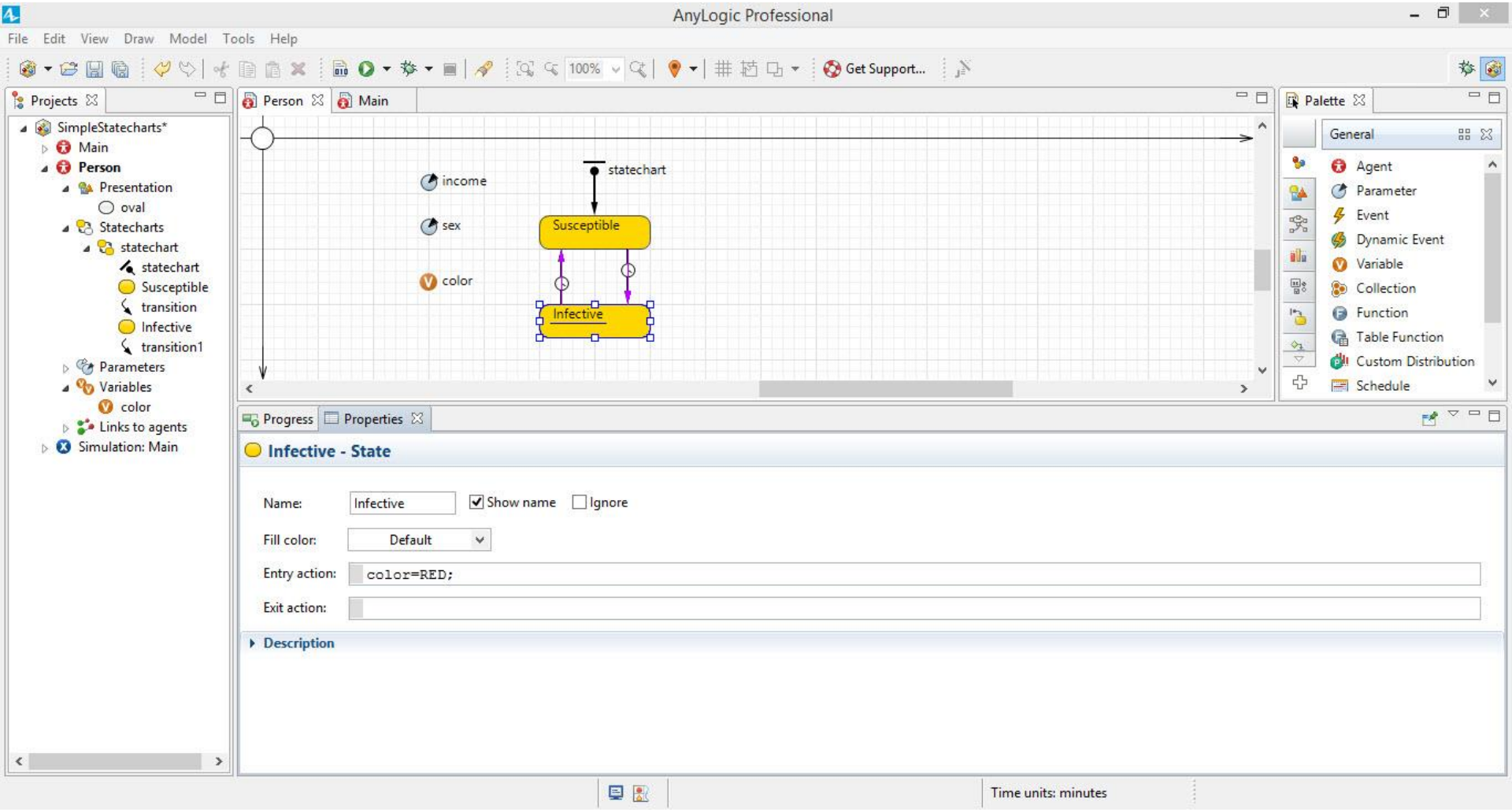
Add a Variable “color” of “type” “Color”



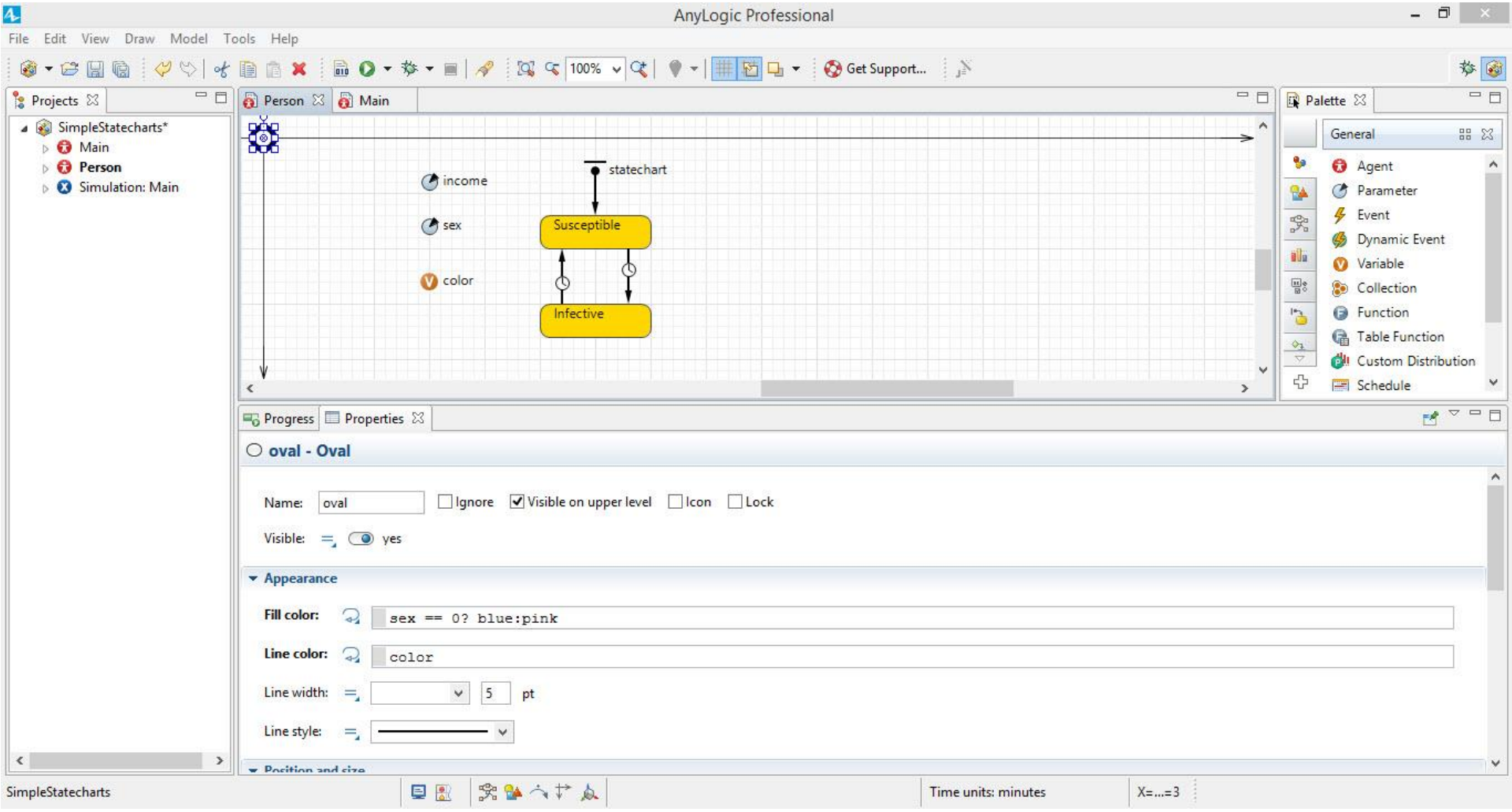
Making “color” Green when Becoming Susceptible



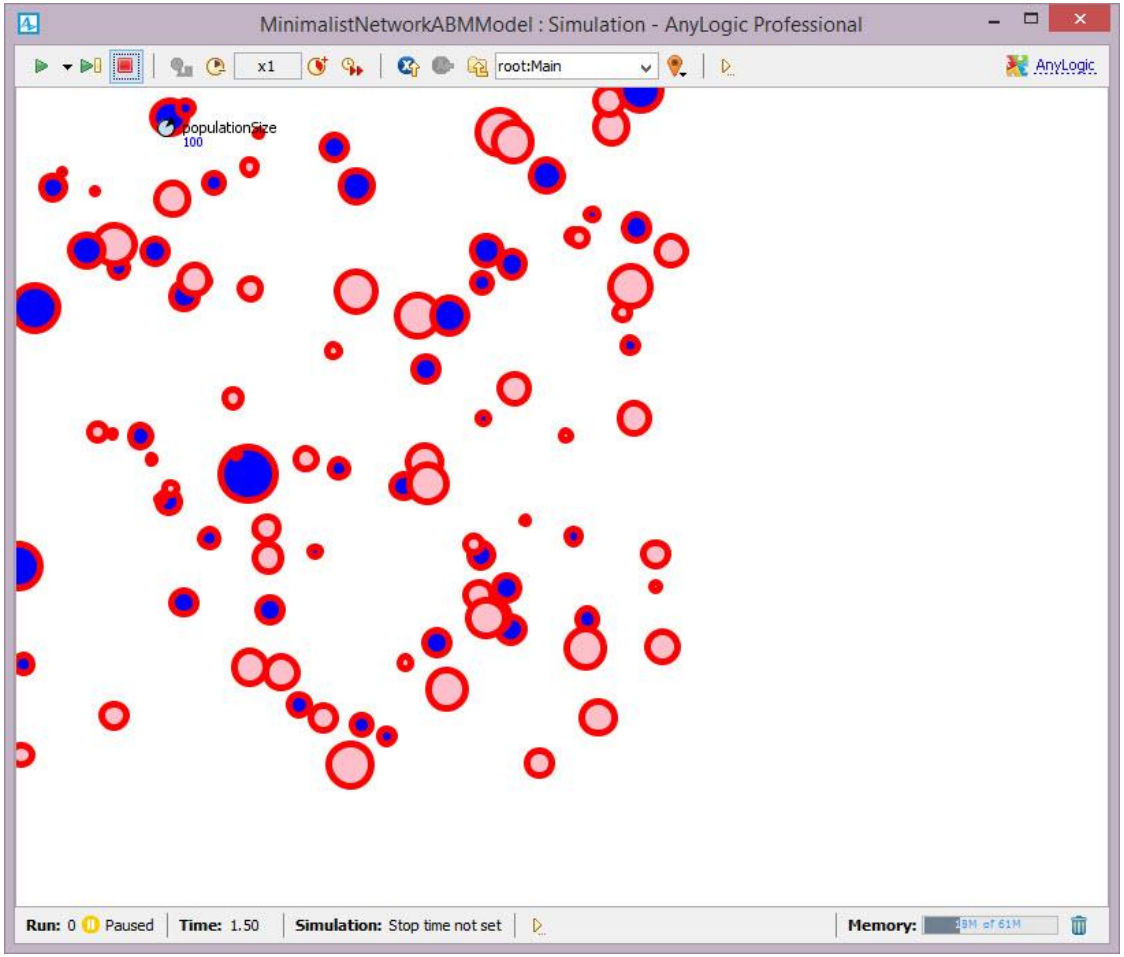
Making “color” Red when Becoming Infective



