Simulating the Social Processes of Science workshop
Leiden, Netherlands, April 7th-14th, 2014

Agent-Based Models of Science:
A Glimpse of the Past and Tools for the Future

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UQÀM

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NORTHWESTERN UNIVERSITY

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Plan

I. An Overview of Some Previous Agent-Based Models of Science

II. Modelling Science with NetLogo: Three New Extensions

Part I

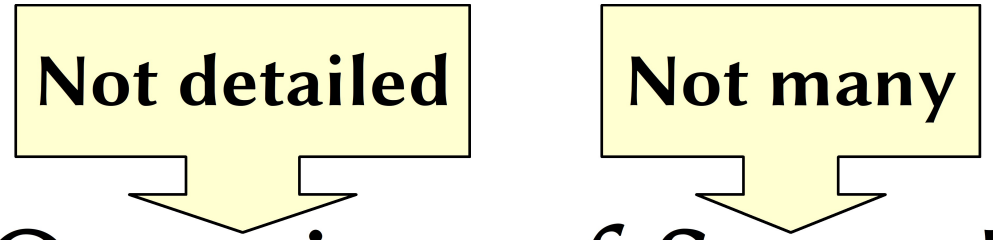
An Overview of Some Previous Agent-Based Models of Science

Part I

Not detailed

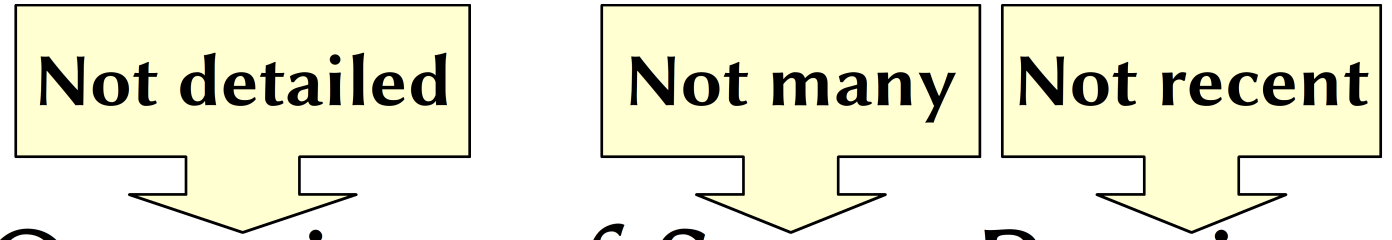
An Overview of Some Previous Agent-Based Models of Science

Part I

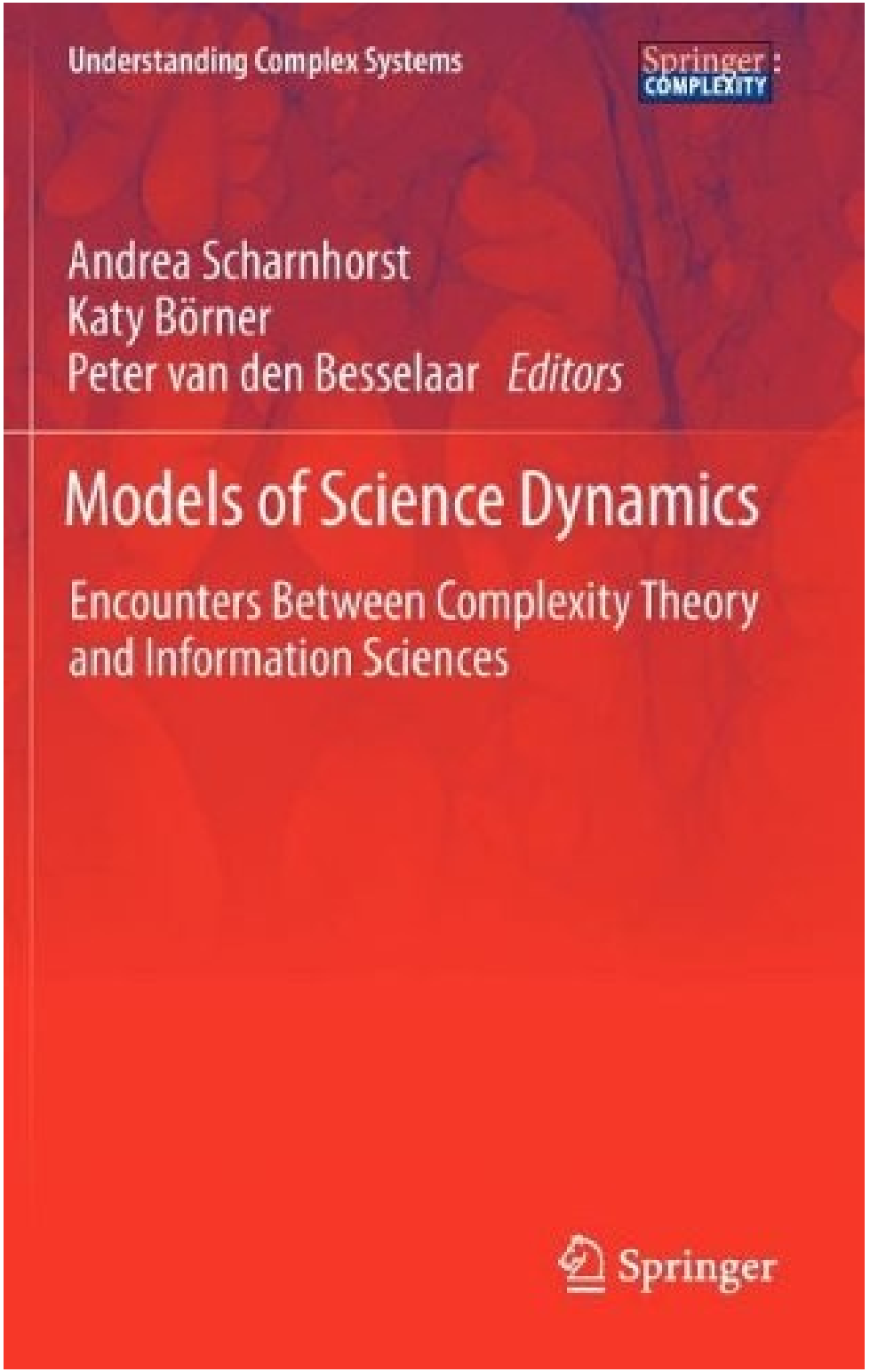


An Overview of Some Previous Agent-Based Models of Science

Part I



An Overview of Some Previous Agent-Based Models of Science



Chapter 4: “Agent-Based Models of Science”

Gilbert, N. (1997).

A simulation of the structure of academic science.

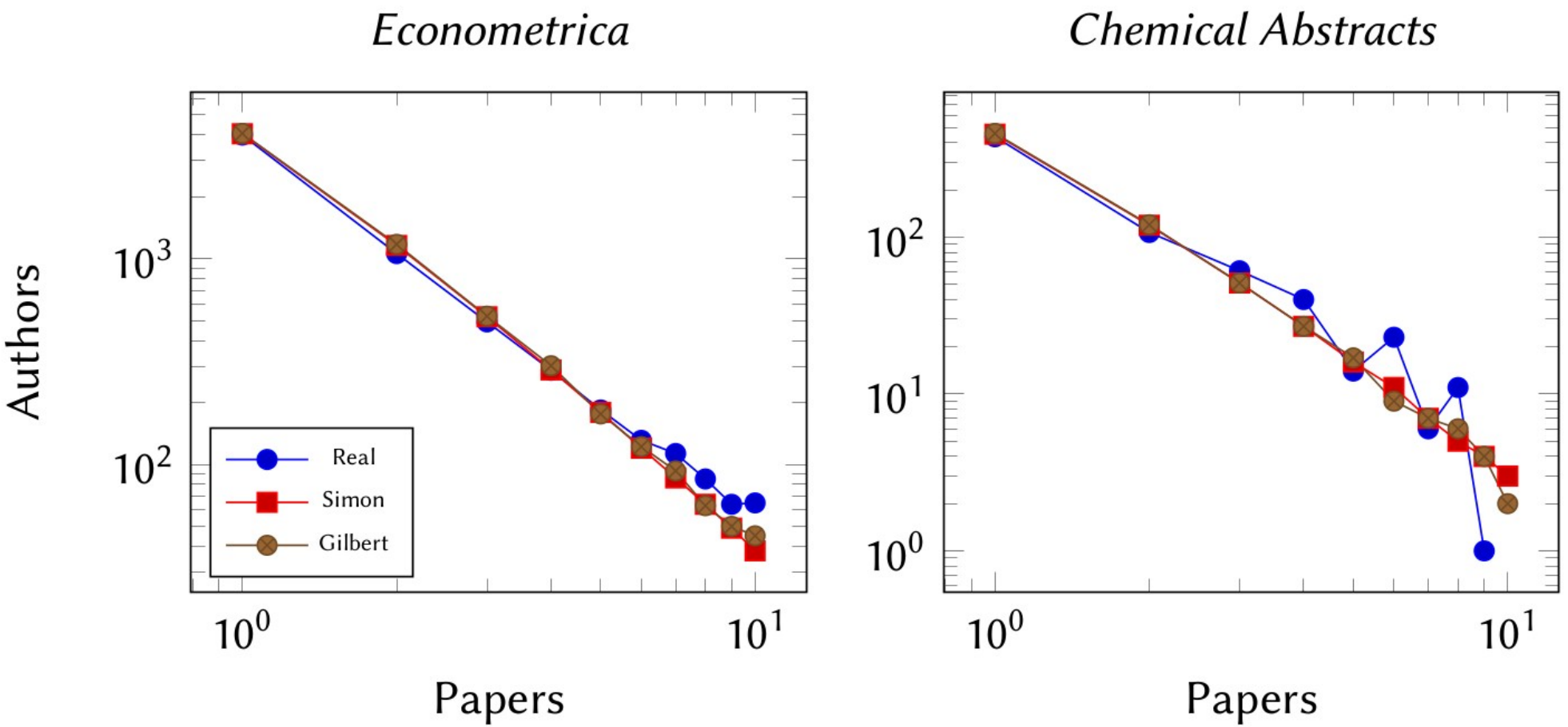
Sociological Research Online, 2(2).

Lotka's Law

- The number of authors making n contributions is about $1/n^2$ of those making one contribution.

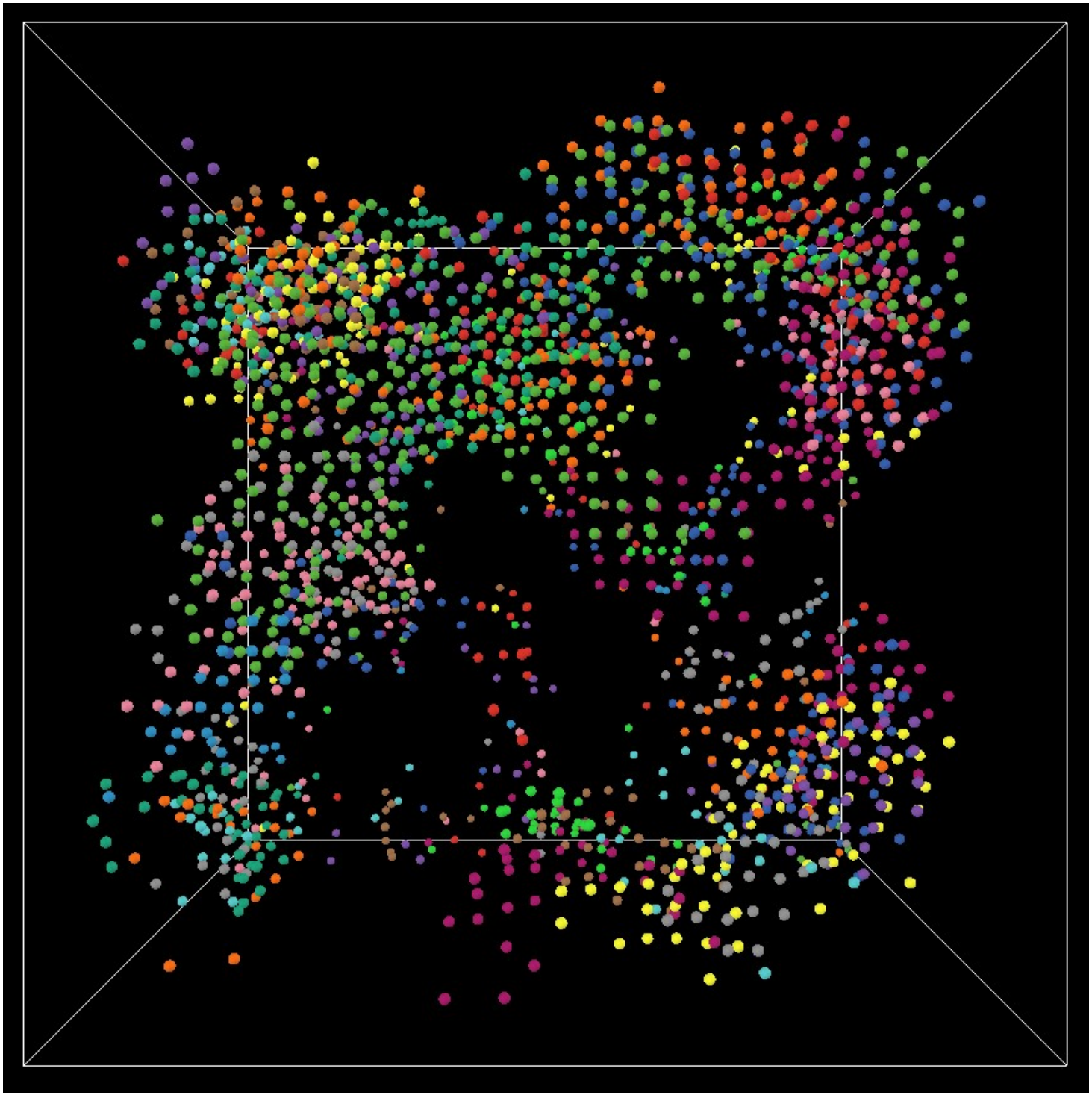
A first, simple model

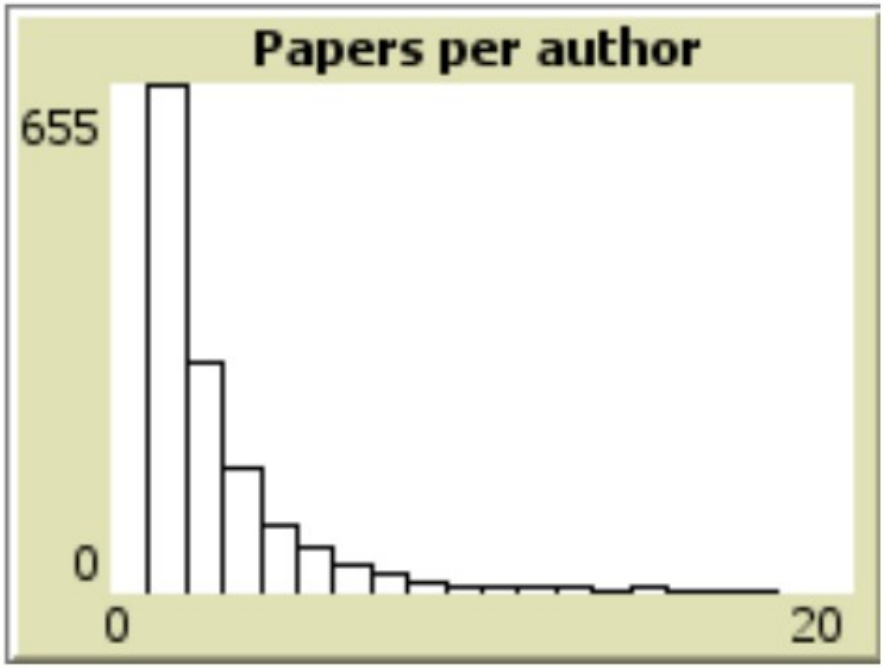
1. Select a random number from a uniform distribution from 0 to 1. If this number is less than α, give the publication to a new (i.e. previously unpublished) author.
2. If the publication is not from a new author, select a paper randomly from those previously published and give the new publication the same author as the one so selected.