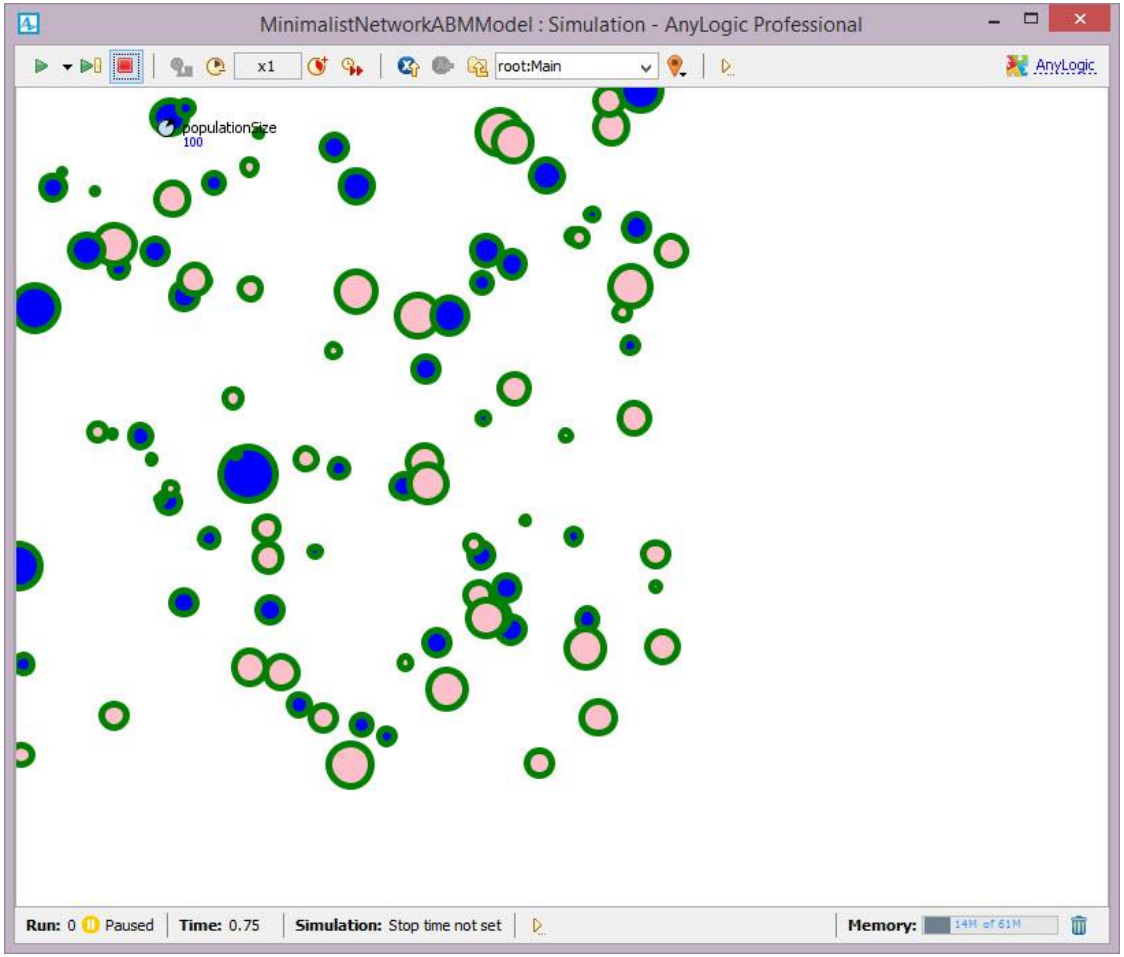
Click on the Oval



Colors Around Agents indicate State



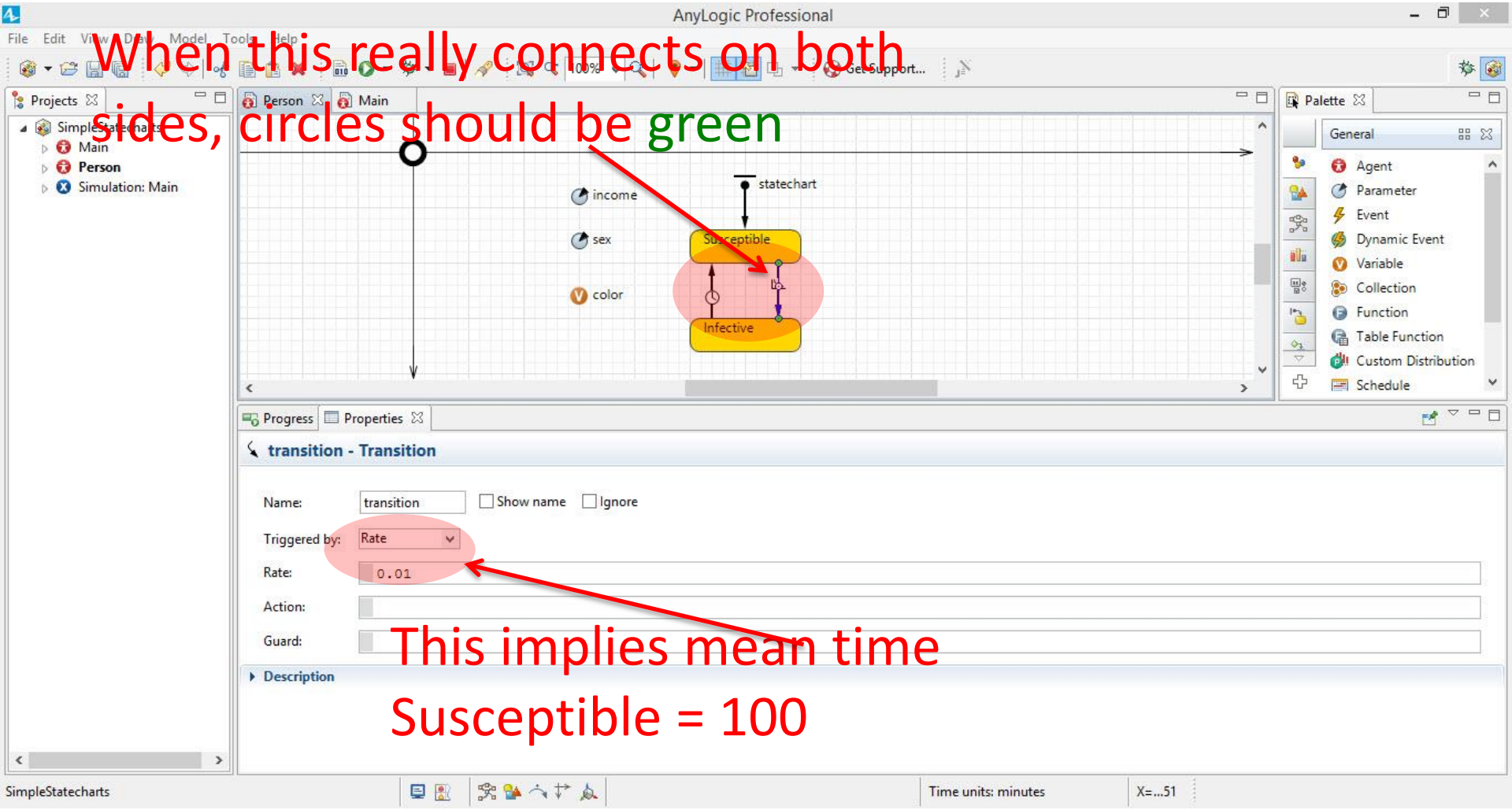
Colors Around Agents indicate State



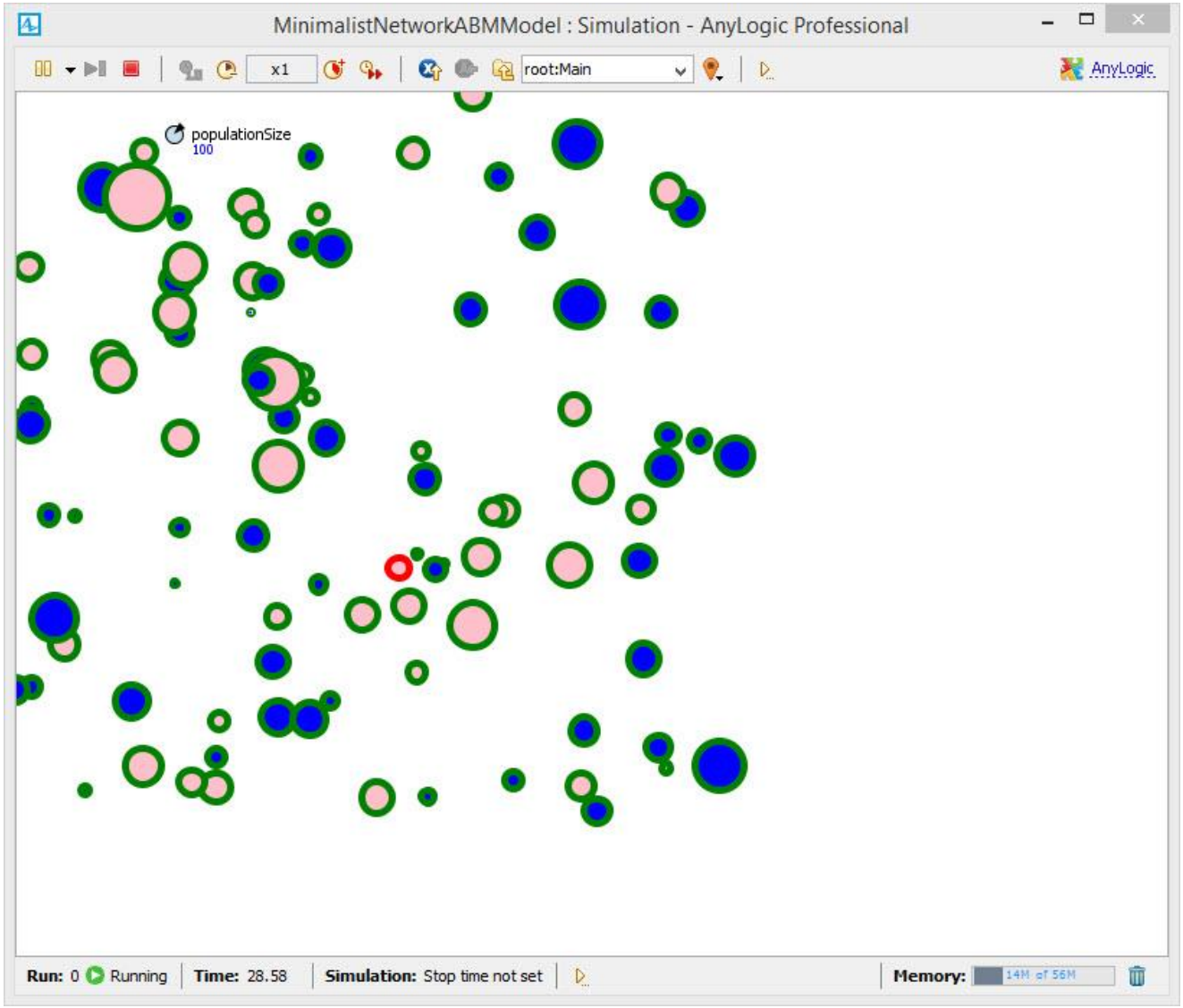
Discrete Agent Dynamics: Transitions

- Many transition conditions are possible
  - Timeout: Spending some period of time in the state
  - Fixed rate: Leave state with some fixed change per unit time
    - This is similar to "first order interarrival time", and is conceptually linked to the operation of first-order delays in stock & flow diagrams
  - Variable rate: If desired, we can change the rate over time – *but Anylogic only "notices" changes when eg agent re-enters the state*
  - Message received: We can transition when a message (any message or particular type of message) is received
  - Predicate: Only transition when condition becomes true
  - Arrival: Reach a location
- These transitions can be conditionally "routed" via branches
  - Conditions can determine to what destination state a particular transition will travel

Eliminate the Lock-Step Transitions by Using a Probabilistic Transition (Hazard)



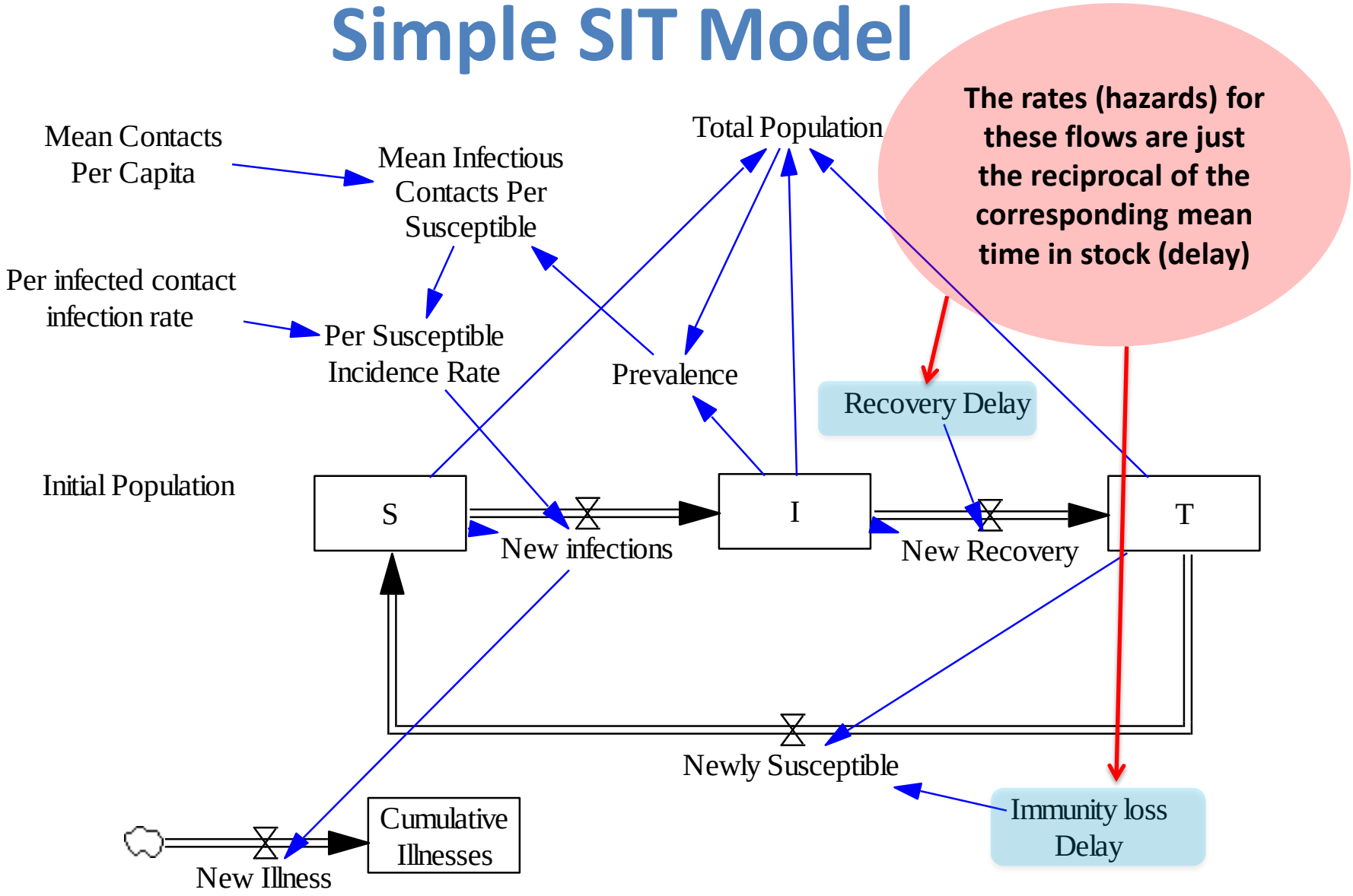
Result


MinimalistNetworkABMModel : Simulation - AnyLogic Professional
x1
root:Main
AnyLogic
populationSize
100
Run: 0 Running
Time: 28.58
Simulation: Stop time not set
Memory:
14M of 56M

Rates & Flows

- Some may have seen fixed rates before – in the form of “transition rates” in Compartment models
- Within a Compartment/SD model, a flow out of a stock was commonly set by the multiplication of the
  - State variable (Stock)
  - Some rate of transition
- We use different names for these rates
  - “Transition rates”
  - “Likelihood of transition per *Unit Time*”
  - Transition (e.g. “infection”, “mortality”) “hazard”

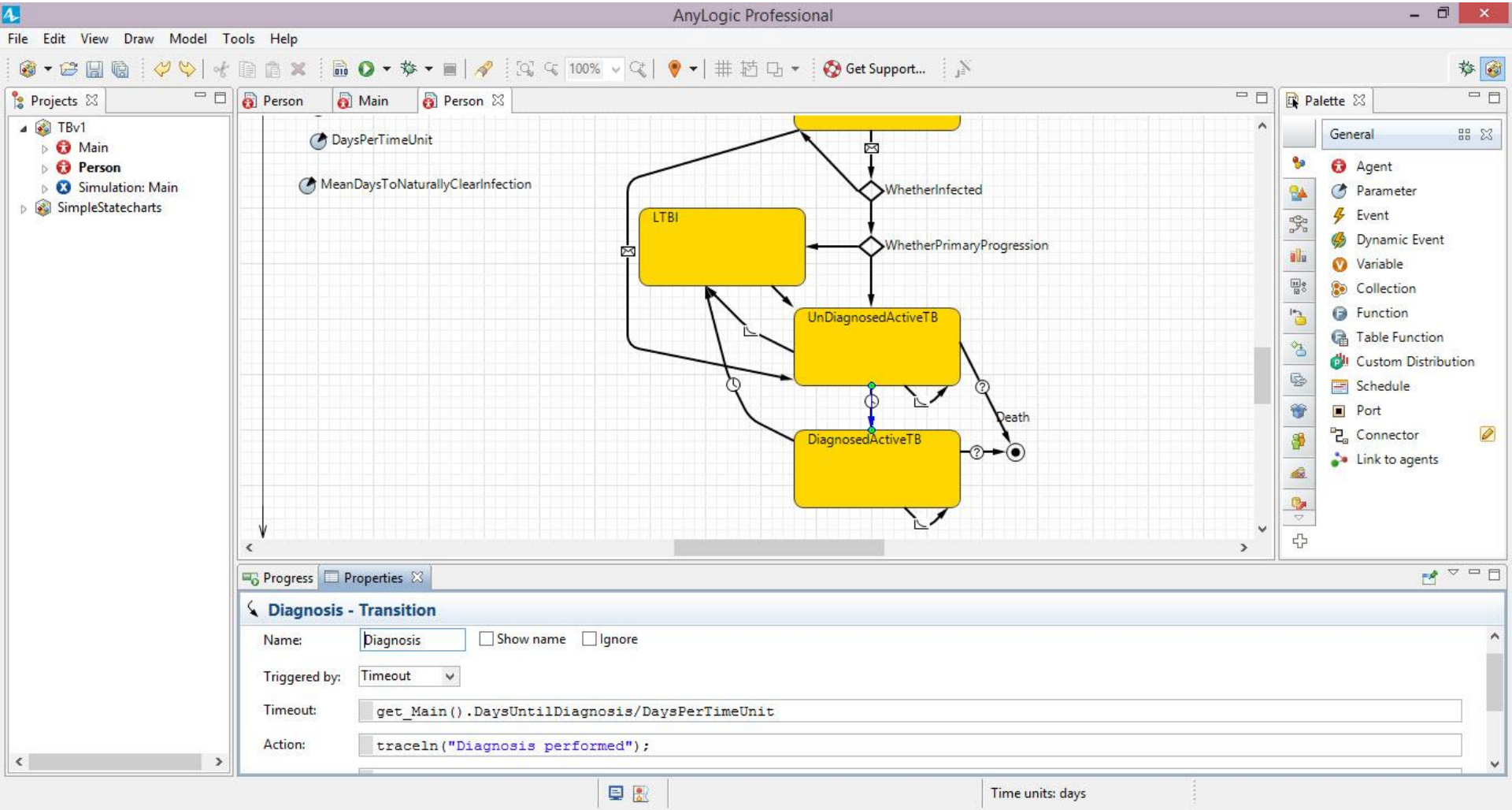
First Order Delays in Action: Simple SIT Model



Fixed Rates: Transition "Hazards"

- With "fixed rates", we are specifying rates of transitions
- Because we are dealing with the chance that each individual transitions, we don't need to multiply by the number of people at risk
  - Here, there is just 1 person at risk!
- As in Compartment models, these rates can change over time, but the statechart needs to be "made aware" of these changes (see later)
  - Leave & go back into current state (circular transition)
  - Trigger "change" event in Agent

Transition Type: Fixed Residence Time (Timeout)