Econometrica
Chemical Abstracts
Authors
10^3
10^2
10^2
10^1
10^0
10^0
10^1
10^0
10^1
Real
Simon
Gilbert
Papers
Papers

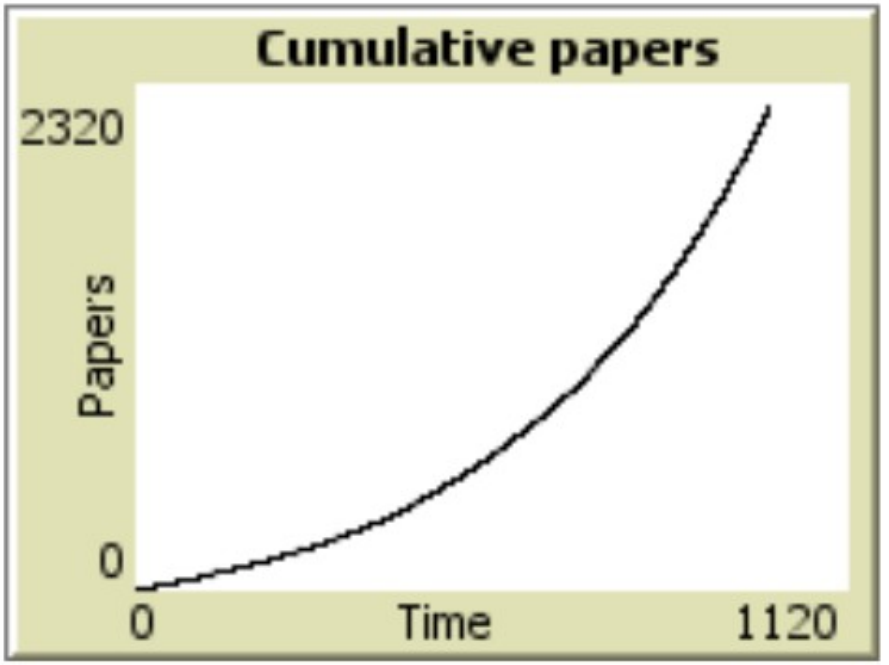
A more complex model

- Every paper contains a *kene*: a string of bits, optionally mapped to a 2D space
- At each time step, every existing paper has a small constant probability of reproducing itself
- Author is assigned like in previous model
- Paper has references, chosen at random from "neighboring" kenes, that "pull" it in their direction

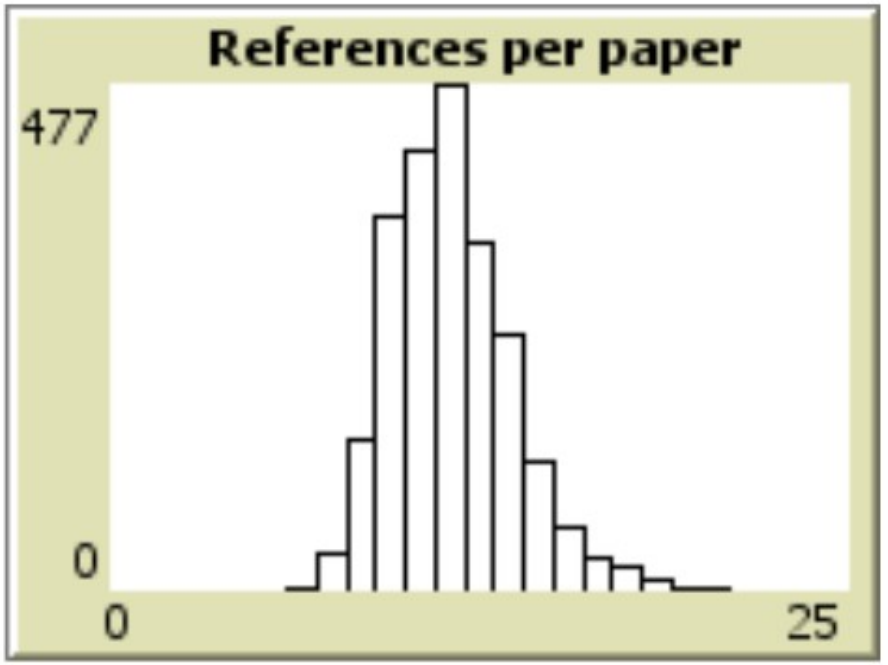



Papers per author
655
0
0
20

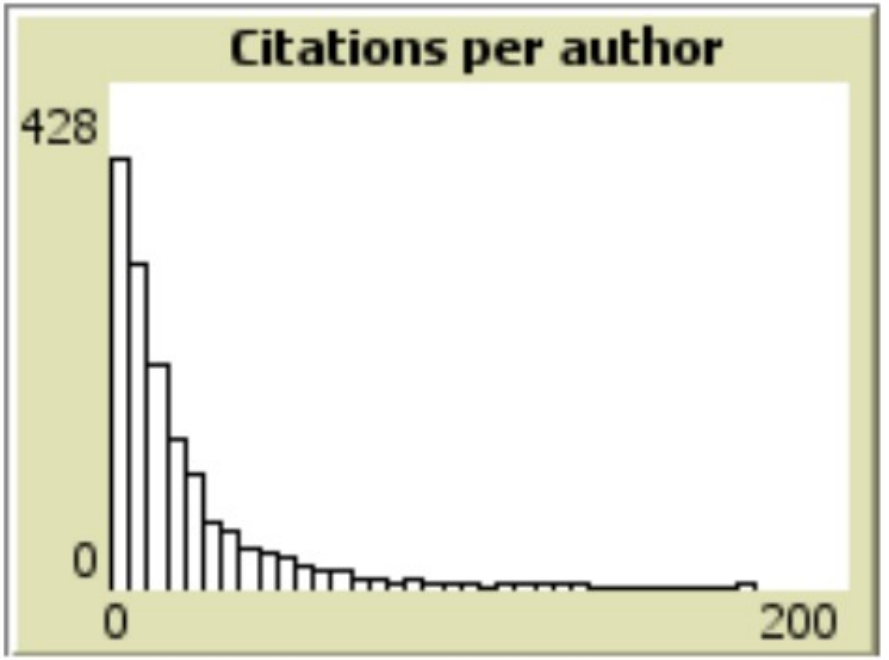
(a)


Cumulative papers
2320
Papers
0
0
Time
1120

(b)


References per paper
477
0
0
25

(c)


Citations per author
428
0
0
200

(d)

Naveh, I., & Sun, R. (2006).

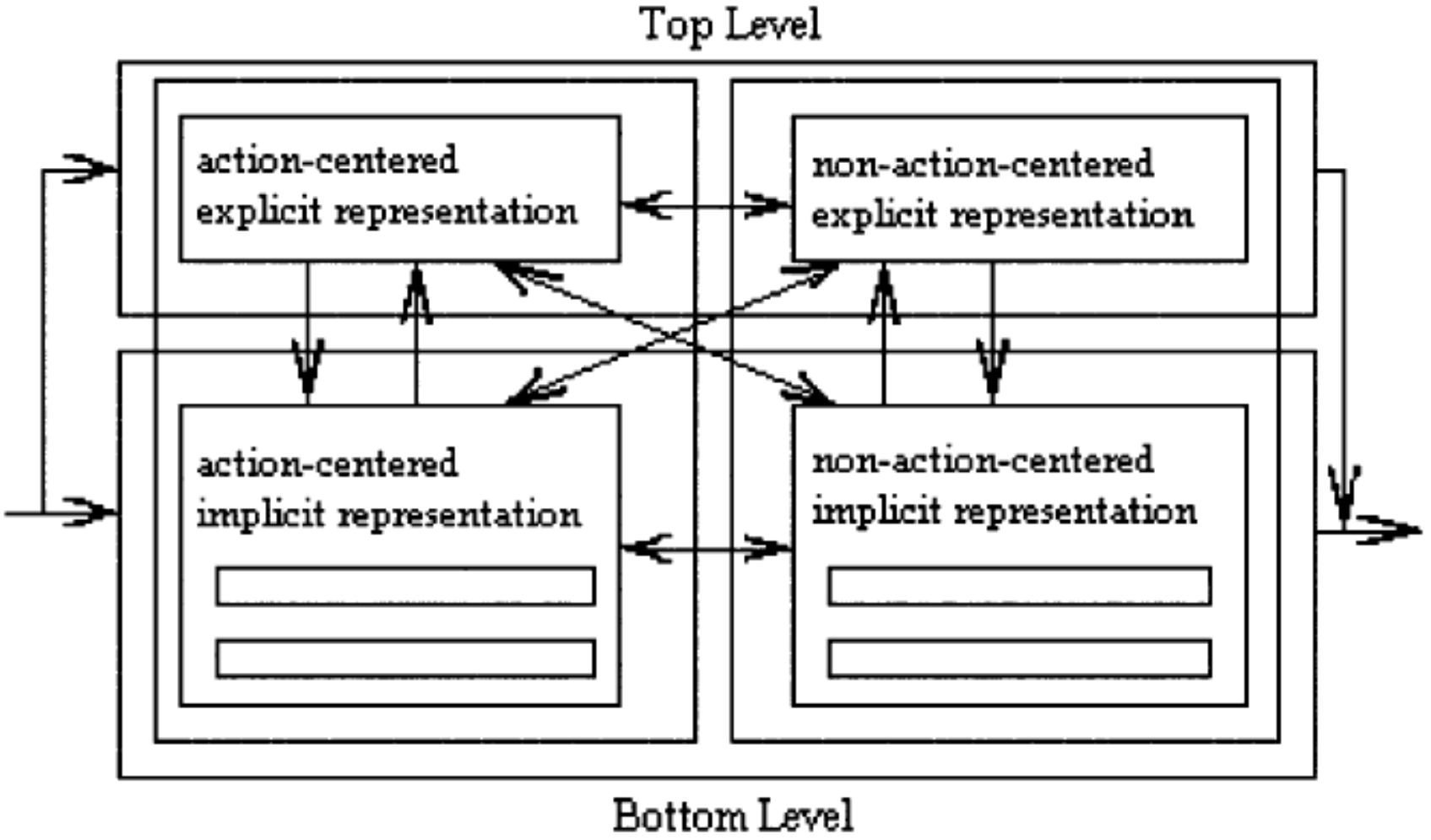
A cognitively based simulation of academic science.

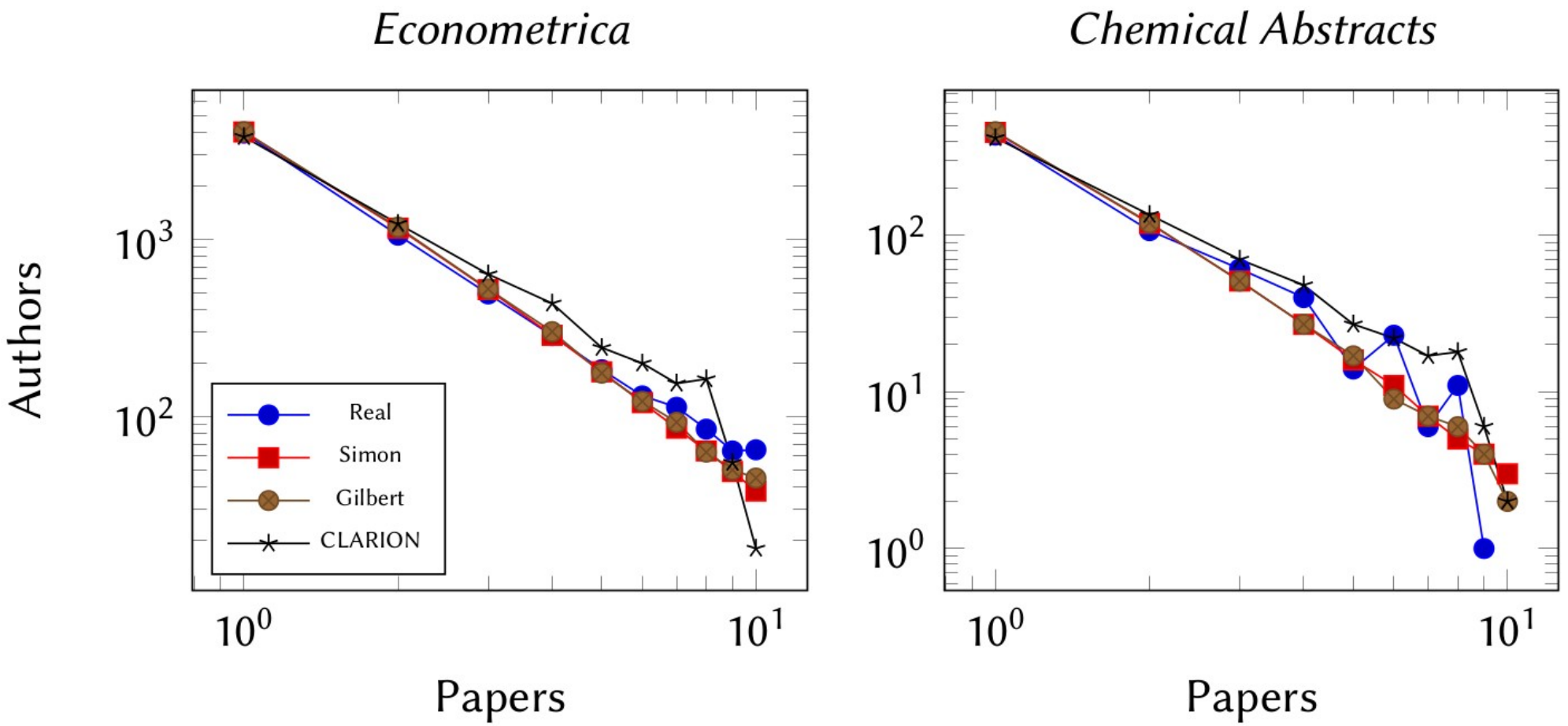
Computational & Mathematical Organization Theory, 12(4), 313–337.

Ideas are not created equals

- Differences in “clarity, insightfulness, empirical evidence, theoretical results, application potential.”
  - “Communal functions” vs. “subjective functions”
- Two tasks for the agents:
  - choosing the focal idea
  - choosing the pull ideas.