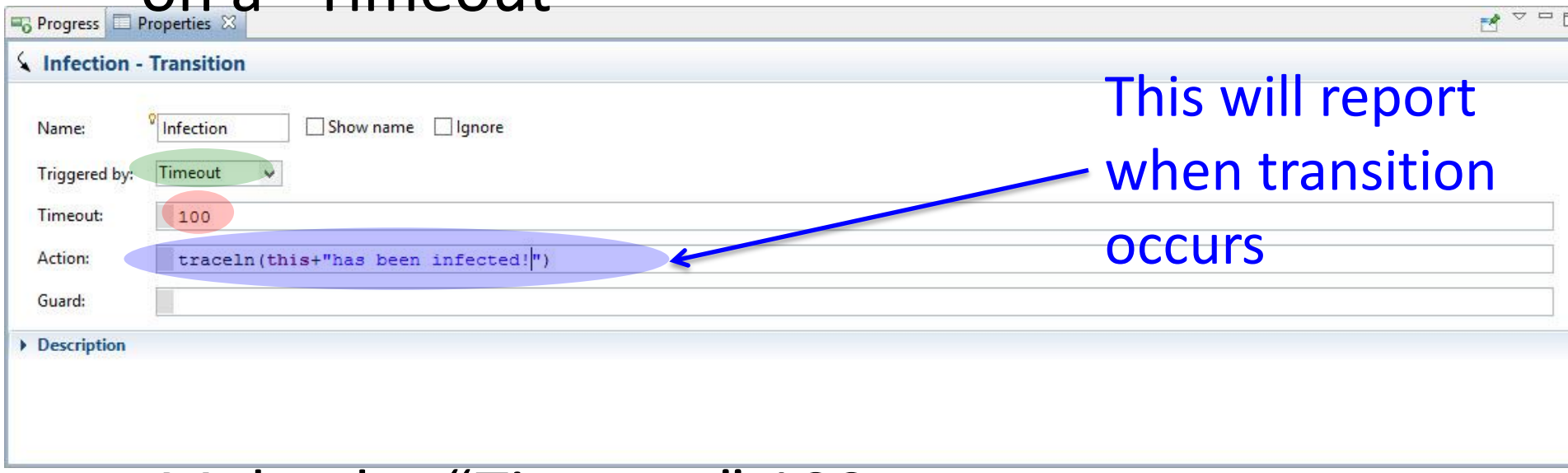


Example of Processes Associated with Fixed Timeouts

- Aging
- Tightly defined time constants associated with natural history
  - While these may be described as associated with a broad distribution (e.g. with a 1^{st} or 2^{nd} order delay), much of that variability may be due to heterogeneity
  - *For a given person, these may be quite specific in duration* $\Rightarrow$ *Can capture through a timeout*

What Happens if this Depends on a Timeout?

- Set the “Infection” transition to Trigger based on a “Timeout”