CLARION Cognitive Architecture



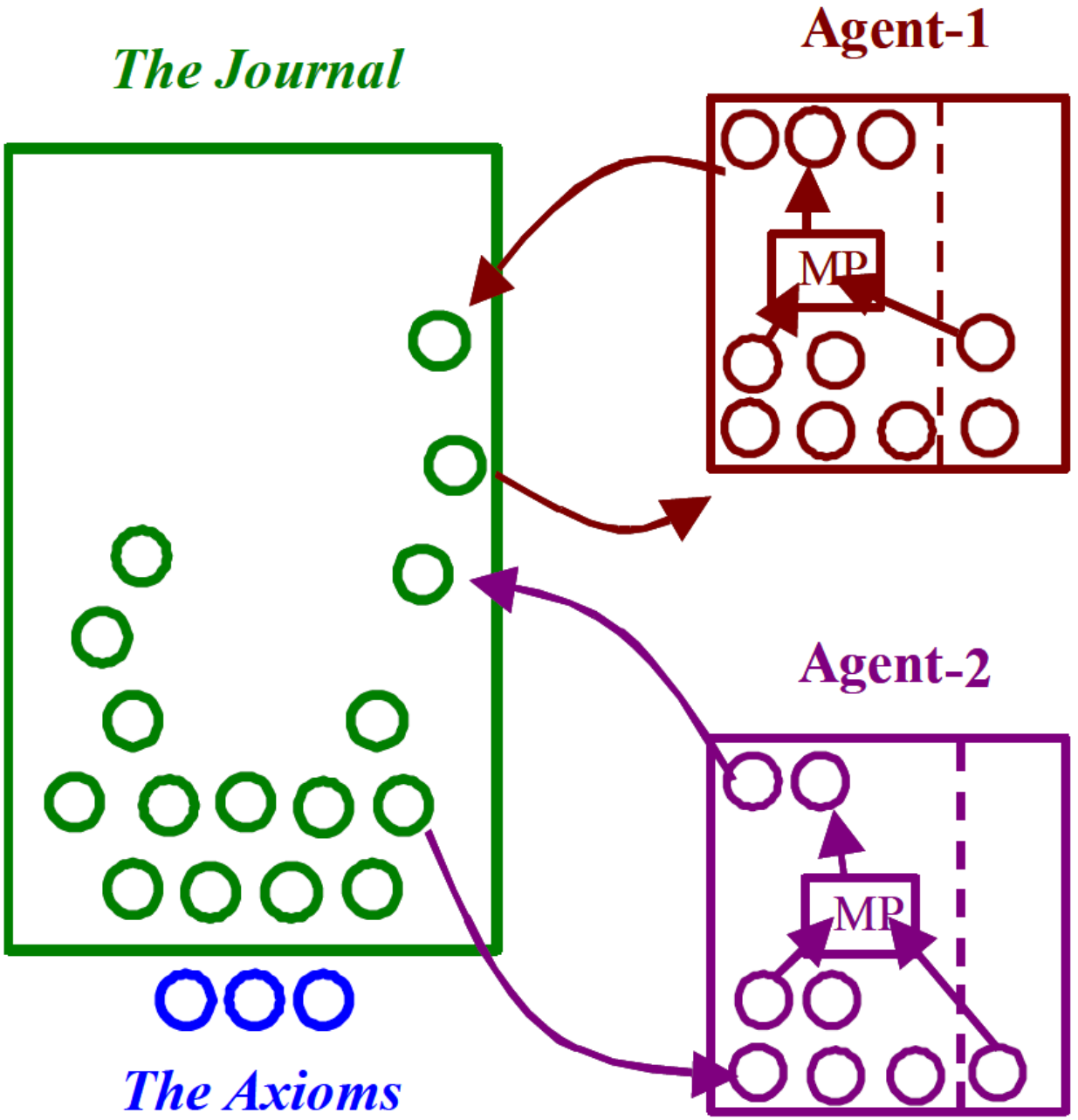

Econometrica
Chemical Abstracts
Authors
Papers
Papers
Real
Simon
Gilbert
CLARION
10^3
10^2
10^1
10^0
10^2
10^1
10^0
10^1
10^1

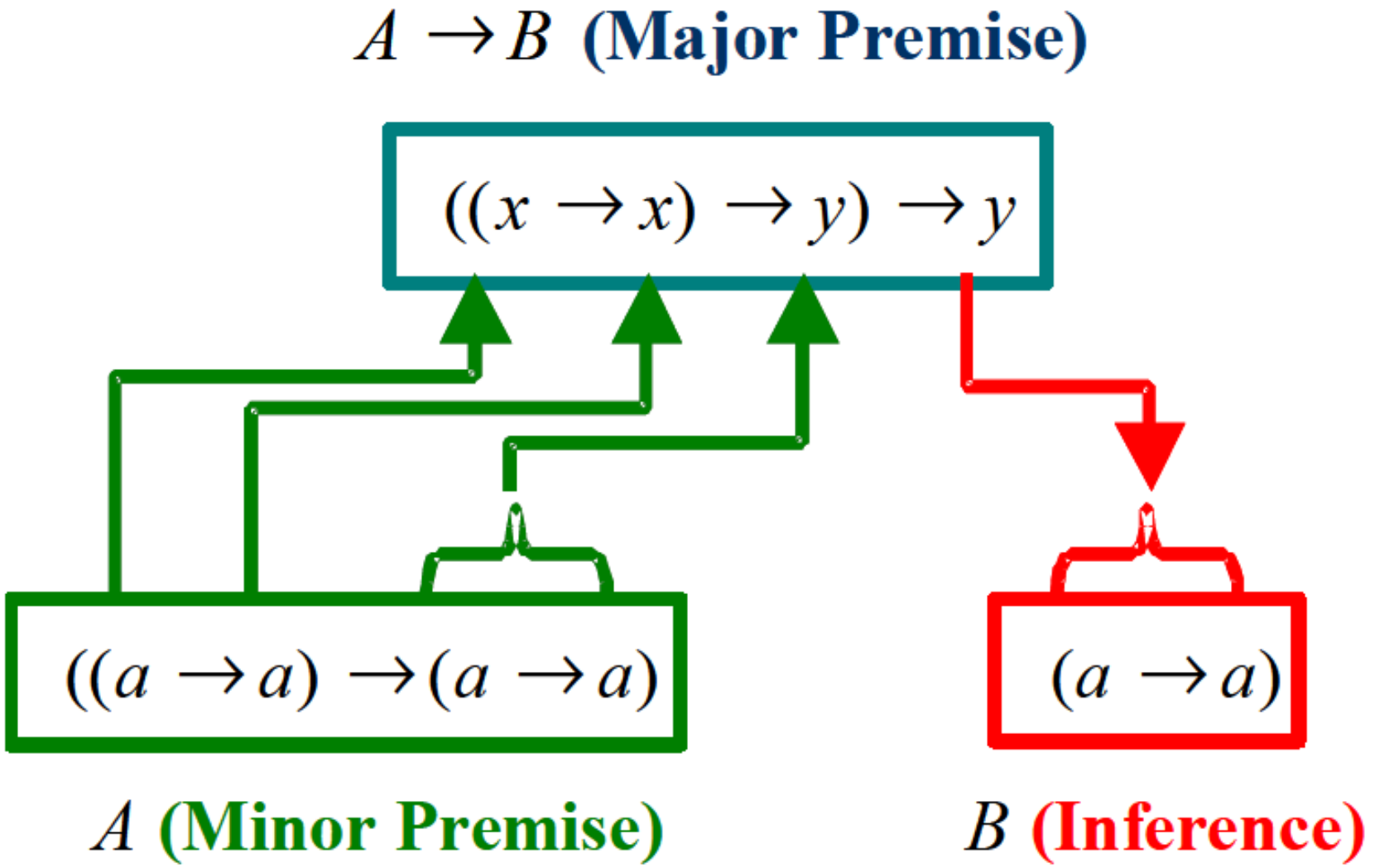
“We put more distance between mechanisms and outcomes, which makes it harder to obtain a match with the human data. Thus, the fact that we were able to match the human data shows the power of our cognitive agent-based approach compared to traditional methods of simulation.” (p. 325)

Edmonds, B. (2007).

Artificial Science: A Simulation to Study the Social Processes of Science.

In *Social Simulation: Technologies, Advances and New Discoveries* (pp. 61–67).


Agent-1
The Journal
MP
Agent-2
MP
The Axioms


$A \to B$ (Major Premise)
$((x \to x) \to y) \to y$
$((a \to a) \to (a \to a))$
$(a \to a)$
A (Minor Premise)
B (Inference)

Weisberg M. & Muldoon, R. (2009).

Epistemic landscapes and the division of cognitive labor.

Philosophy of Science, 76(2), 225-252.

Distribution of cognitive labor

- **Controls**

  ...are basically “hill climbers”: they set a direction and move forward as long as they get better results. If they get worse results, they backtrack and change direction.

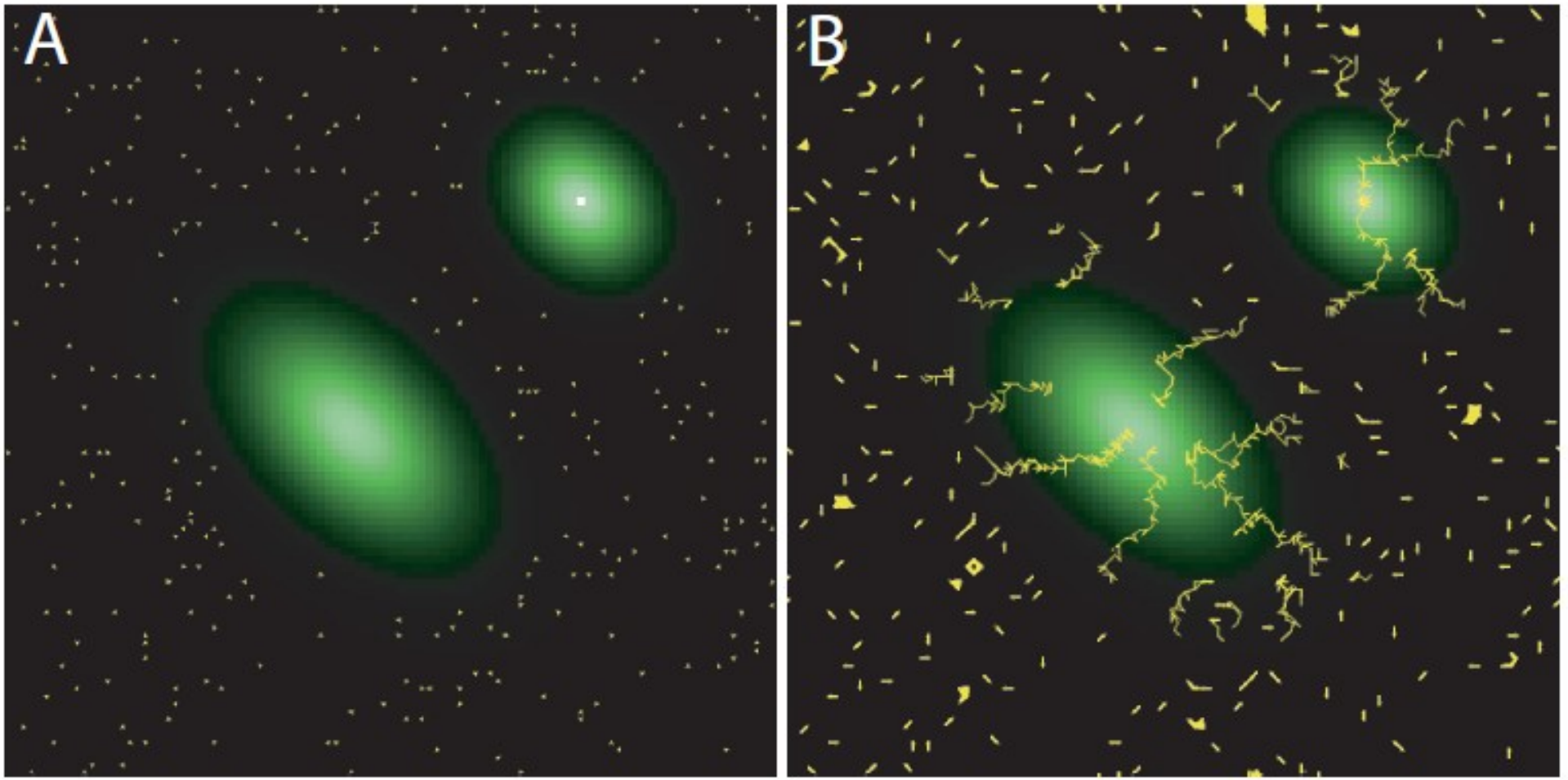
- **Followers**

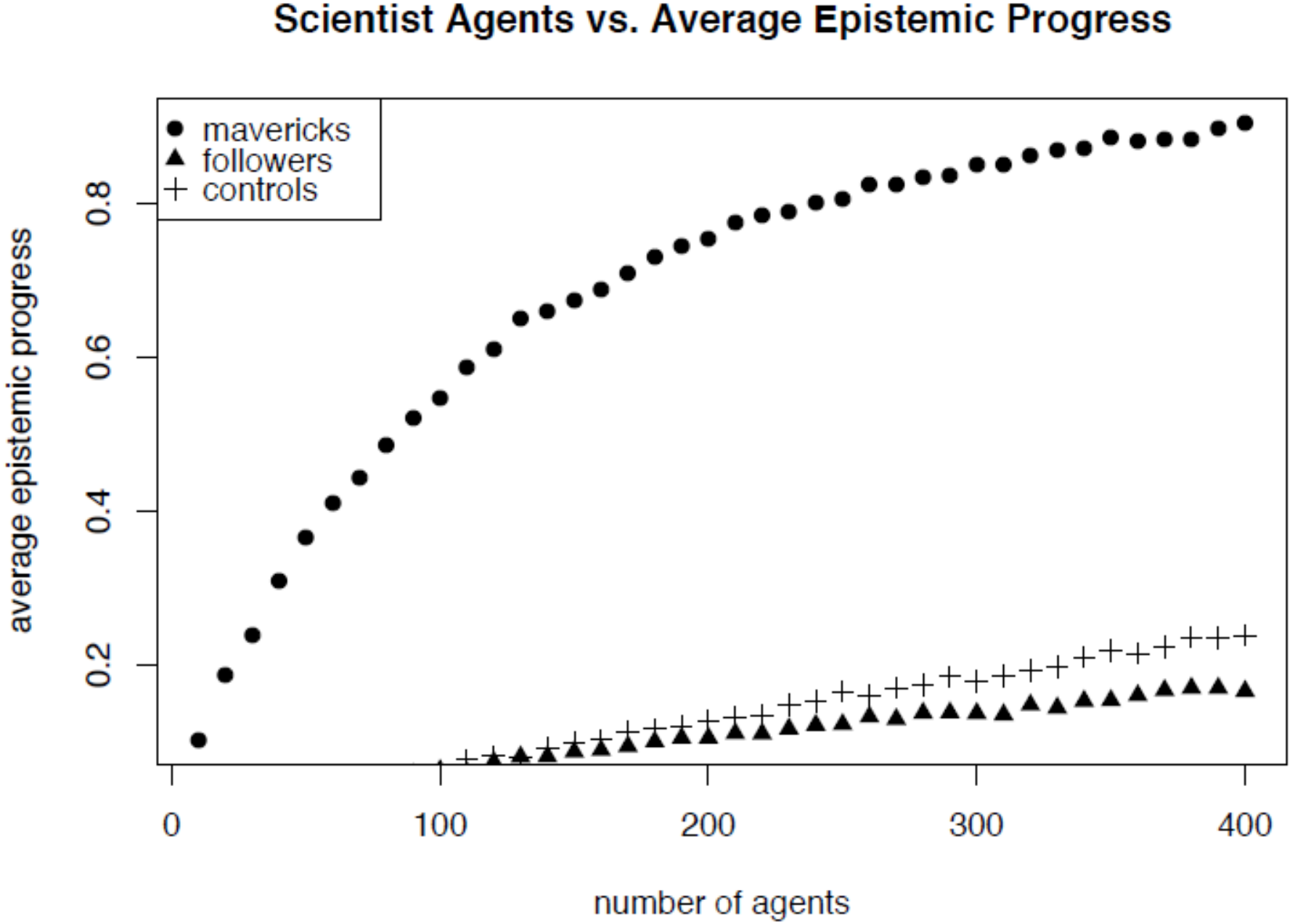
  ...look around them to see if previous agents have found better approaches in their neighborhood and move there if there are. If not, they will look for unvisited place or choose at random.