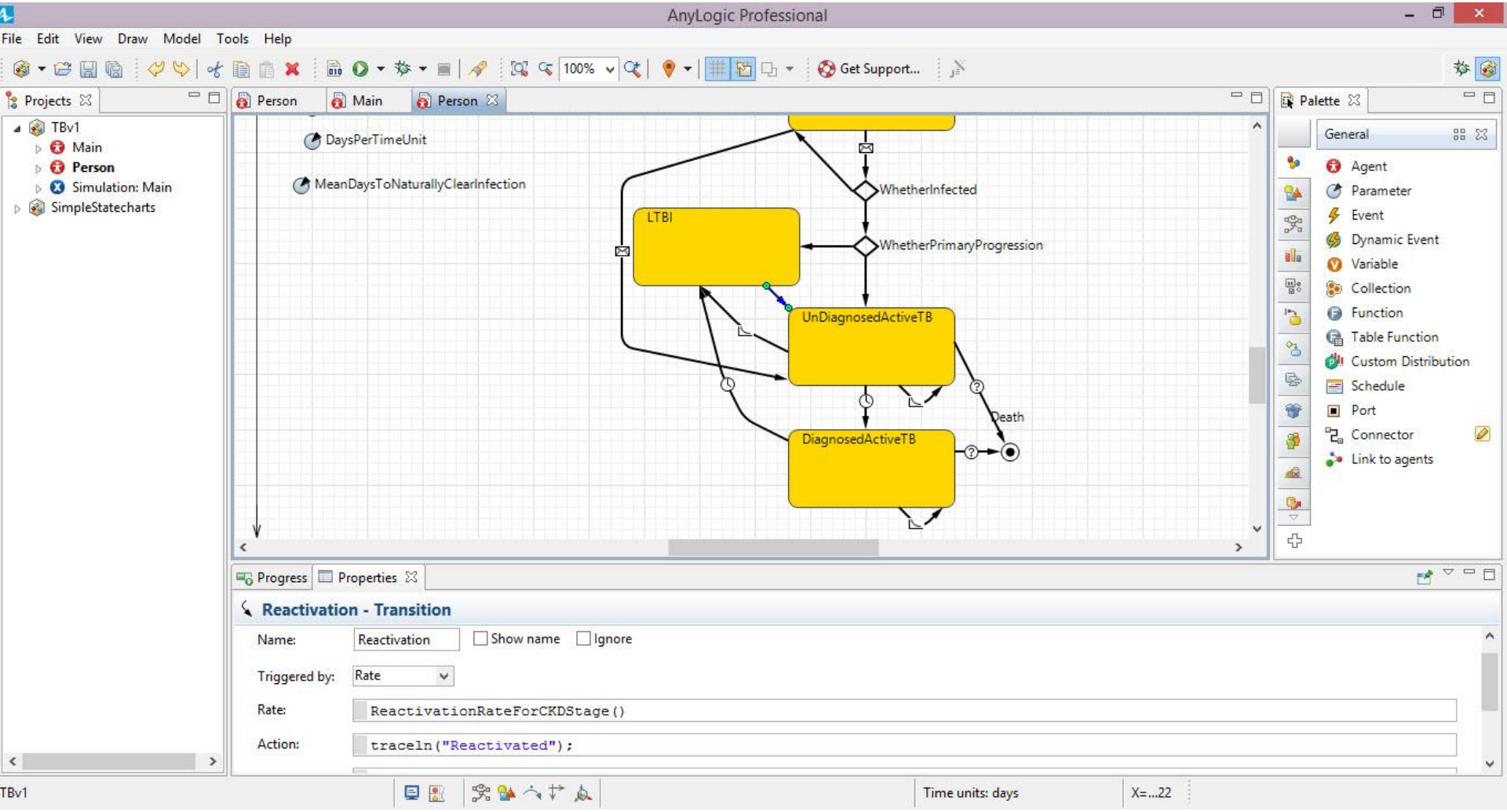
- Make the “Timeout” 100

Now run the model, and observe the difference

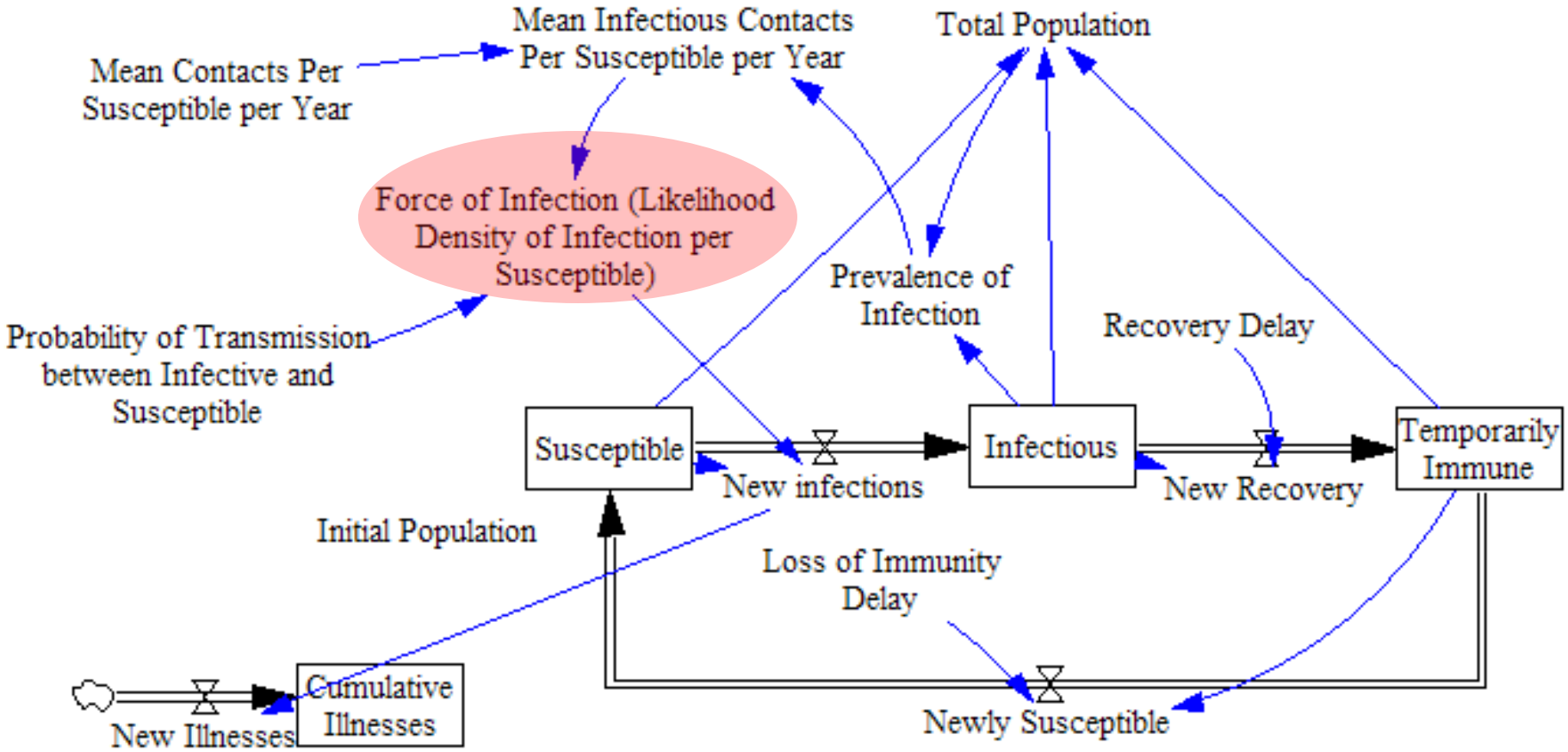
Hands on Model Use Ahead

Load model: TBv1.alp

Transition Type: Variable Rate



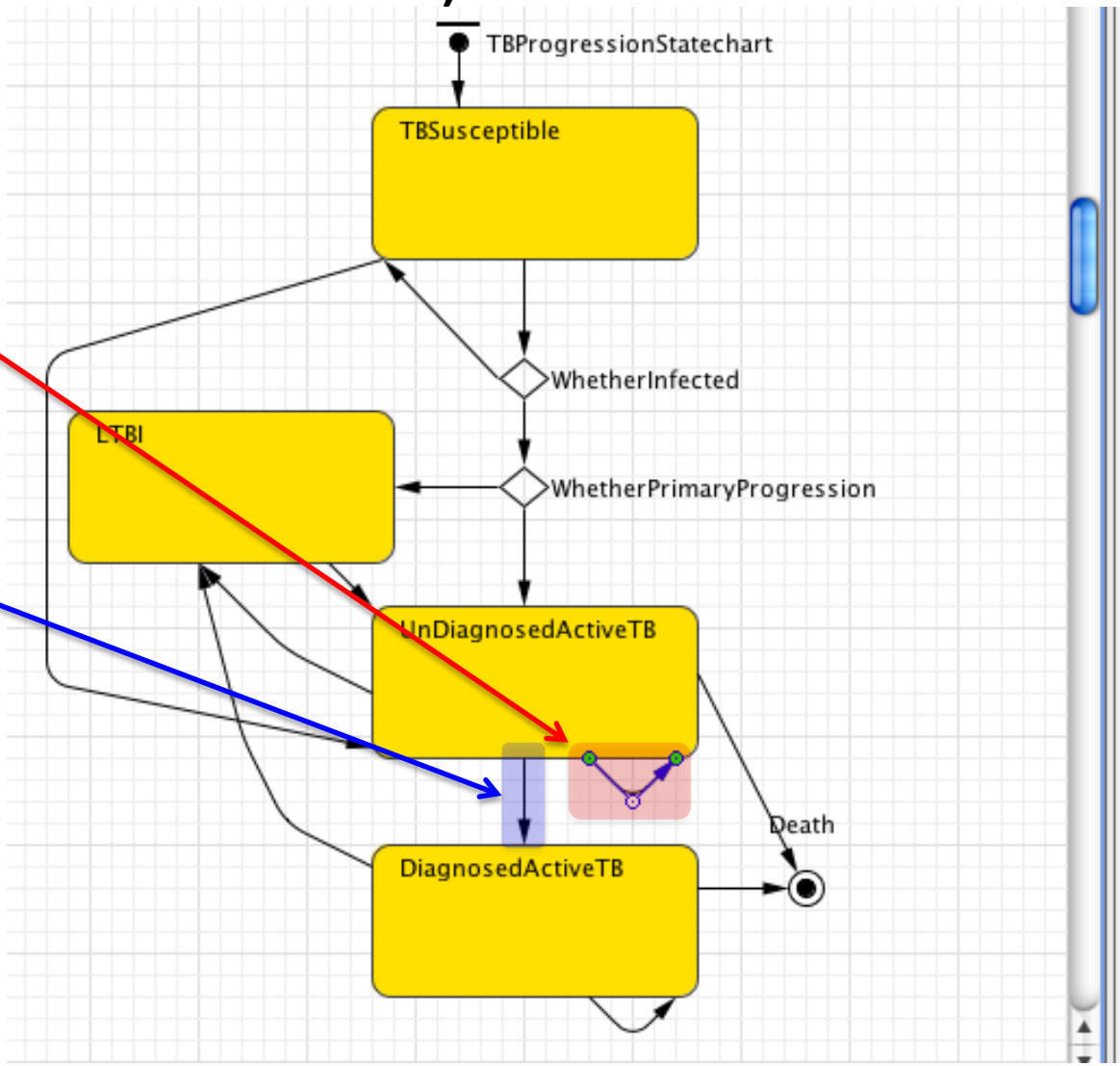
Example Transition Rate/Hazard



Special Elements: Self-Transition

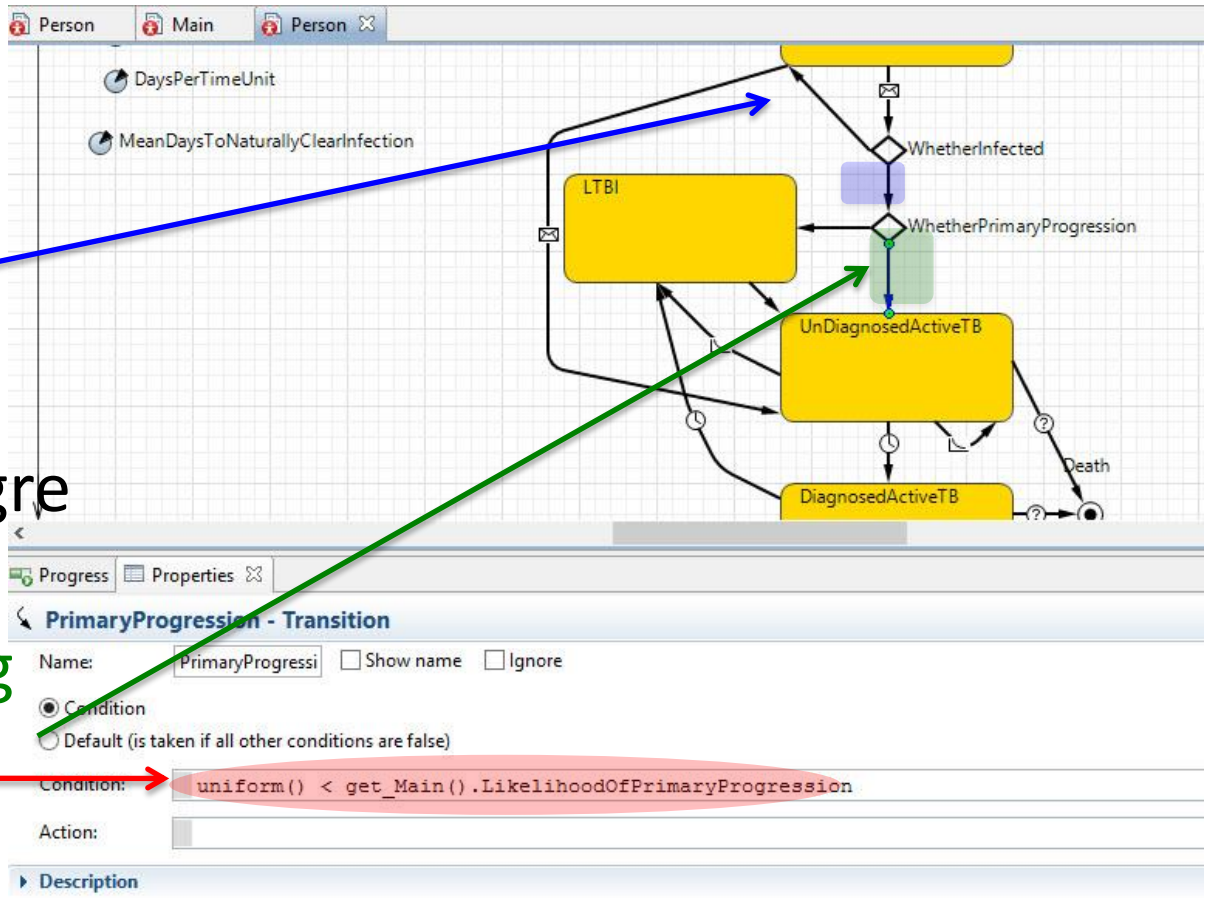
(Use if Wish To Have State Register Changing Out-transition rates)

The self-transition will "make the state realize" that the rate associated with any out transition (e.g. this one) has changed

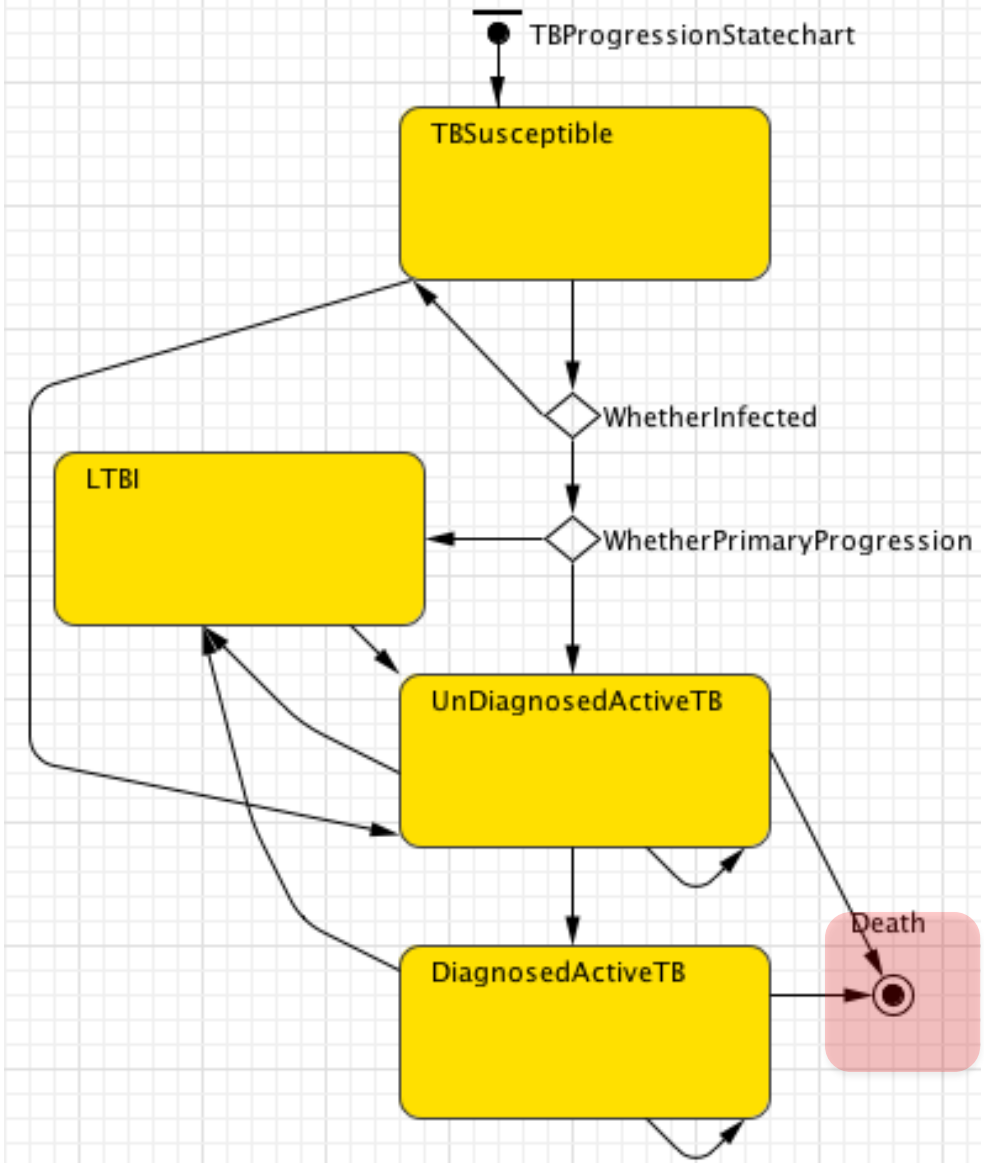


Example Conditional Transition

The incoming transition into "WhetherPrimaryProgression" will be routed to thisoutgoing transitionif this condition is true