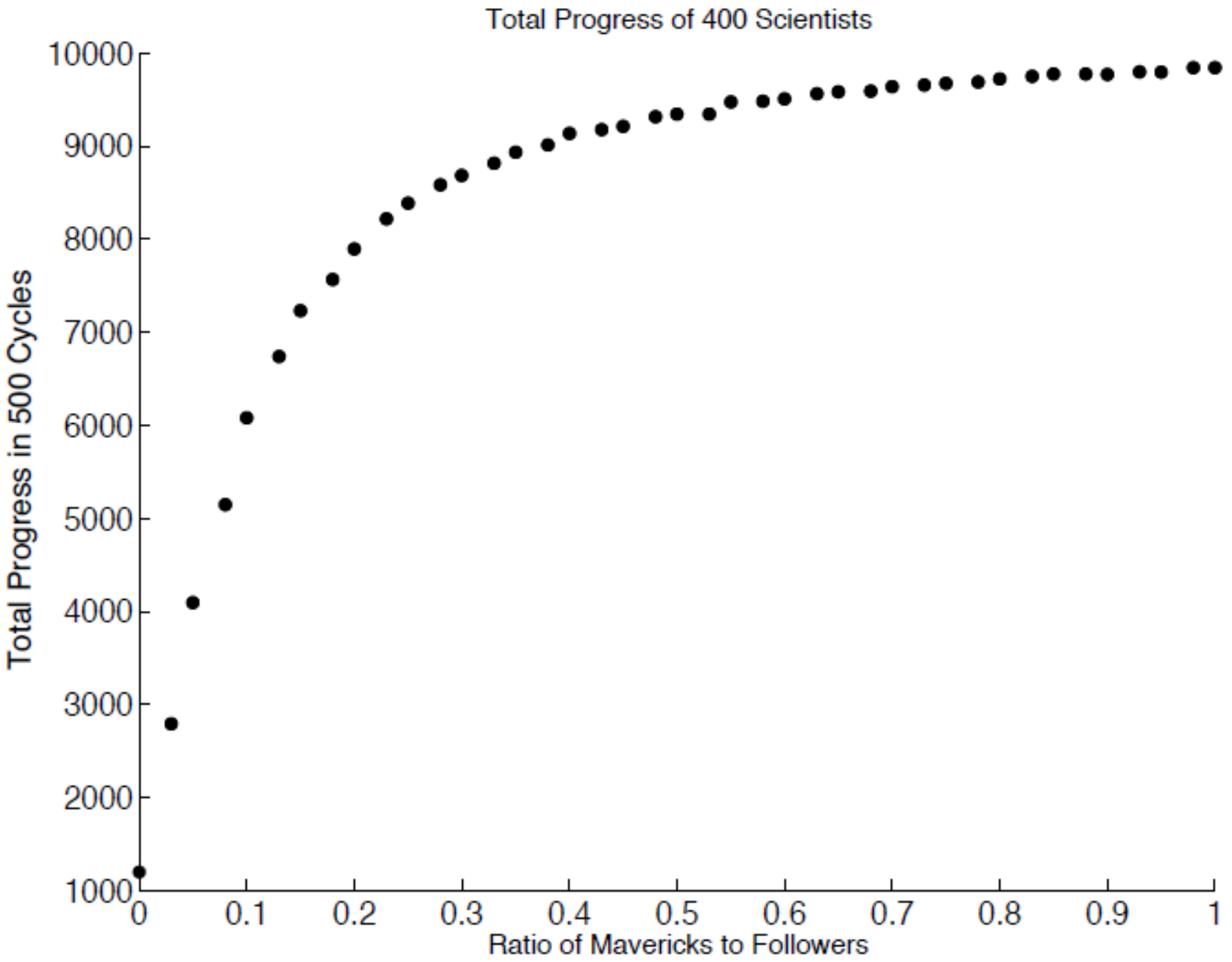
- **Mavericks**

  ...first look for unvisited spots. Only if there are none will they move at the best visited place in their neighborhood.

Follower Dynamics




Scientist Agents vs. Average Epistemic Progress
mavericks
followers
controls
average epistemic progress
0.2
0.4
0.6
0.8
0
100
200
300
400
number of agents


Total Progress of 400 Scientists
Total Progress in 500 Cycles
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Ratio of Mavericks to Followers

Grim, P. (2009).

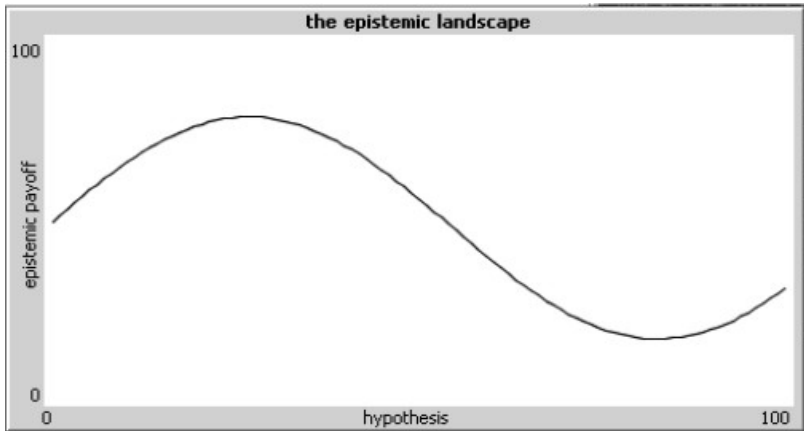
Threshold phenomena in epistemic networks.

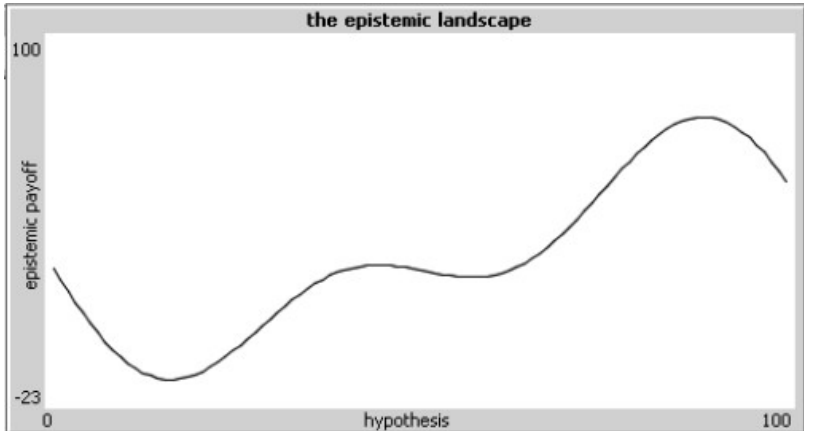
In *Complex Adaptive Systems and the Threshold Effect: Views from the Natural and Social Sciences.*

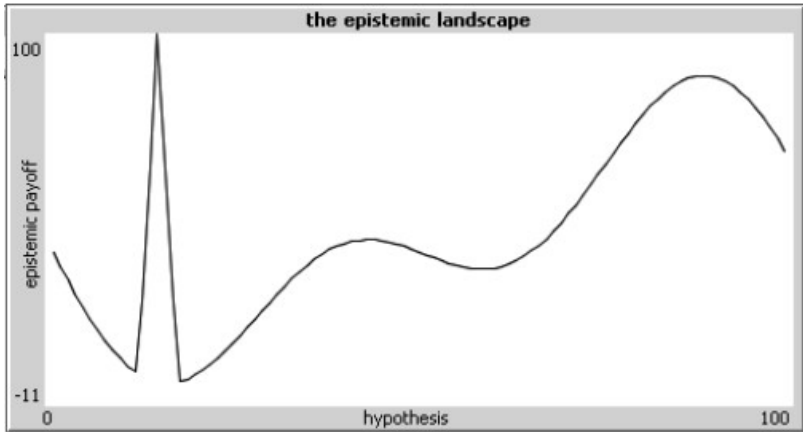
Social structure matters

“How does an individual figure out the structure of the world? The truth is that no individual does. It is cultures and communities that plumb the structure of reality; individuals figure out the structure of the world only as they participate in the epistemic networks in which they are embedded.”

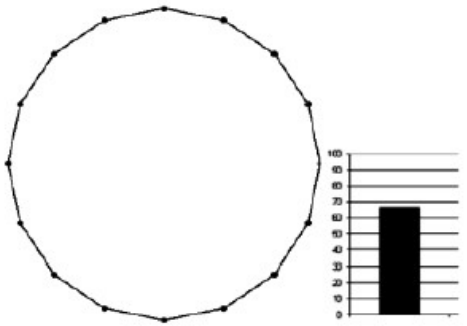
Some landscapes are harder than others



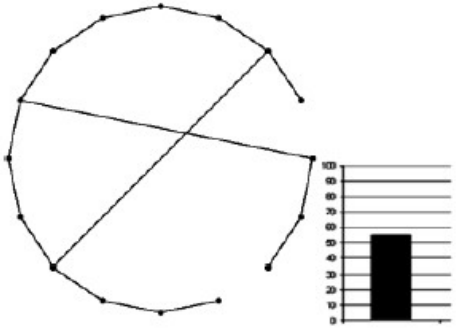




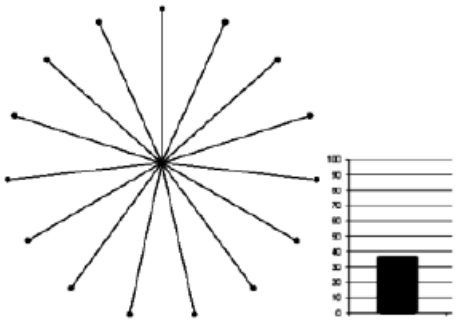
Network structure performance



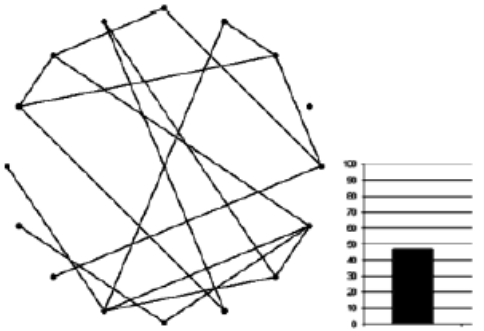
ring



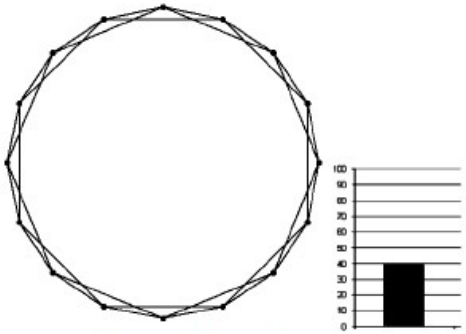
small world



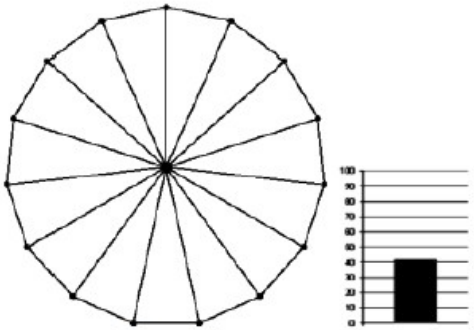
hub



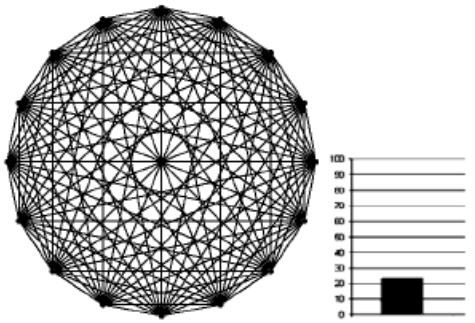
random



ring radius 2



wheel



complete

Part II

Modelling Science with NetLogo

Three New Extensions

NetLogo Home Page - Mozilla Firefox

NetLogo Home Page

ccl.northwestern.edu/netlogo/

Google

NetLogo

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Extensions
FAQ
References
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Community
Modeling Commons

User Manuals:
Web
Printable
Chinese
Czech
Japanese

Donate

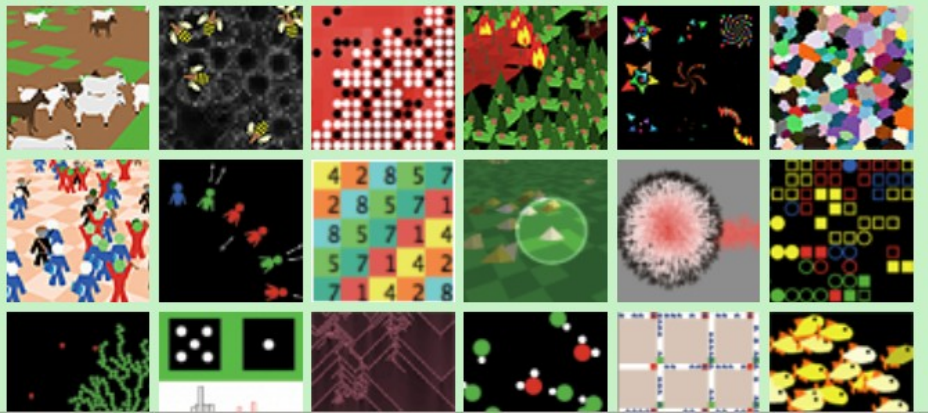
NetLogo is a multi-agent programmable modeling environment. It is used by tens of thousands of students, teachers and researchers worldwide. It also powers HubNet participatory simulations. It is authored by Uri Wilensky and developed at the CCL. You can download it free of charge.

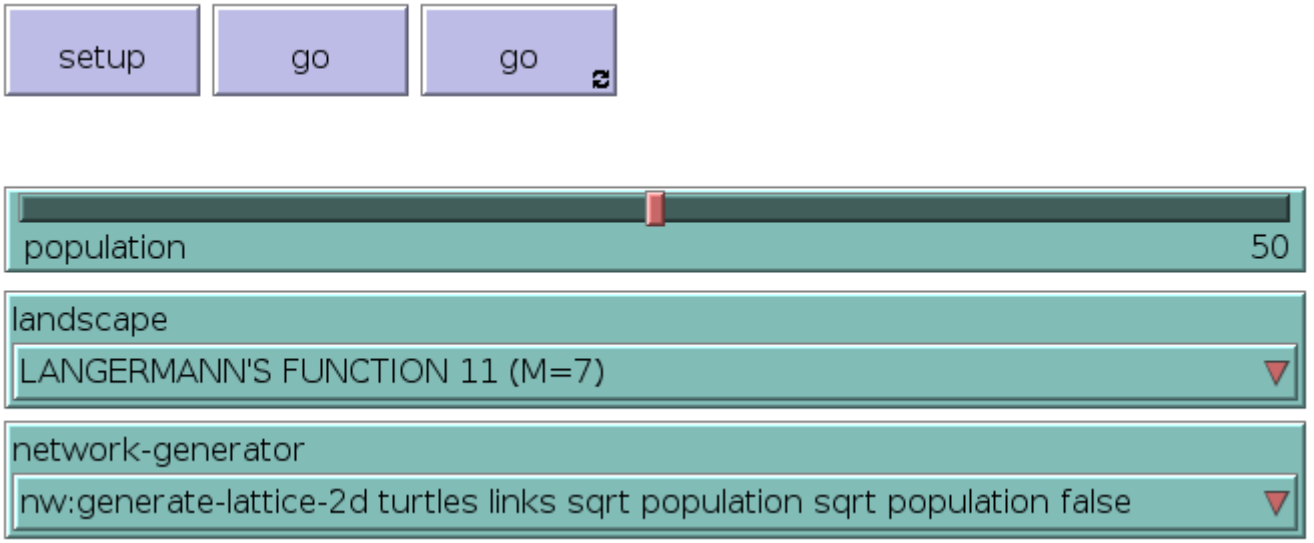
What can you do with NetLogo? Read more here. Click here to watch videos.

Join mailing lists here.

Download

NetLogo comes with a large library of sample models. Click on some examples below.

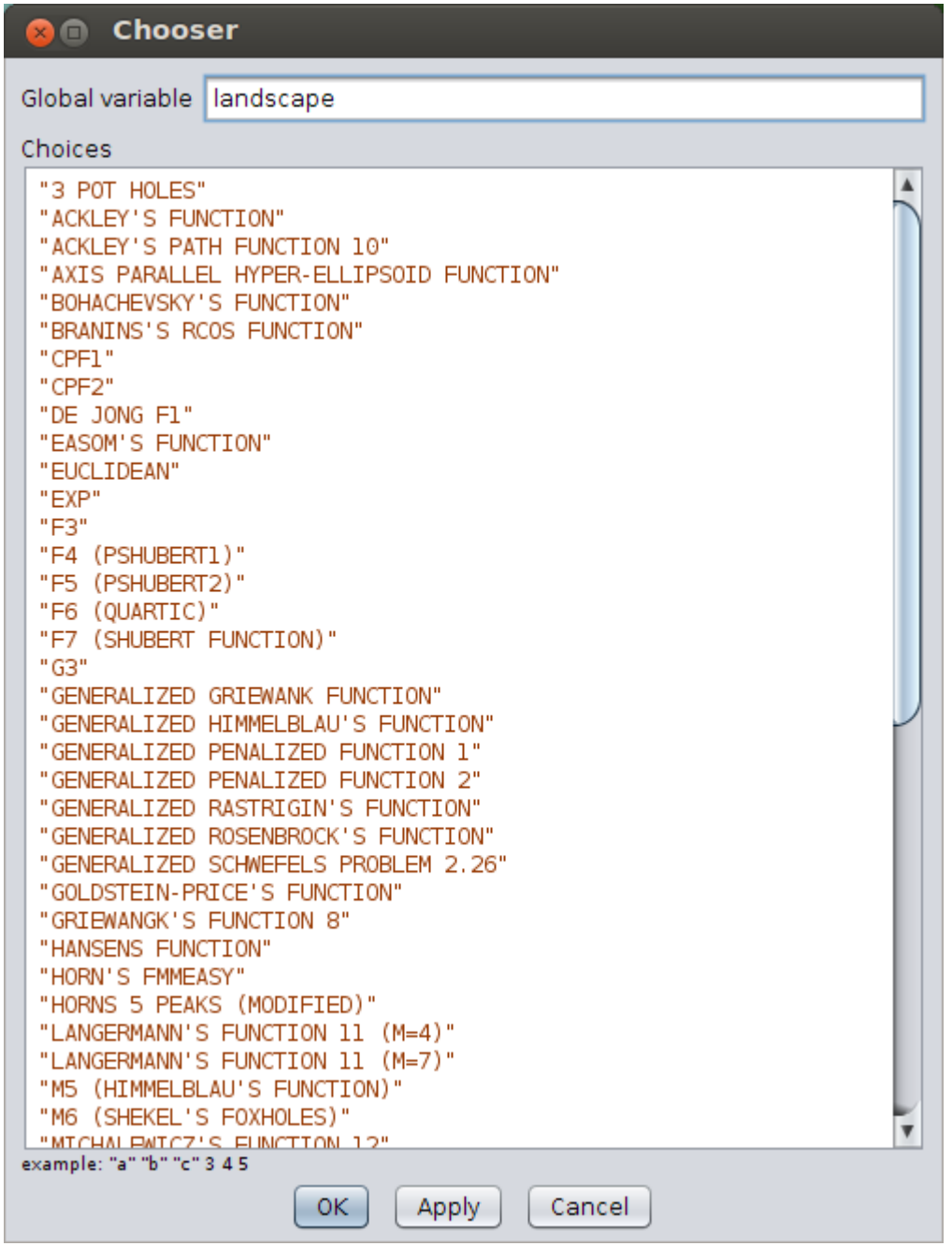


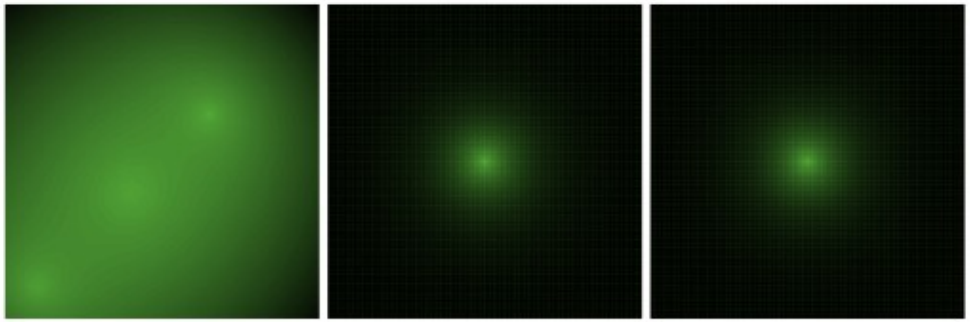

setup
go
go
population
50
landscape
LANGERMANN'S FUNCTION 11 (M=7)
network-generator
nw:generate-lattice-2d turtles links sqrt population sqrt population false

```
extensions [ nw rnd landscapes ]

patches-own [ value ]

to setup
  clear-all
  setup-landscape
  setup-network
  reset-ticks
end
```


Chooser
Global variable
landscape
Choices
"3 POT HOLES"
"ACKLEY'S FUNCTION"
"ACKLEY'S PATH FUNCTION 10"
"AXIS PARALLEL HYPER-ELLIPSOID FUNCTION"
"BOHACHEVSKY'S FUNCTION"
"BRANINS'S RCOS FUNCTION"
"CPF1"
"CPF2"
"DE JONG F1"
"EASOM'S FUNCTION"
"EUCLIDEAN"
"EXP"
"F3"
"F4 (PSHUBERT1)"
"F5 (PSHUBERT2)"
"F6 (QUARTIC)"
"F7 (SHUBERT FUNCTION)"
"G3"
"GENERALIZED GRIEWANK FUNCTION"
"GENERALIZED HIMMELBLAU'S FUNCTION"
"GENERALIZED PENALIZED FUNCTION 1"
"GENERALIZED PENALIZED FUNCTION 2"
"GENERALIZED RASTRIGIN'S FUNCTION"
"GENERALIZED ROSENBROCK'S FUNCTION"
"GENERALIZED SCHWEFELS PROBLEM 2.26"
"GOLDSTEIN-PRICE'S FUNCTION"
"GRIEWANGK'S FUNCTION 8"
"HANSENS FUNCTION"
"HORN'S FMMEASY"
"HORNS 5 PEAKS (MODIFIED)"
"LANGERMANN'S FUNCTION 11 (M=4)"
"LANGERMANN'S FUNCTION 11 (M=7)"
"M5 (HIMMELBLAU'S FUNCTION)"
"M6 (SHEKEL'S FOXHOLES)"
"MICHALEWICZ'S FUNCTION 12"
example: "a" "b" "c" 3 4 5
OK
Apply
Cancel



(I) 3 POT HOLES

(II) ACKLEY'S FUNCTION

(III) ACKLEY'S PATH FUNCTION 10

(IV) AXIS PARALLEL HYPER-ELLIPSOID FUNCTION

(V) BOHACHEVSKY'S FUNCTION

(VI) BRANINS'S RCOS FUNCTION

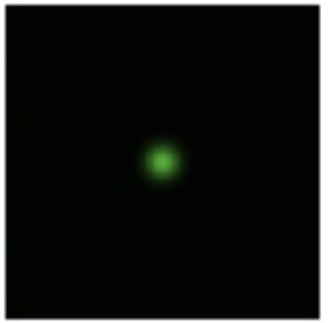
(VII) CPF1

(VIII) CPF2

(IX) DE JONG F1

(X) EASOM'S FUNCTION

(XI) EUCLIDEAN



(XII) EXP

(XIII) F3

(XIV) F4 (PSHUBERT1)

(XV) F5 (PSHUBERT2)

(XVI) F6 (QUARTIC)

(XVII) F7 (SHUBERT FUNCTION)

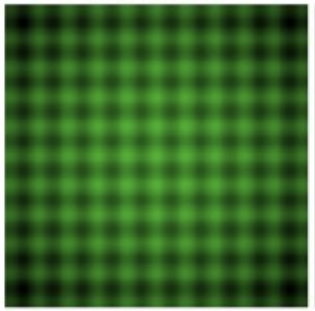
(XVIII) G3

(XIX) GENERALIZED GRIEWANK FUNCTION

(XX) GENERALIZED HIMMELBLAU'S FUNCTION

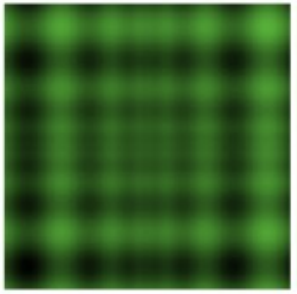
(XXI) GENERALIZED PENALIZED FUNCTION 1

(XXII) GENERALIZED PENALIZED FUNCTION 2



(XXIII) GENERALIZED RASTRIGIN'S FUNCTION

(XXIV) GENERALIZED ROSENBROCK'S FUNCTION



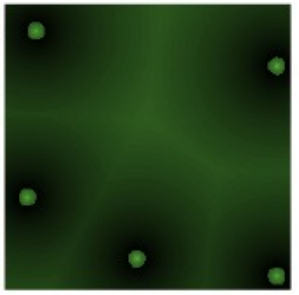
(XXV) GENERALIZED SCHWEFELS PROBLEM 2.26

(XXVI) GOLDSTEIN-PRICE'S FUNCTION

(XXVII) GRIEWANGK'S FUNCTION 8

(XXVIII) HANSENS FUNCTION

(XXIX) HORN'S FMMEASY

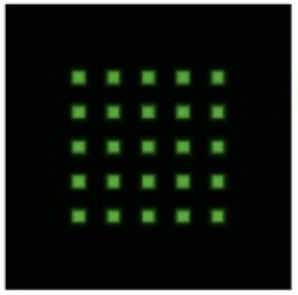


(XXX) HORNS 5 PEAKS (MODIFIED)

(XXXI) LANGERMANN'S FUNCTION 11 (M=4)

(XXXII) LANGERMANN'S FUNCTION 11 (M=7)

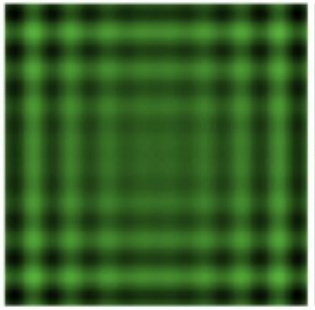
(XXXIII) M5 (HIMMELBLAU'S FUNCTION)



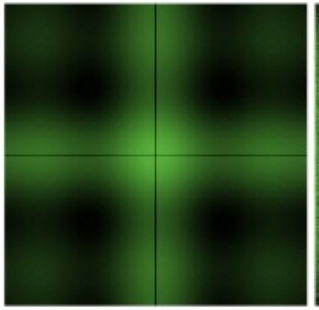
(XXXIV) M6 (SHEKEL'S FOXHOLES)

(XXXV) MICHALEWICZ'S FUNCTION 12

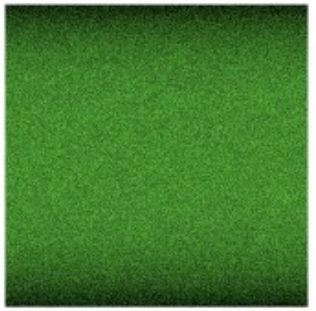
(XXXVI) MOVED AXIS PARALLEL HYPER-ELLIPSOID FUNCTION



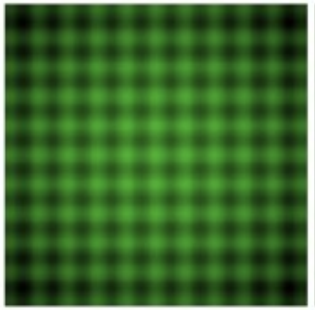
(XXXVII) MULTI FUNCTION



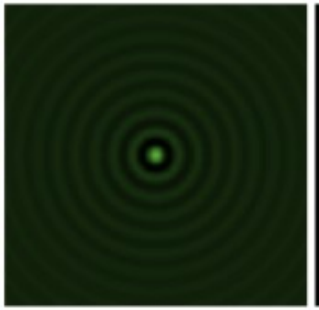
(XXXVIII) PEAKS



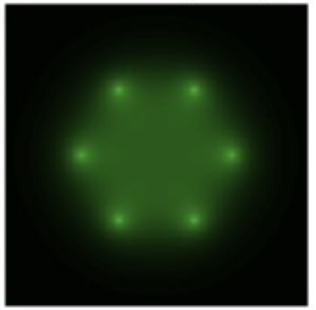
(XXXIX) QUARTIC FUNCTION (NOISE)



(XL) RASTRIGIN'S FUNCTION 6



(XLI) RIPPLES

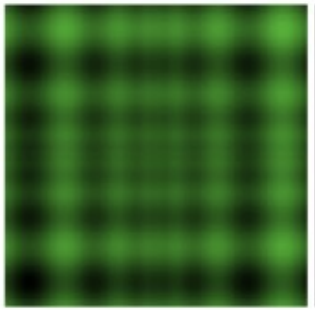


(XLII) ROOTS

(XLIII) ROSENBROCK'S VALLEY (DE JONG F2)

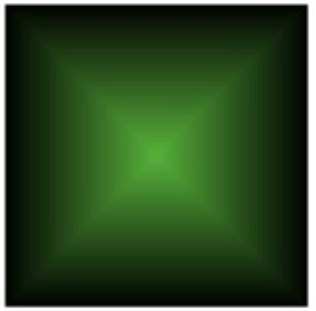
(XLIV) ROTATED HYPER-ELLIPSOID FUNCTION

(XLV) SCHAFFER'S FUNCTION



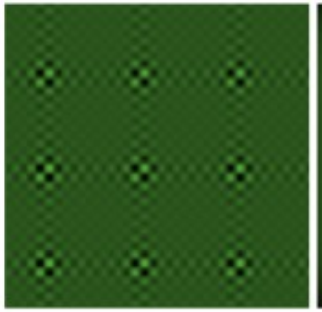
(XLVI) SCHWEFEL'S FUNCTION 7

(XLVII) SCHWEFEL'S PROBLEM 1.2



(XLVIII) SCHWEFEL'S PROBLEM 2.21

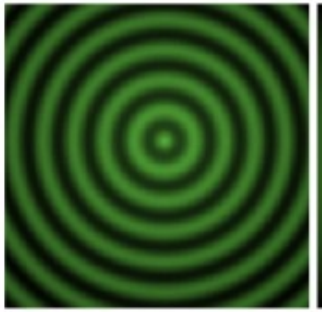
(XLIX) SCHWEFEL'S PROBLEM 2.22



(L) SHUBERT FUNCTION

(LI) SIX-HUMP CAMEL BACK FUNCTION

(LII) SPHERE



(LIII) SQUASHED FROG FUNCTION (TIMBO)

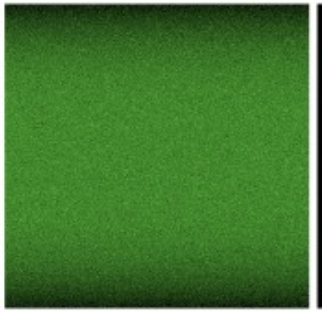
(LIV) STEP FUNCTION

(LV) SUM OF DIFFERENT POWER FUNCTION

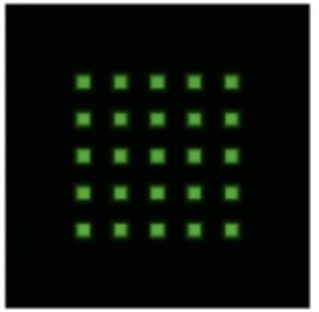
(LVI) TEST FUNCTION F1

(LVII) TEST FUNCTION F2 (ROSENBROCK'S FUNCTION)