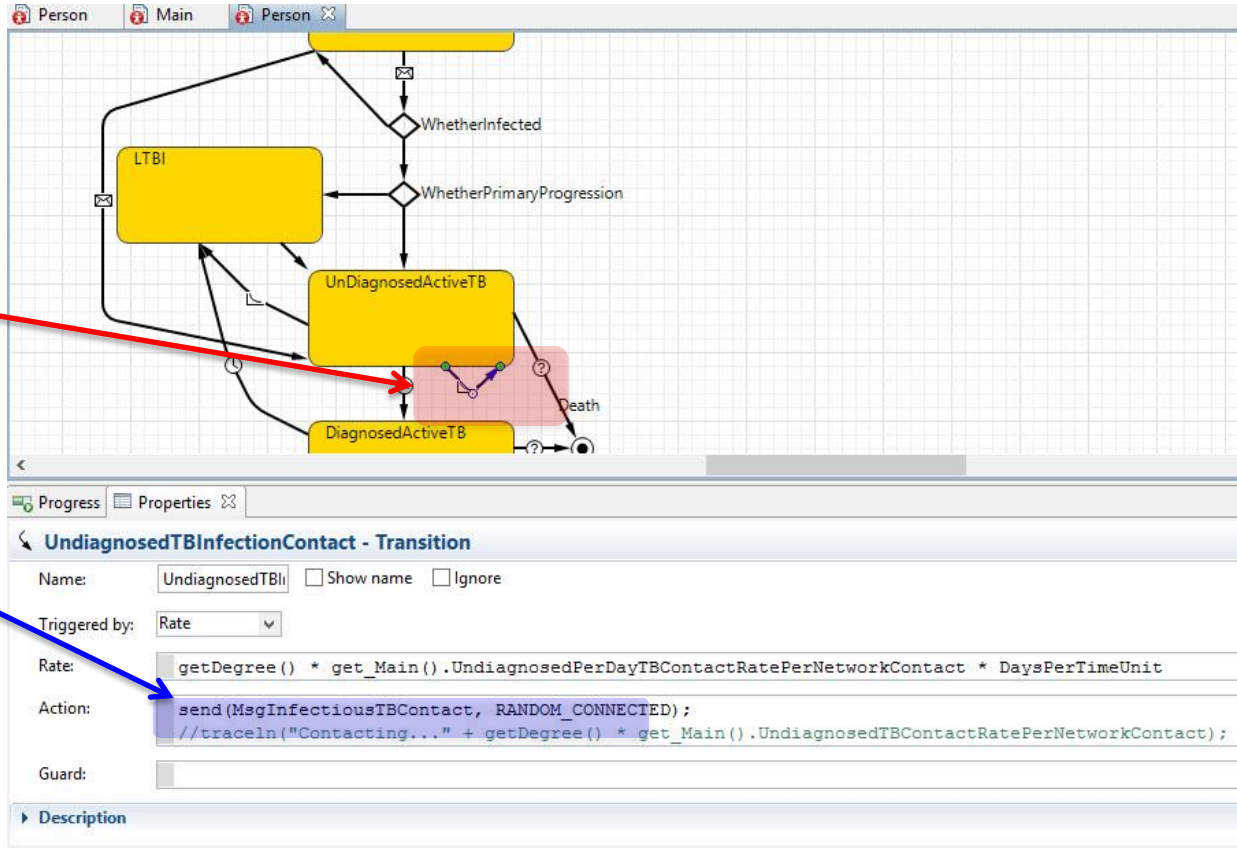
Special Elements: Exit Point



Special Elements: Self-Transition

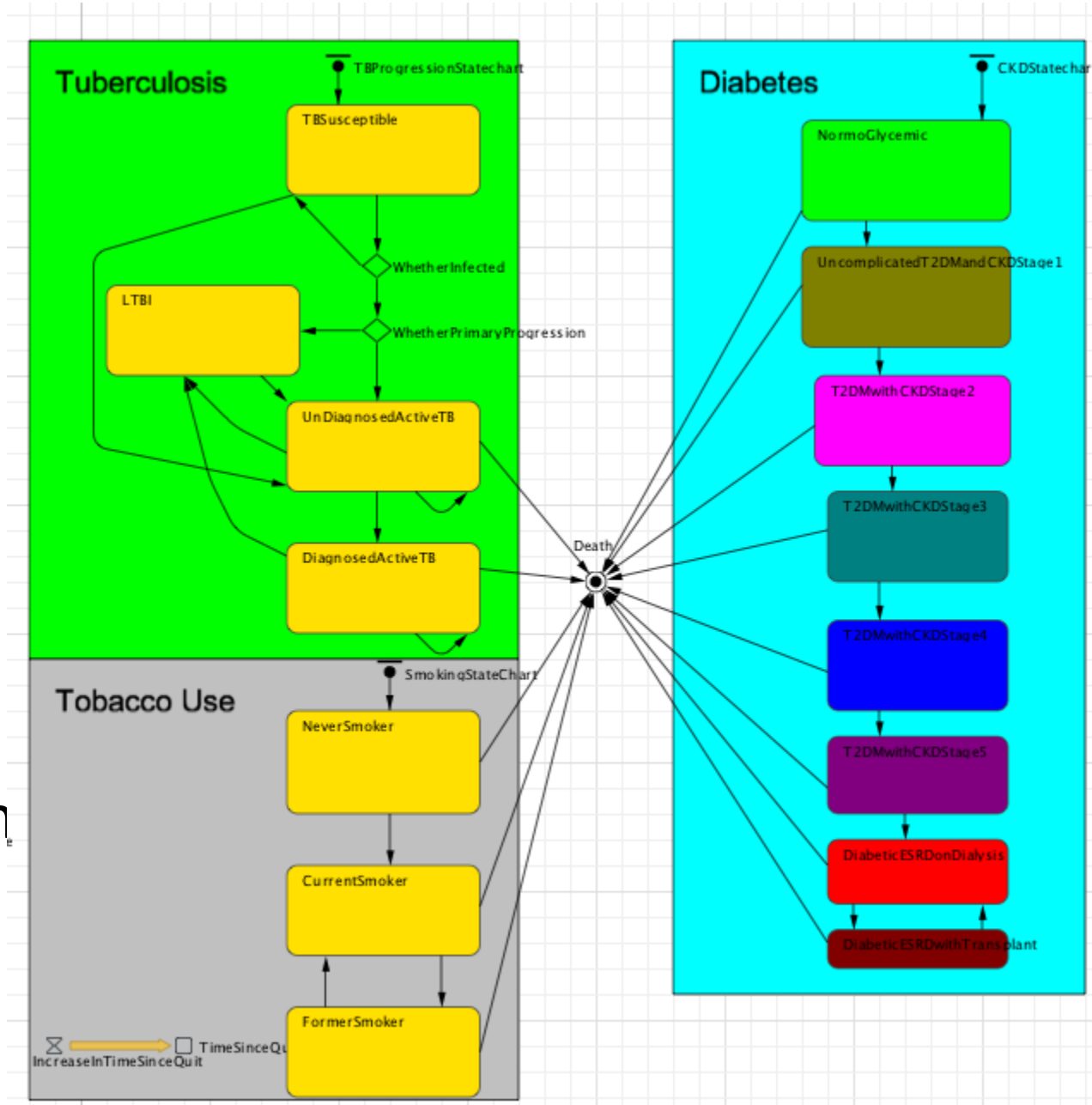
(Use if Wish To Trigger an Action w/o Leaving State)

The self-transition will invoke this action when it occurs



Parallel Statecharts

- By default, each statechart evolves independently.
- If coupling is desired, can make transitions/actions dependent on state of other statecharts