(LVIII) TEST FUNCTION F3

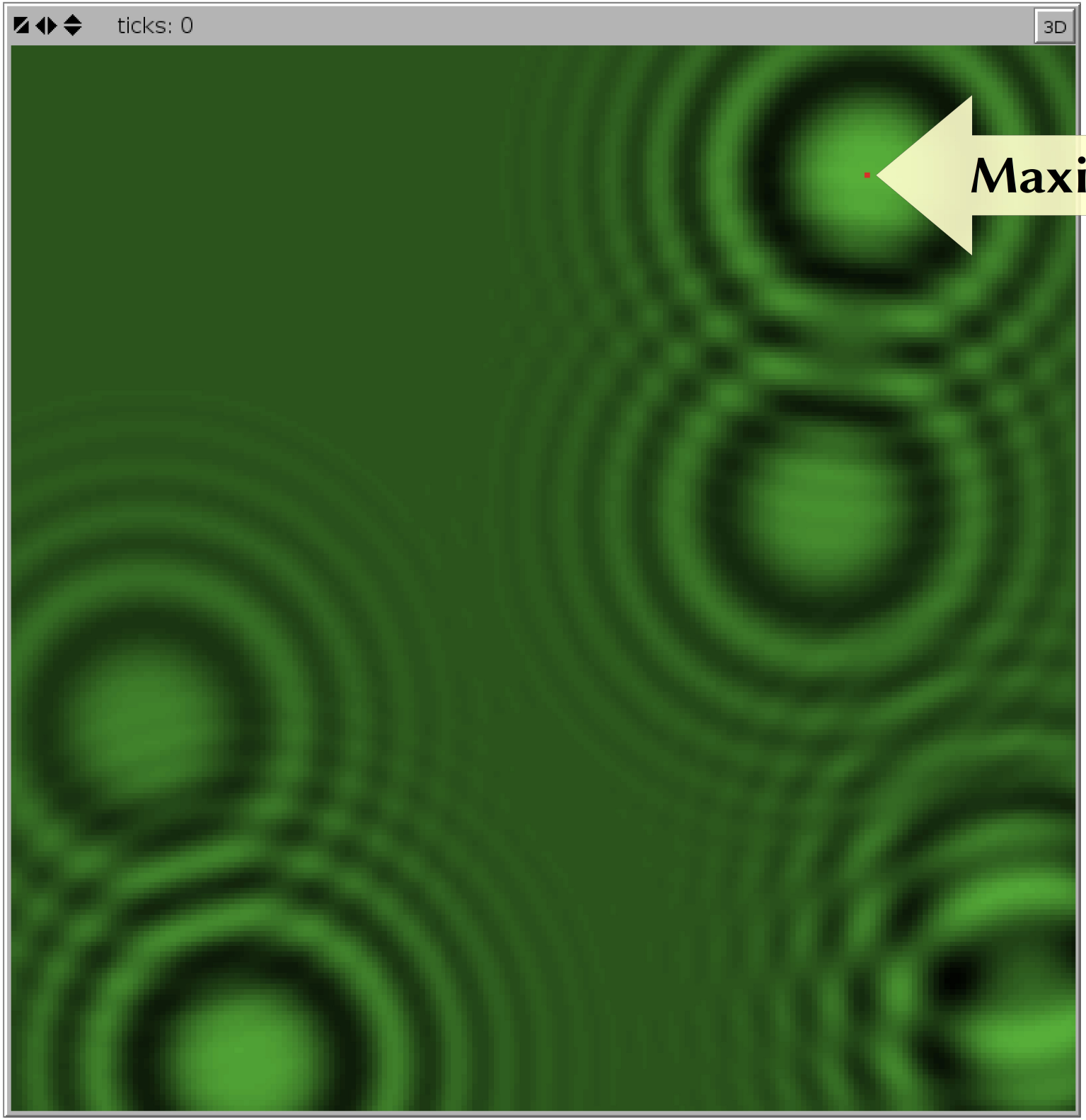


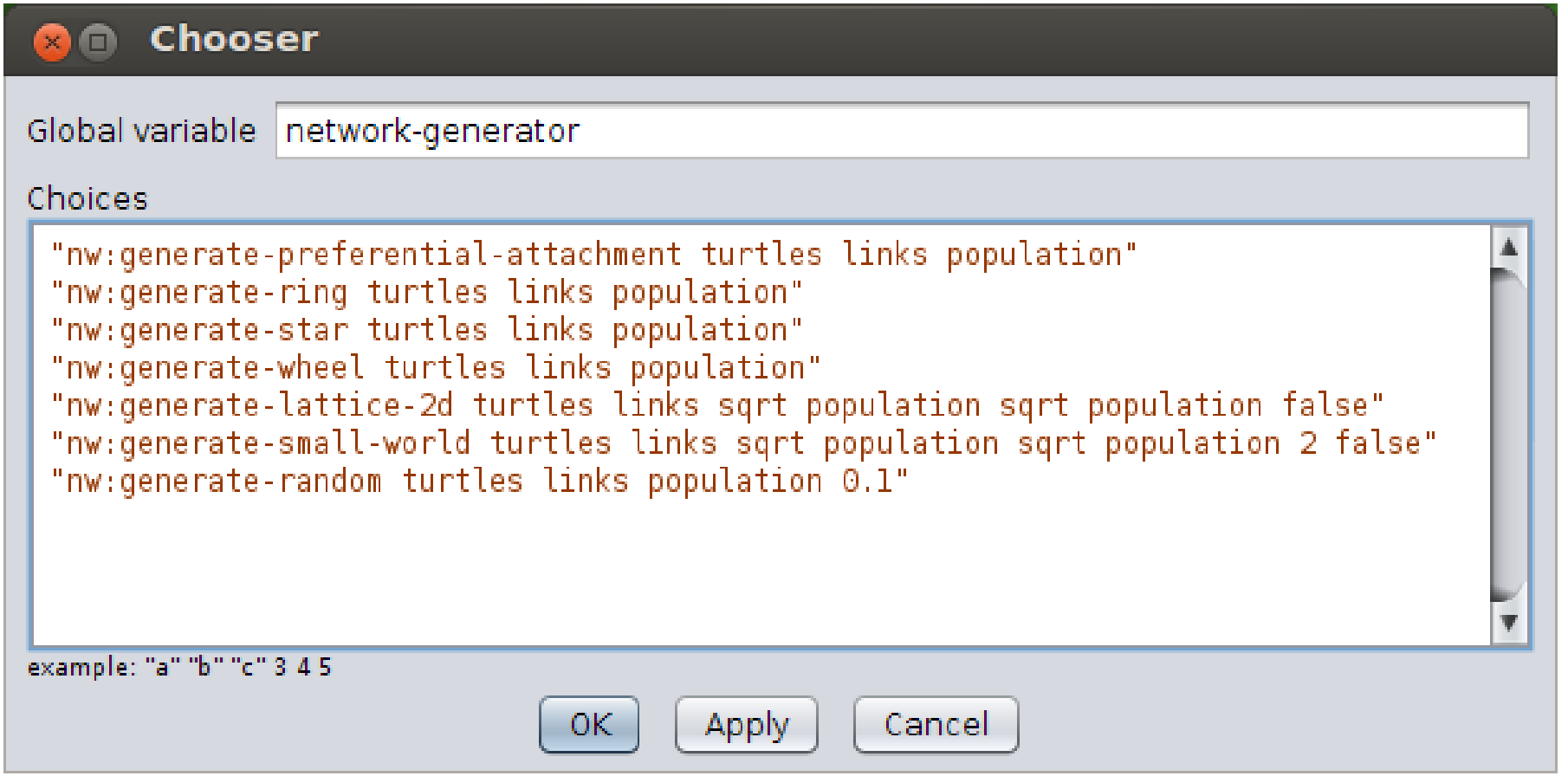
(LIX) TEST FUNCTION F4 (QUARTIC FUNCTION)



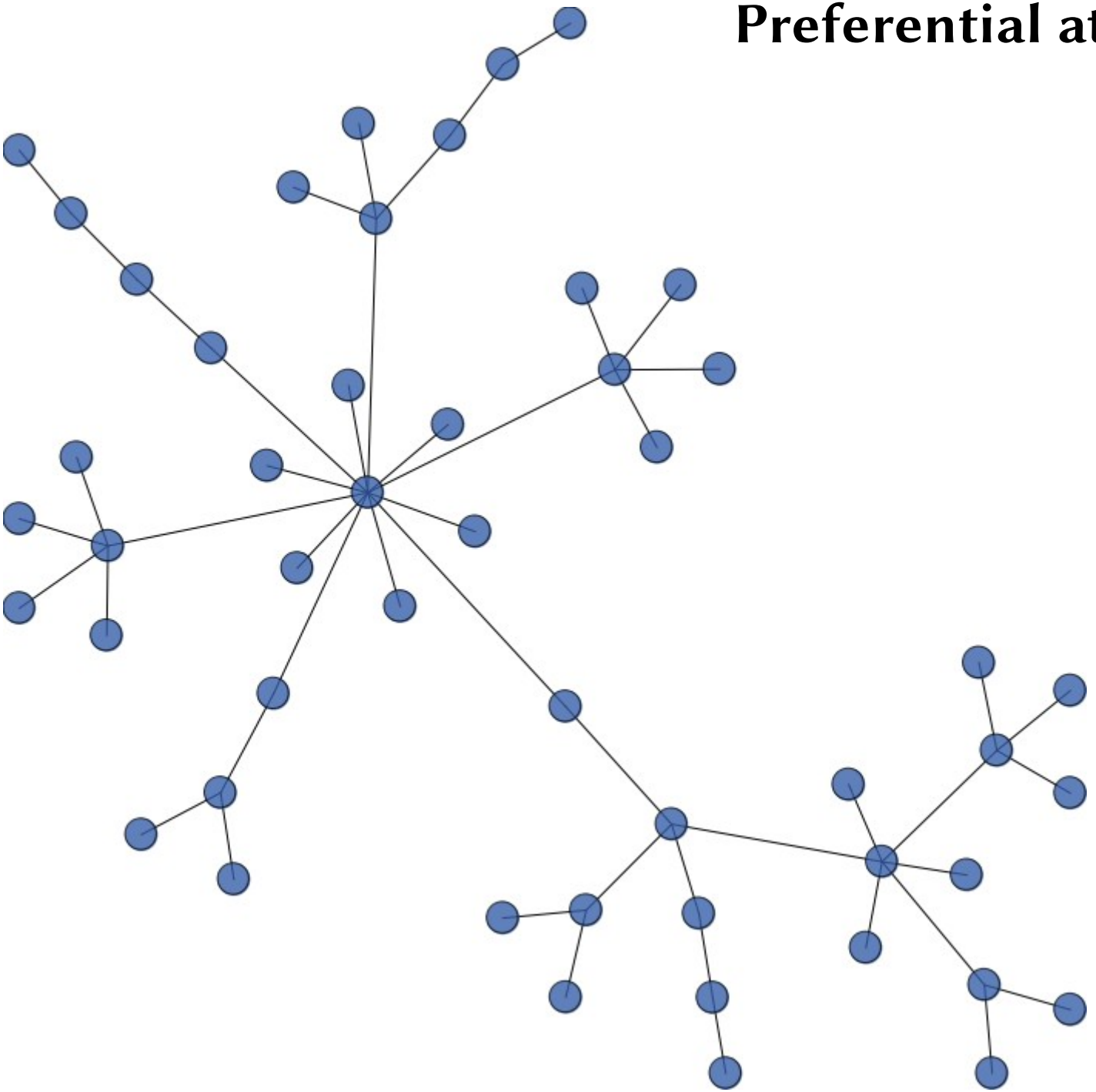
(LX) TEST FUNCTION F5 (SHEKEL'S FUNCTION)

```
to setup-landscape
  resize-world -100 100 -100 100
  set-patch-size 3
  landscapes:generate landscape "value"
  ask patches [
    set pcolor scale-color green value 0 2
  ]
  ask patches with-max [ value ] [
    set pcolor red
  ]
end
```

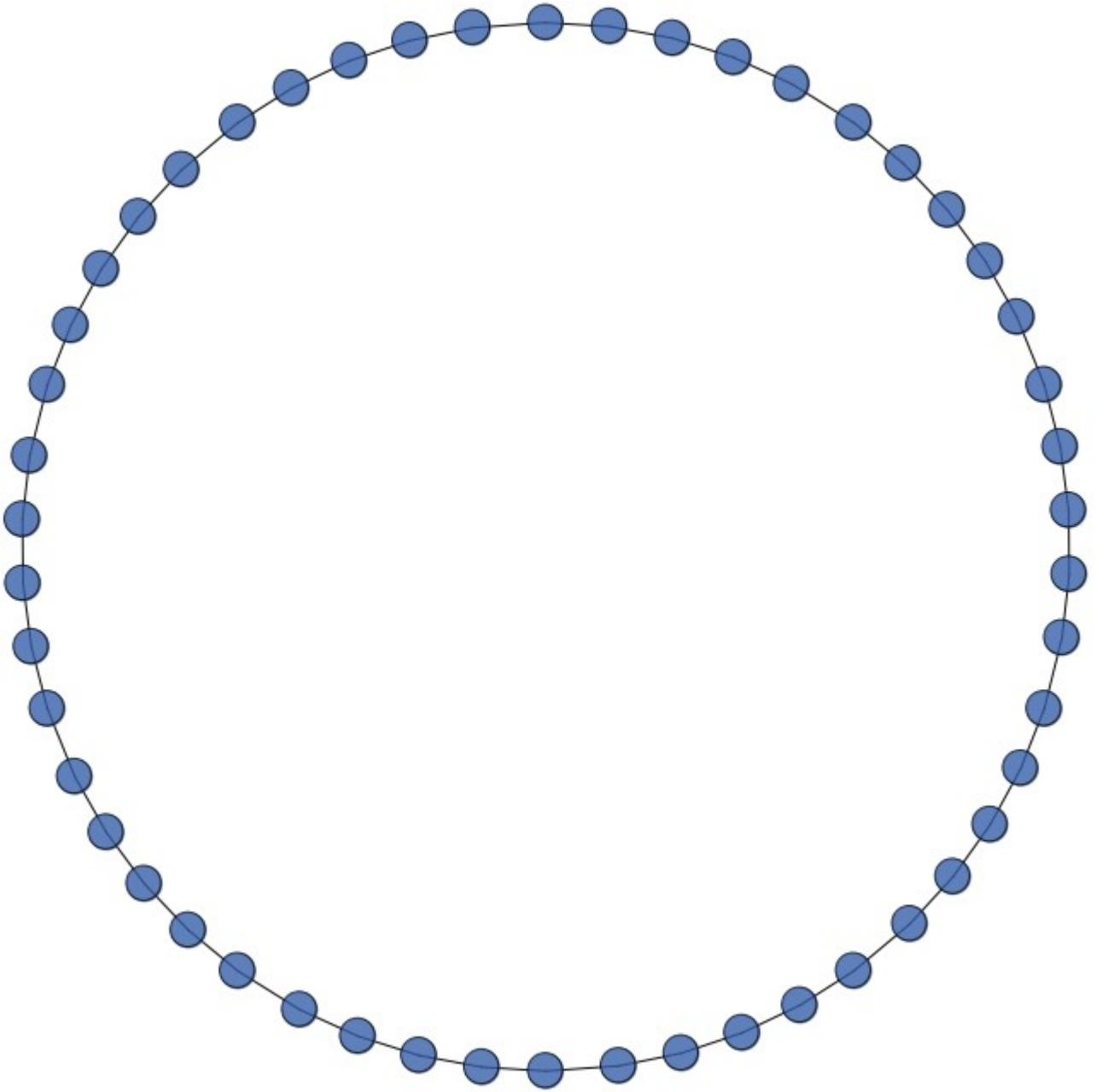

ticks: 0
3D
Maximum


Chooser
Global variable
network-generator
Choices
"nw:generate-preferential-attachment turtles links population"
"nw:generate-ring turtles links population"
"nw:generate-star turtles links population"
"nw:generate-wheel turtles links population"
"nw:generate-lattice-2d turtles links sqrt population sqrt population false"
"nw:generate-small-world turtles links sqrt population sqrt population 2 false"
"nw:generate-random turtles links population 0.1"
example: "a" "b" "c" 3 4 5
OK
Apply
Cancel

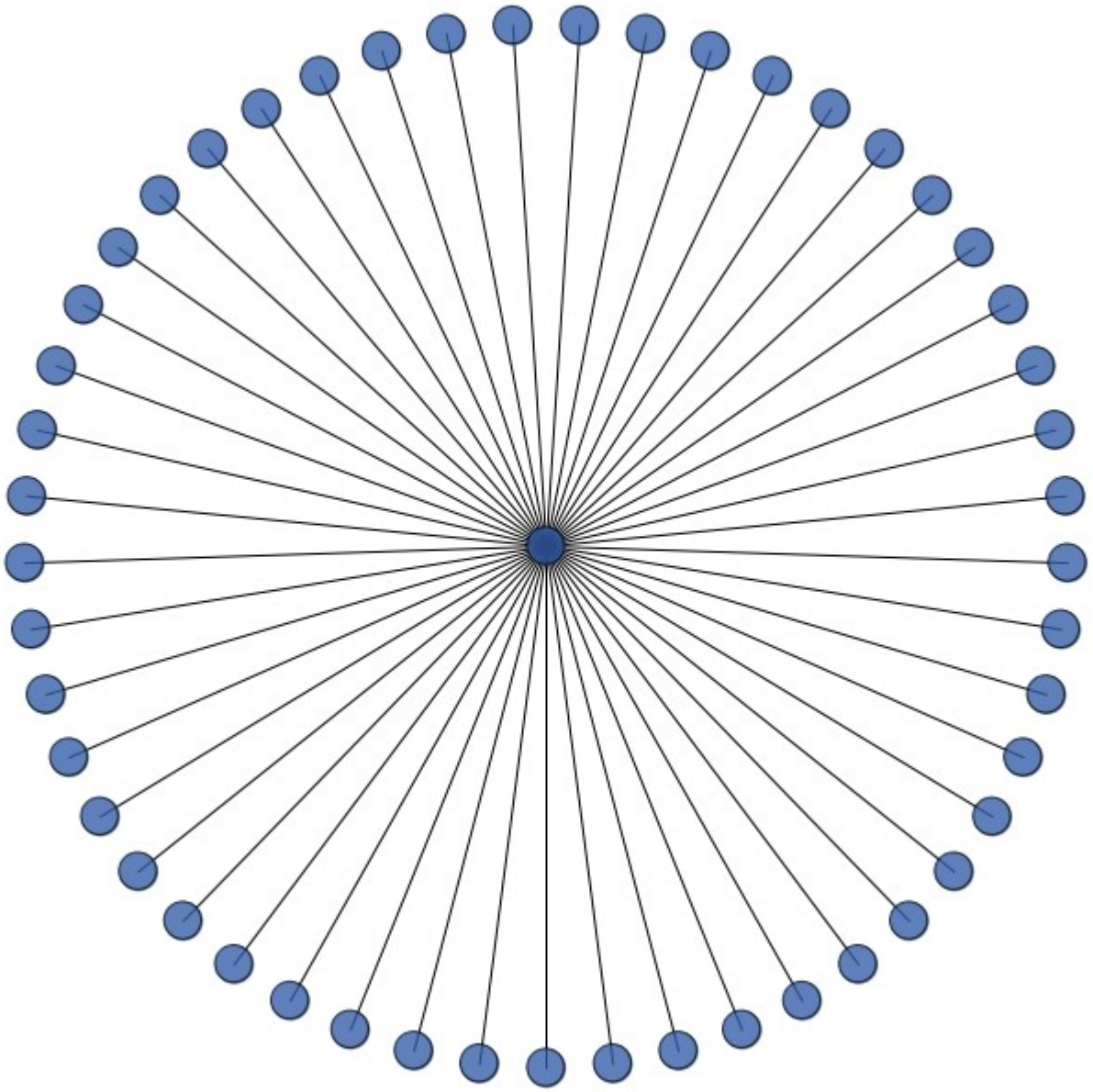
Preferential attachment



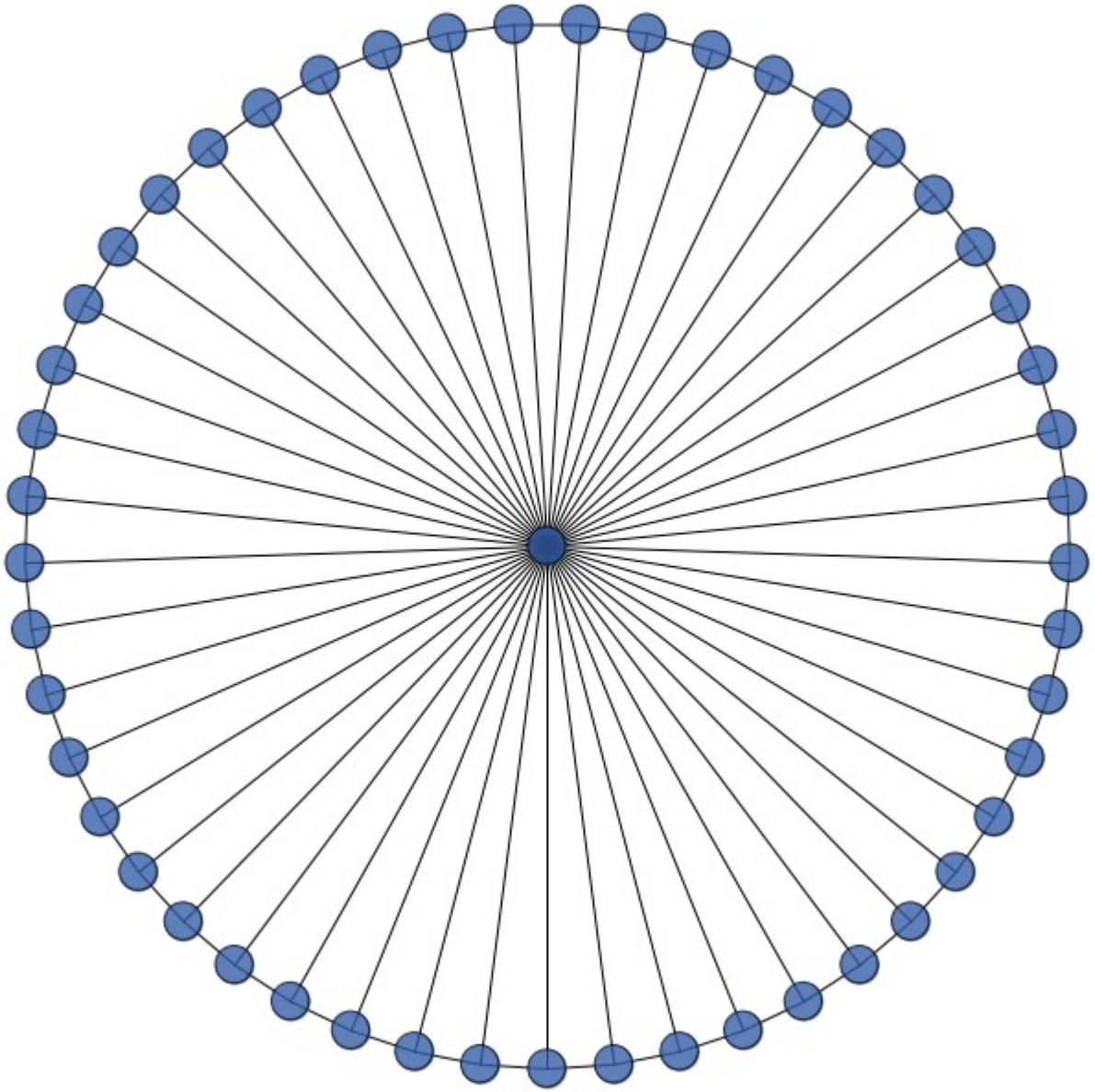
Ring



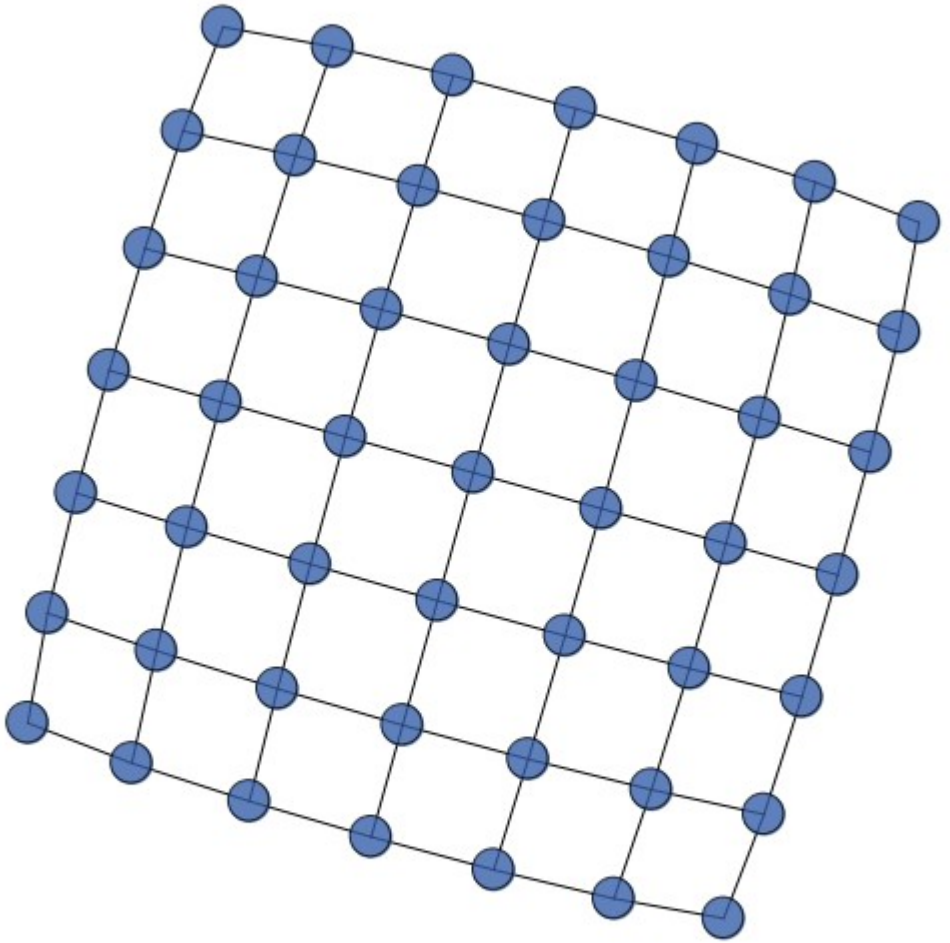
Star



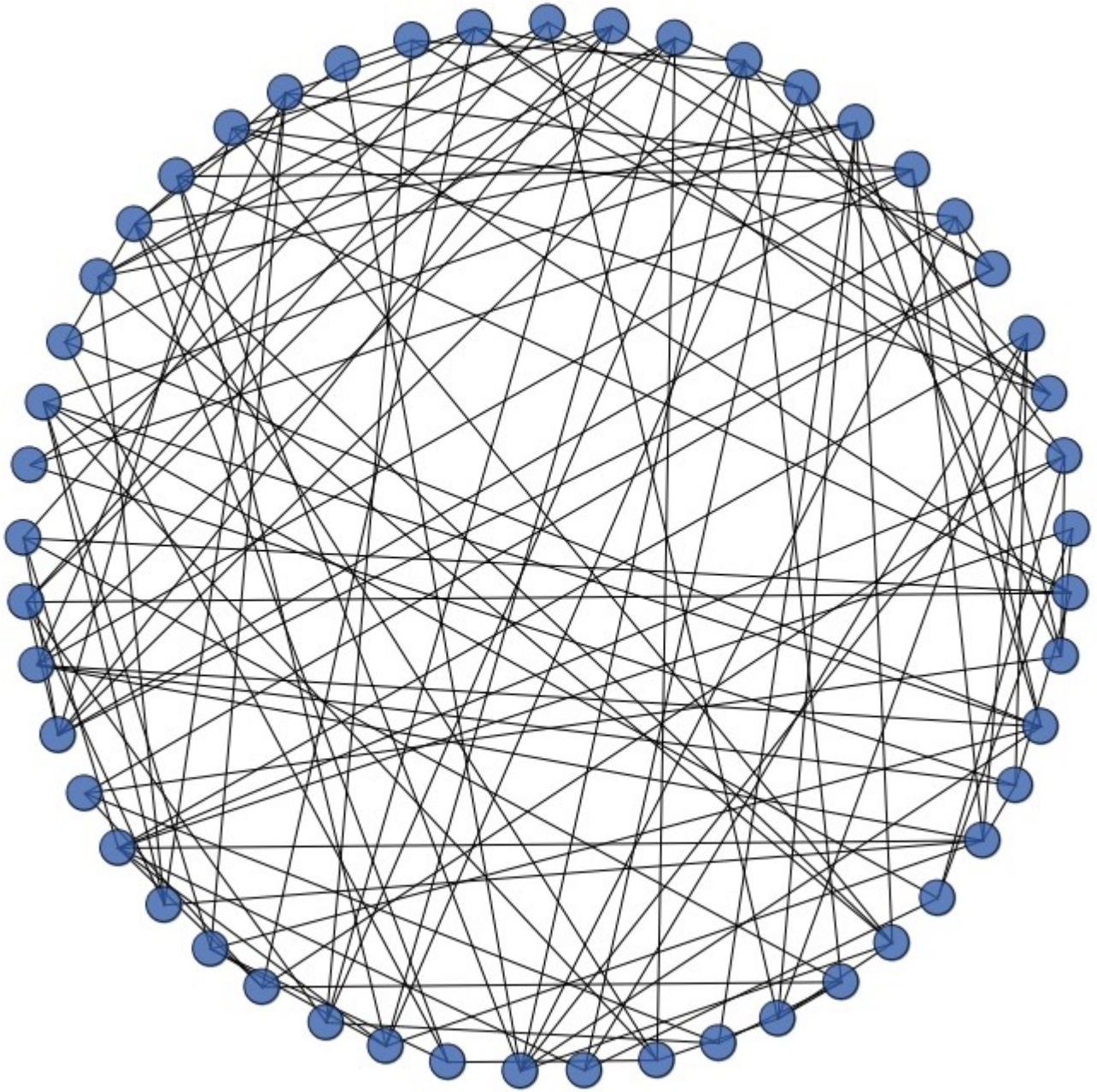
Wheel



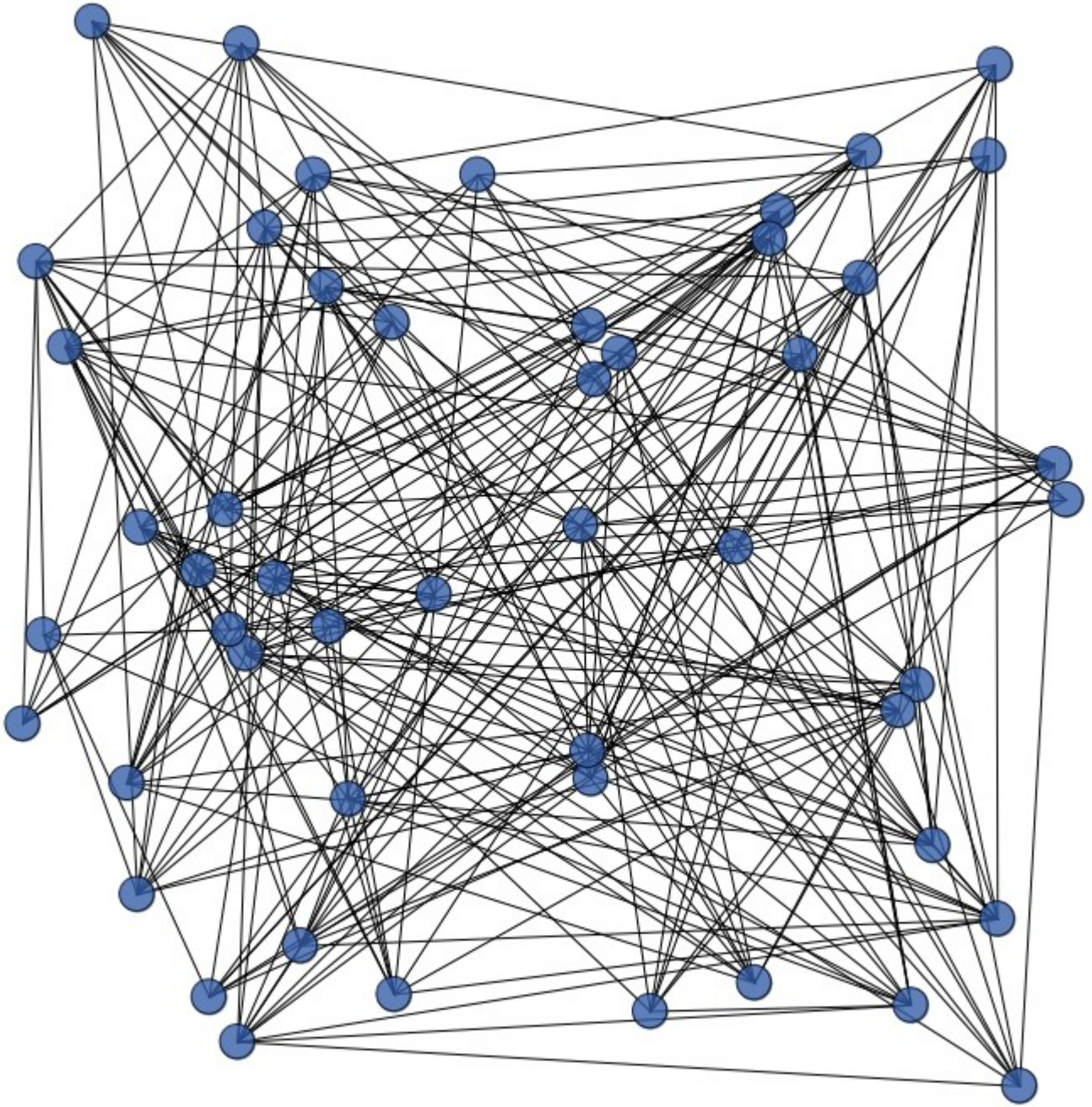
Lattice



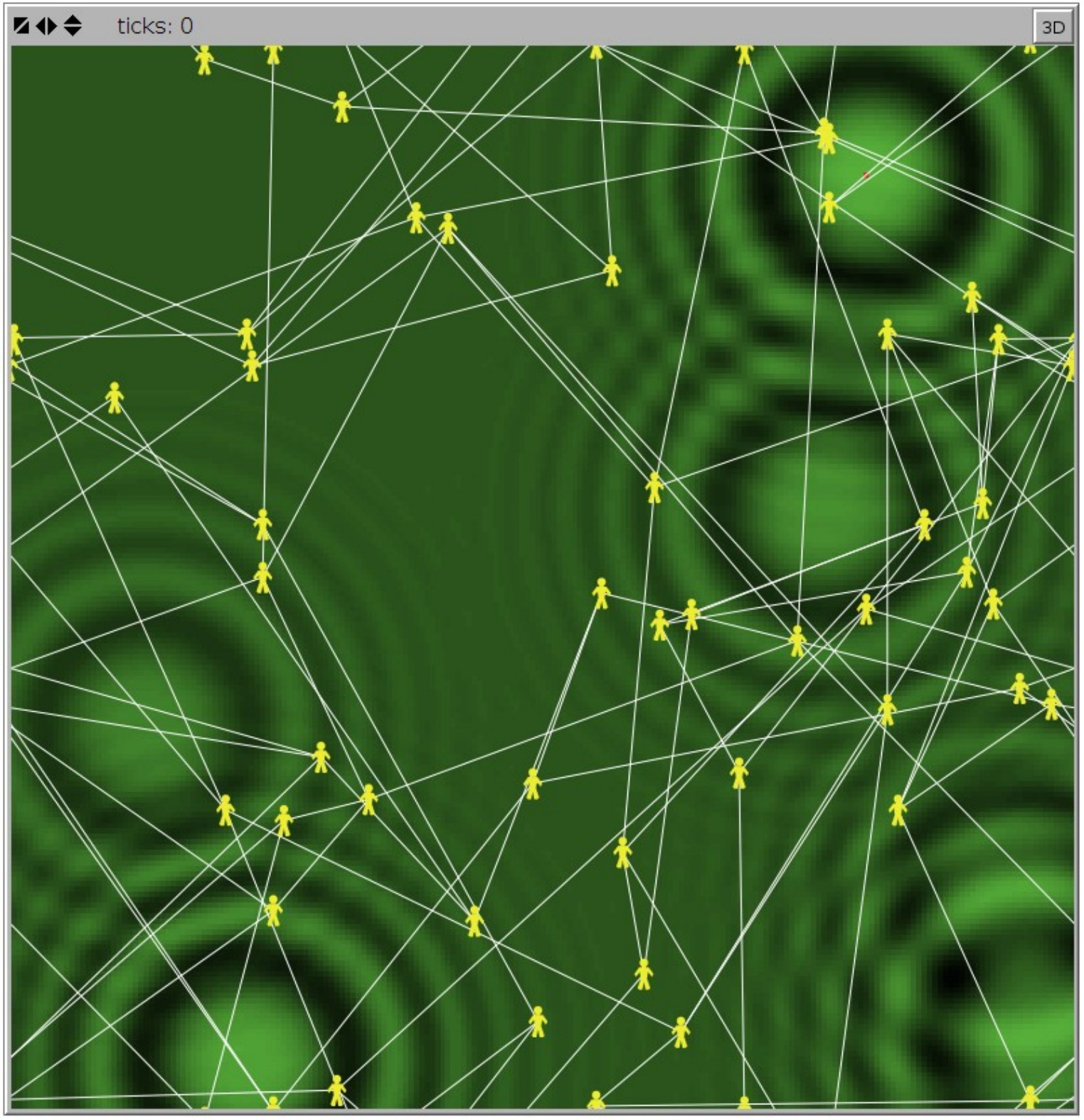
Small World



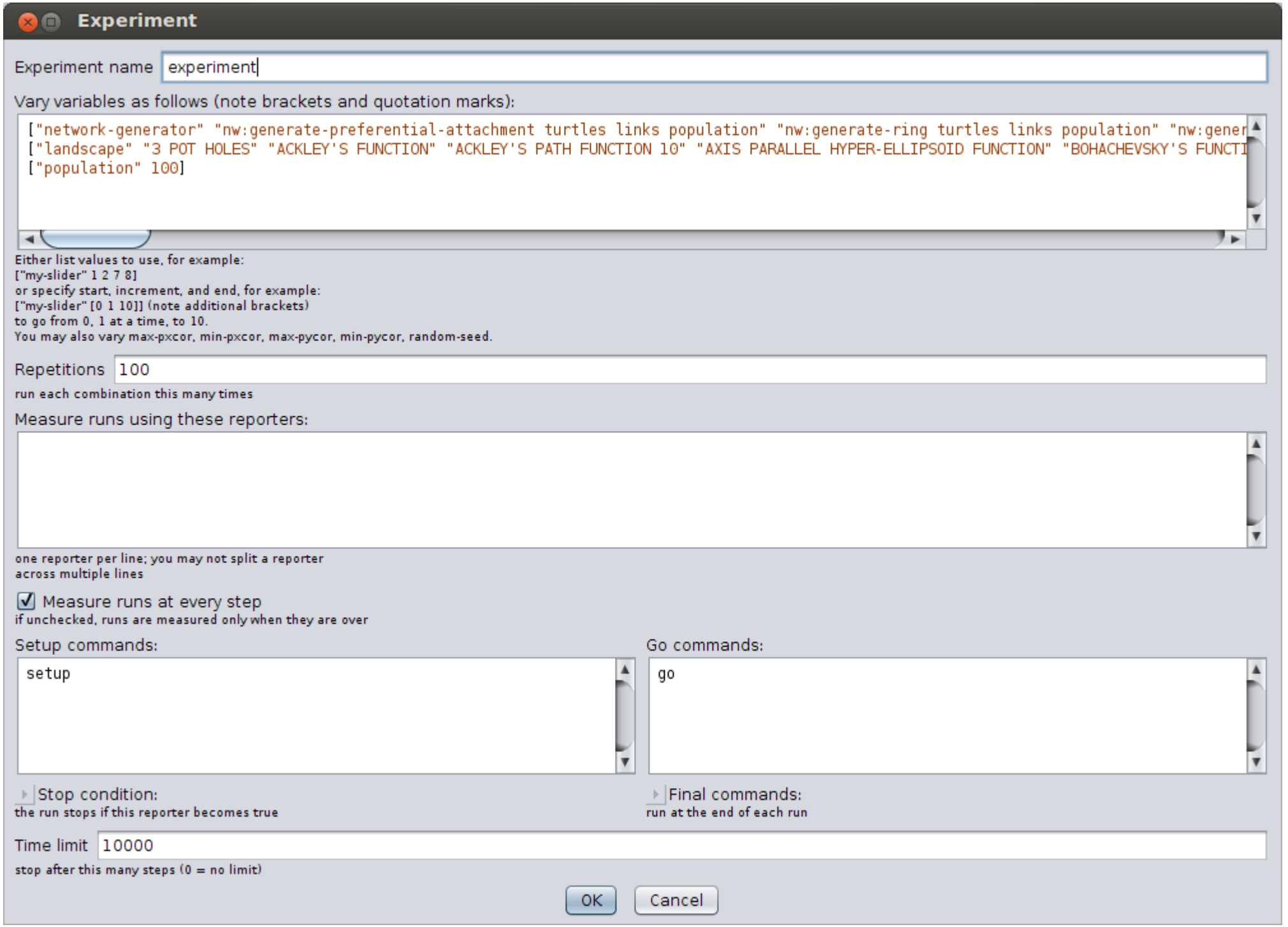
Random



```
to setup-network
  run network-generator
  ask turtles [
    set color yellow
    set shape "person"
    set size 6
    setxy random-pxcor random-pycor
  ]
  ask links [ set color white ]
end
```


ticks: 0
3D

```
to go
  ask turtles [
    let target rnd:weighted-one-of link-neighbors [
      [ value ] of ?
    ]
    if-else target != nobody and [ value ] of target > value [
      face target
      move-to patch-ahead 1
    ]
    [
      move-to one-of patches in-radius 1 with-max [ value ]
    ]
  ]
  if all? turtles [ value = 1 ] [ stop ]
  tick
end
```


Experiment
Experiment name
experiment
Vary variables as follows (note brackets and quotation marks):
["network-generator" "nw:generate-preferential-attachment turtles links population" "nw:generate-ring turtles links population" "nw:gener
["landscape" "3 POT HOLES" "ACKLEY'S FUNCTION" "ACKLEY'S PATH FUNCTION 10" "AXIS PARALLEL HYPER-ELLIPSOID FUNCTION" "BOHACHEVSKY'S FUNCTI
["population" 100]
Either list values to use, for example:
["my-slider" 1 2 7 8]
or specify start, increment, and end, for example:
["my-slider" [0 1 10]] (note additional brackets)
to go from 0, 1 at a time, to 10.
You may also vary max-pxcor, min-pxcor, max-pycor, min-pycor, random-seed.
Repetitions
100
run each combination this many times
Measure runs using these reporters:
one reporter per line; you may not split a reporter
across multiple lines
Measure runs at every step
if unchecked, runs are measured only when they are over
Setup commands:
setup
Go commands:
go
Stop condition:
the run stops if this reporter becomes true
Final commands:
run at the end of each run
Time limit
10000
stop after this many steps (0 = no limit)
OK
Cancel

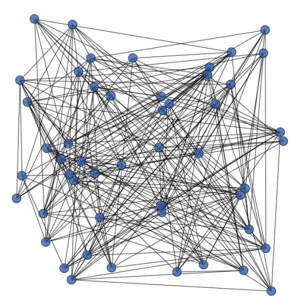
	"EUCLIDEAN"	"SCHWEFEL'S PROBLEM 2.21"	"STEP FUNCTION"	"SPHERE"	"CPF2"	"DE JONG F1"	"TEST FUNCTION F1"	"SUM OF DIFFERENT POWER FUNCTION"	"BOHACHEVSKY'S FUNCTION"	"EXP"	"SCHWEFEL'S PROBLEM 2.22"	"CPF1"	"GENERALIZED PENALIZED FUNCTION 2"	"GENERALIZED PENALIZED FUNCTION 1"	"TEST FUNCTION F3"	"MICHALEWICZ'S FUNCTION 12"	"SCHWEFEL'S PROBLEM 1.2"	"AXIS PARALLEL HYPER-ELLIPSOID FUNCTION"	"MOVED AXIS PARALLEL HYPER-ELLIPSOID FUNCTION"	"ROTATED HYPER-ELLIPSOID FUNCTION"
random	174	170	182	183	182	185	183	183	189	147	195	195	224	277	320	465	530	521	564	557
small world	179	177	189	188	190	189	191	189	195	156	204	207	234	291	382	592	622	748	664	639
wheel	182	180	191	193	192	192	195	192	205	161	206	210	214	228	412	347	326	326	324	337
lattice	185	190	194	196	193	197	196	199	205	187	216	212	258	320	489	1015	1074	1057	977	1075
ring	198	199	208	207	206	208	204	205	210	289	223	221	386	472	867	2124	2427	2453	2645	2602
star	154	166	152	151	154	153	156	156	153	161	156	158	164	148	839	152	163	164	151	164
pref. attachment	188	198	192	192	193	194	194	199	200	267	201	203	294	339	1431	1071	1474	1447	1534	1512