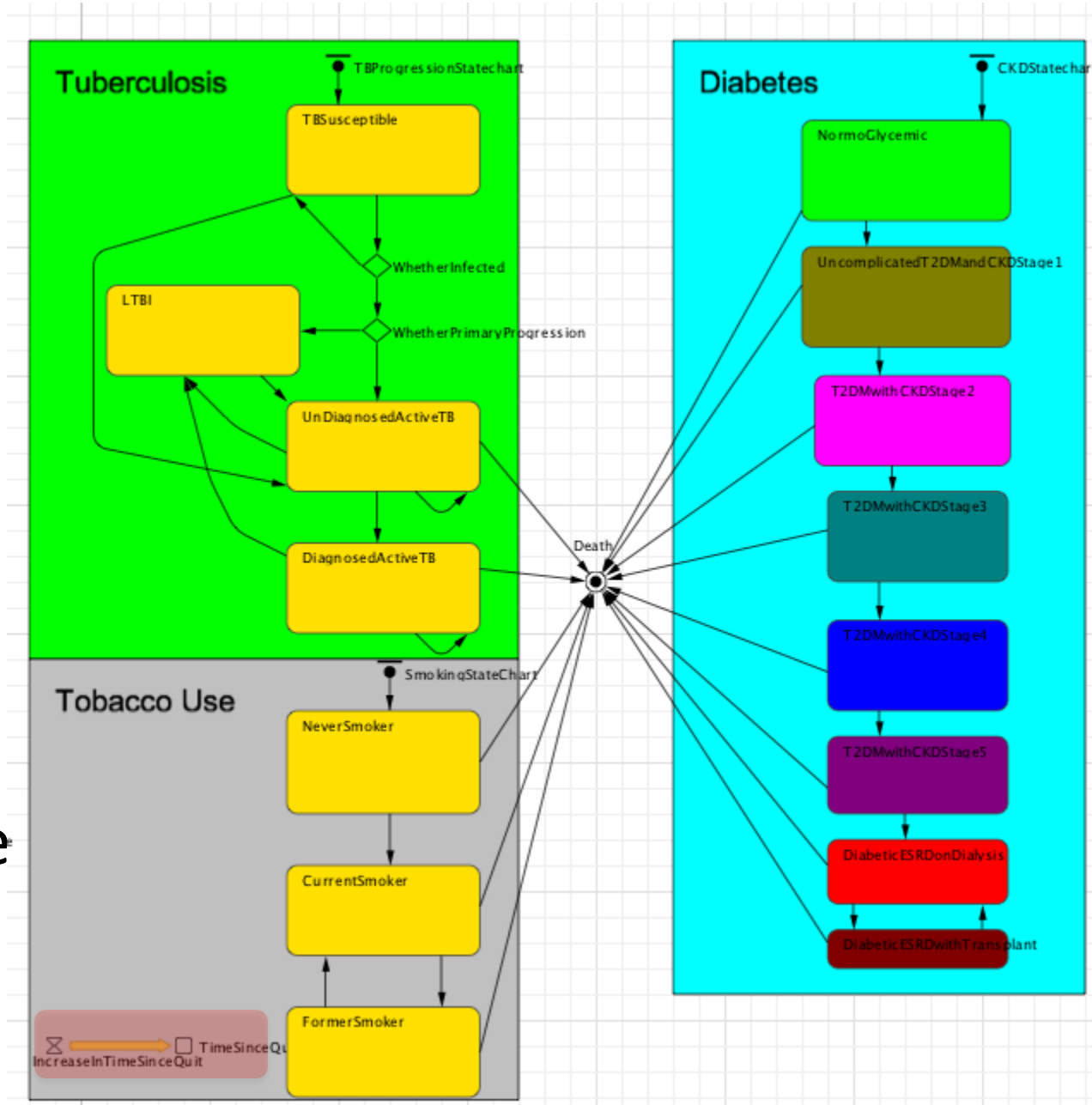


Comparison with Aggregate Stock & Flows

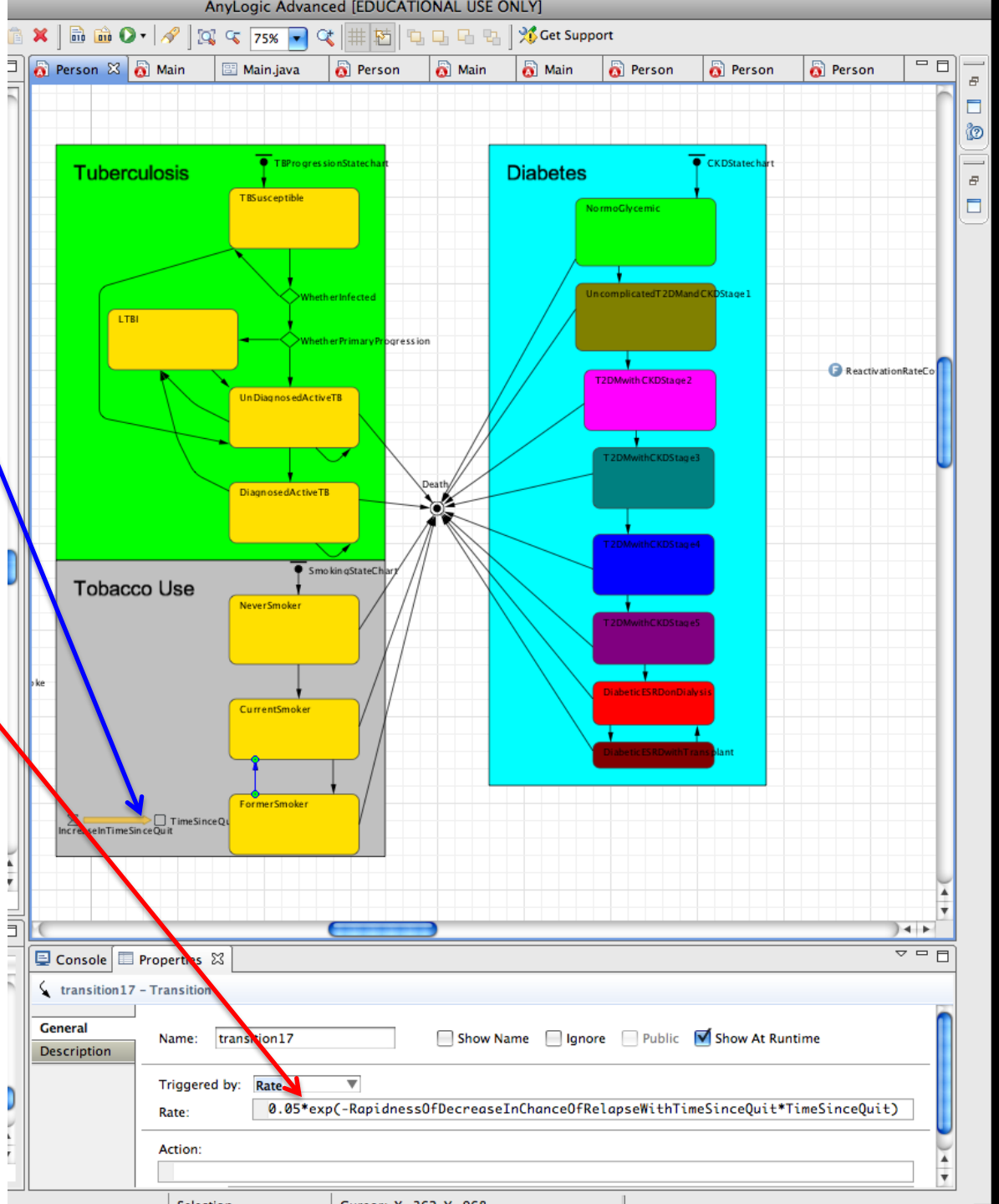
- As for aggregate stocks & flow, individuals' states are discrete
- Unlike aggregate stocks & flows
  - One state within a given statechart is active at a time
  - For parallel flows (e.g. comorbidities), there is no need for considering all combinations of the possible states
  - We can keep track of how long an individual is in a given state & adjust the transition rate accordingly

Parallel Transitions

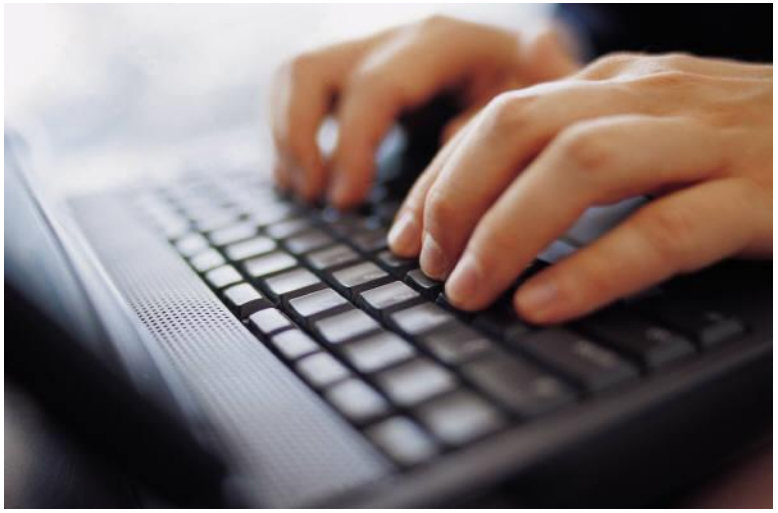
- Example recording the residence time in a state (via a stock with unit inflow -- i.e. just accumulates the time present in that state)



- The residence time in the state determines the transition rate out of that state.
- Transition rates depending on residence time are generally not possible with aggregate models



Hands on Model Use Ahead



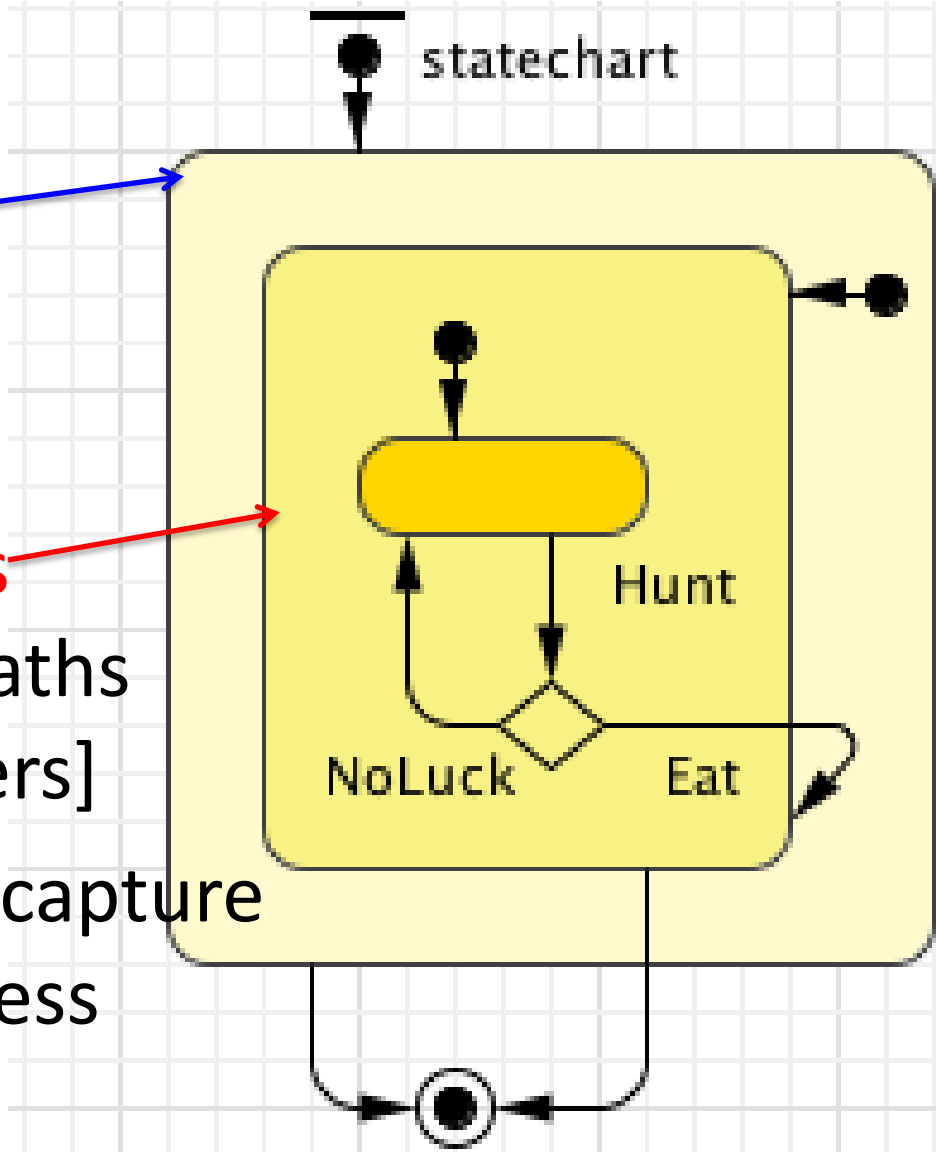
Load Sample Model:

Predator-Prey Agent Based

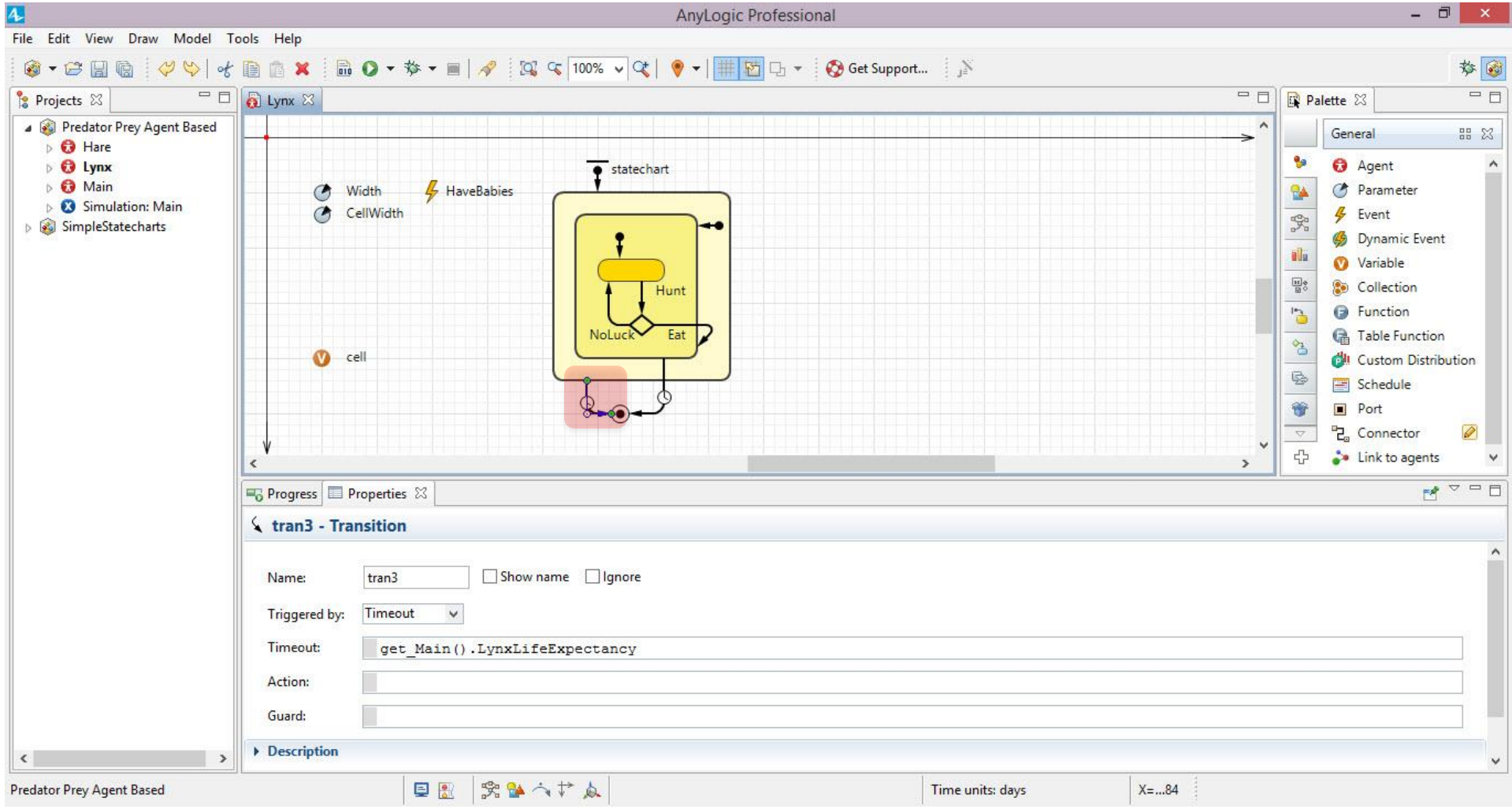
(Via “ExamplesModels” under “Help” Menu)

Advanced Element: Hierarchical States

- The outermost state captures time since born (for natural deaths)
- The middle-state captures time since last ate (for deaths by hunger). [Eating reenters]
- The inner state transition capture hunting frequency & success

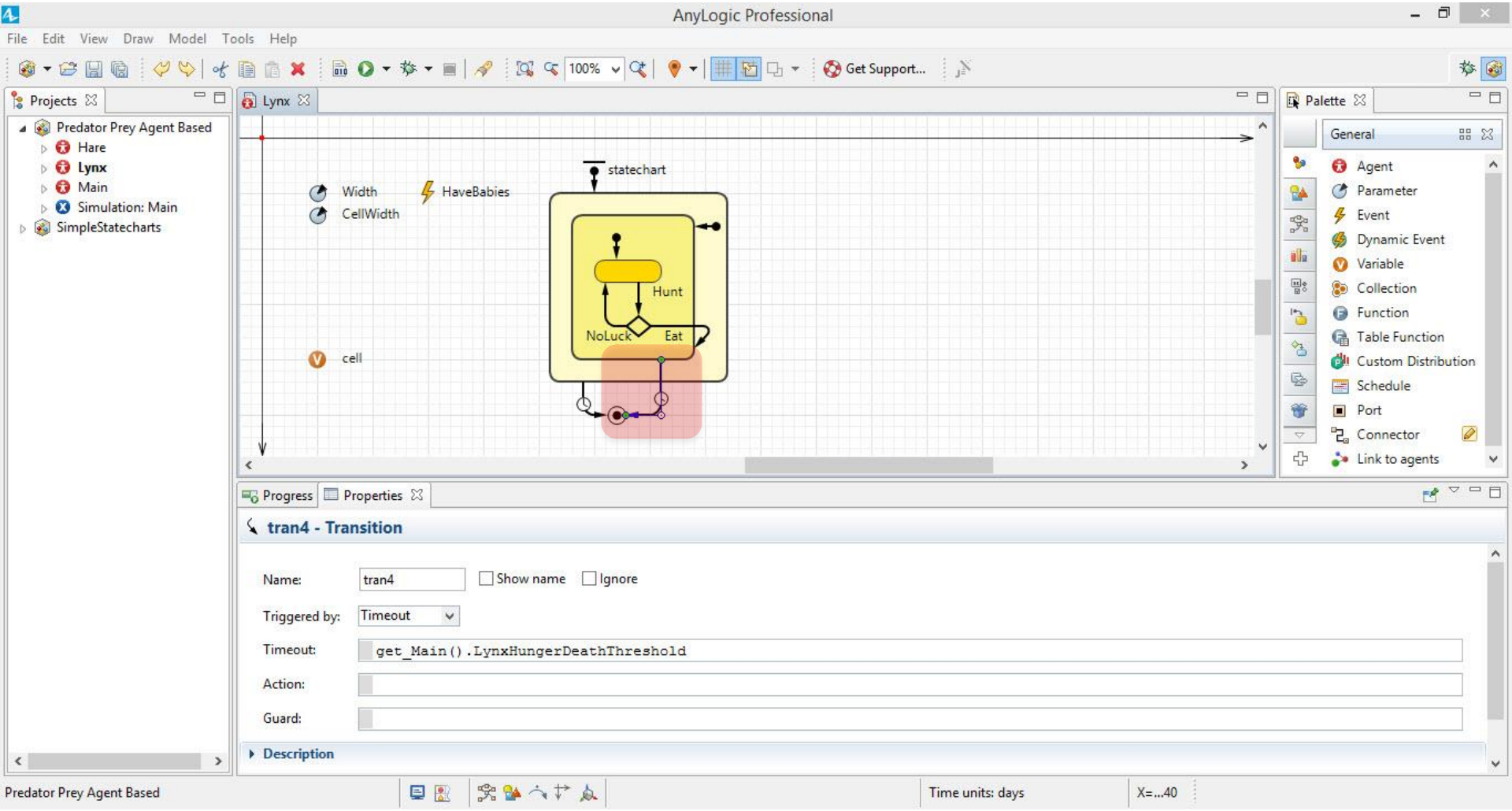


Natural Death Transition

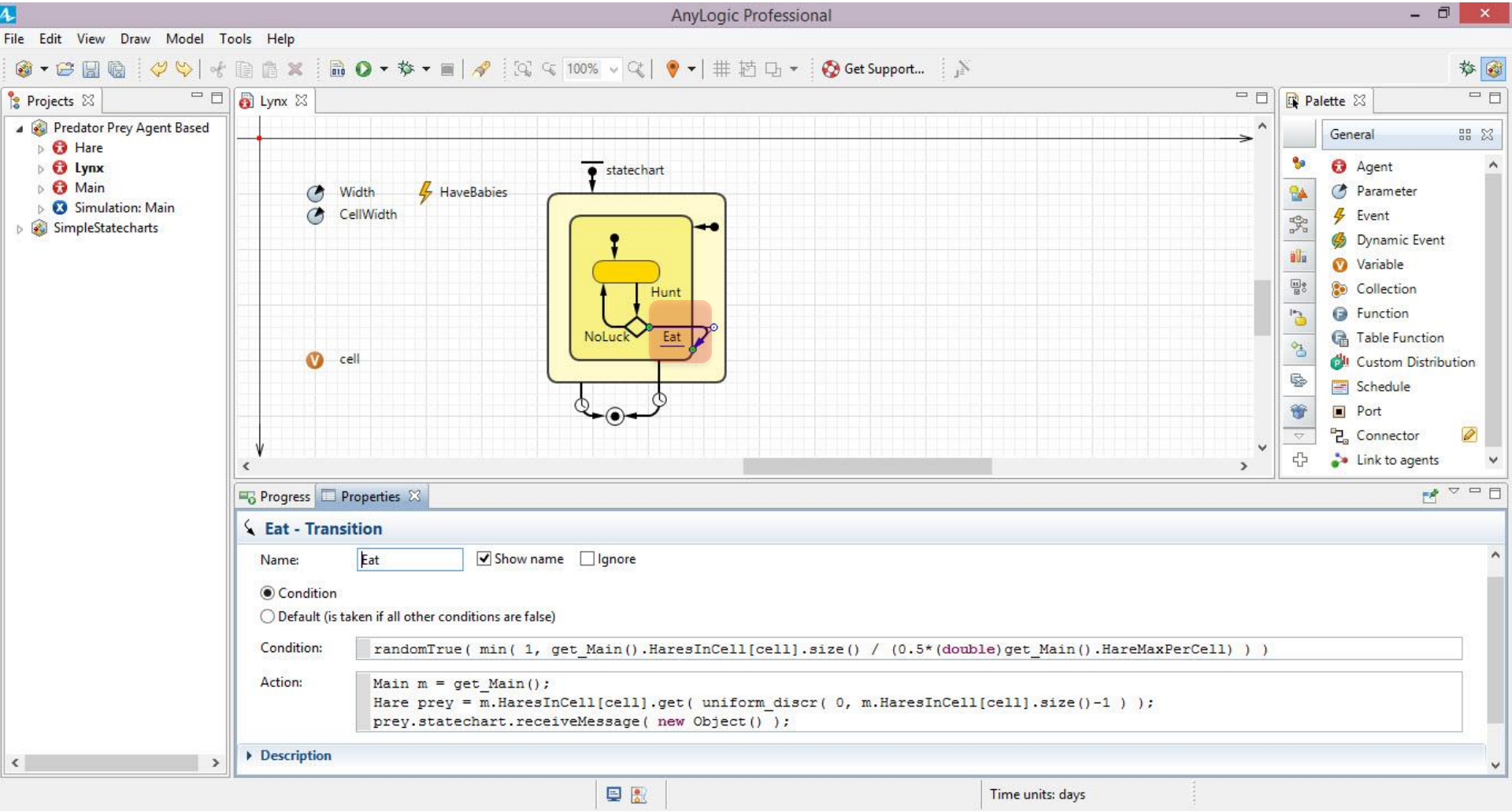


Death By Hunger

(Note that Depends on Time in State – i.e. time Since last ate)



Eating Transition Leaves & Reenters Middle State



Tips on Statechart Code

- Each State & Transition has an integer index
  - This by accessed via a (static) constant holding the name of state within the statechart class (*statechart*.*StateName*)
- To determine length of time spent in state
  - *Statename*.getLocalTime(*StateIndex*)
- To determine current state
  - *statechart*.getActiveSimpleState()
- To find out if a state (either simple or composite) is currently active
  - *statechart*.isStateActive(*StateIndex*)