Total Result	**180**	**183**	**187**	**187**	**187**	**188**	**188**	**189**	**194**	**195**	**200**	**201**	**253**	**296**	**677**	**824**	**945**	**959**	**980**	**984**

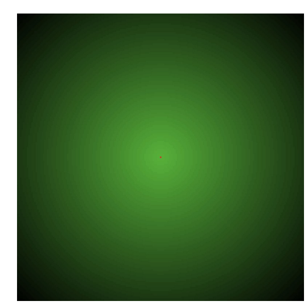
	"ACKLEY'S FUNCTION"	"EASOM'S FUNCTION"	"GENERALIZED GRIEWANK FUNCTION"	"ACKLEY'S PATH FUNCTION 10"	"RIPPLES"	"PEAKS"	"F6 (QUARTIC)"	"GRIEWANGK'S FUNCTION 8"	"SQUASHED FROG FUNCTION (TIMBO)"	"ROSENBROCK'S VALLEY (DE JONG F2)"	"TEST FUNCTION F2 (ROSENBROCK'S FUNCTION)"	"GENERALIZED ROSENBROCK'S FUNCTION"	"SIX-HUMP CAMEL BACK FUNCTION"	"HORN'S FMMEASY"	"GENERALIZED SCHWEFELS PROBLEM 2.26"	"MULTI FUNCTION"	"F5 (PSHUBERT2)"	"SCHWEFEL'S FUNCTION 7"	"LANGERMANN'S FUNCTION 11 (M=4)"	"RASTRIGIN'S FUNCTION 6"
random	170	920	207	170	276	203	425	227	1291	358	565	387	1576	2776	1594	3174	1740	3088	3969	2567
small world	189	717	211	188	341	320	560	284	548	431	402	707	2432	2082	3408	6515	2484	3548	3900	2632
wheel	190	823	218	189	466	337	2987	331	1065	532	527	1173	1555	3498	4874	4715	5128	5192	5935	8207
lattice	228	1175	237	222	462	586	1342	485	722	981	958	1773	4727	2165	5632	5071	4912	5533	6529	5168
ring	413	2501	438	403	971	1202	1394	889	2196	8350	9048	8274	7266	8163	7781	4379	9456	7974	7225	8613
star	7584	2481	5118	8547	8321	2819	3171	9772	10000	7087	6632	5447	4062	9336	8880	8939	9902	8735	8874	10000
pref. attachment	355	1131	3411	587	930	8397	10000	9847	10000	9363	9514	9927	9825	10000	10000	10000	10000	10000	10000	10000
Total Result	**1304**	**1393**	**1406**	**1472**	**1681**	**1981**	**2840**	**3119**	**3689**	**3872**	**3949**	**3956**	**4492**	**5431**	**6024**	**6113**	**6232**	**6296**	**6633**	**6741**

	"GENERALIZED RASTRIGIN'S FUNCTION"	"ROOTS"	"G3"	"F4 (PSHUBERT1)"	"LANGERMANN'S FUNCTION 11 (M=7)"	"GENERALIZED HIMMELBLAU'S FUNCTION"	"GOLDSTEIN-PRICE'S FUNCTION"	"SCHAFFER'S FUNCTION"	"BRANINS'S RCOS FUNCTION"	"3 POT HOLES"	"HORNS 5 PEAKS (MODIFIED)"	"F7 (SHUBERT FUNCTION)"	"SHUBERT FUNCTION"	"HANSENS FUNCTION"	"TEST FUNCTION F4 (QUARTIC FUNCTION)"	"M5 (HIMMELBLAU'S FUNCTION)"	"QUARTIC FUNCTION (NOISE)"	"M6 (SHEKEL'S FOXHOLES)"	"TEST FUNCTION F5 (SHEKEL'S FUNCTION)"	"F3"	**Total**
random	2831	3016	4555	4217	5518	3168	9031	6827	6915	9097	7193	7861	7365	7666	8788	8395	8886	9600	9523	10000	**2863**
small world	2376	4624	4854	4927	5886	7072	6383	5212	8432	8335	7288	8032	8495	8845	8357	9824	8051	9782	9772	10000	**3081**
wheel	8085	4751	6305	7146	5108	6884	9218	8287	7089	9043	7716	7590	8461	8693	9327	8401	9642	9430	9745	9490	**3553**
lattice	5408	8140	6642	6638	8062	9671	9303	8242	9935	8805	8943	9408	9842	9725	8760	9934	8928	9782	9872	10000	**3893**
ring	8757	9456	6818	10000	9892	9989	3873	9971	10000	5874	10000	10000	10000	10000	10000	10000	10000	10000	9972	10000	**4968**
star	9901	7559	9331	9818	9212	7430	9705	9901	7427	8819	9705	9541	9713	9524	9933	8635	10000	9802	9706	9508	**5578**
pref. attachment	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	**6080**
Total Result	**6766**	**6792**	**6929**	**7535**	**7668**	**7745**	**8216**	**8349**	**8543**	**8568**	**8692**	**8919**	**9125**	**9208**	**9309**	**9313**	**9358**	**9771**	**9799**	**9857**	**4288**

Networks **Landscapes**

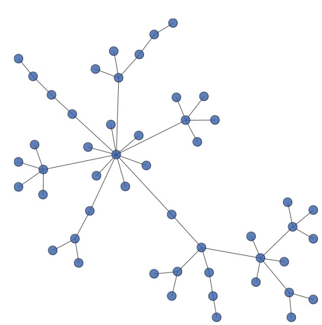
Best (Random)





Easiest (Euclidian)

Worst (Pref. attachment)



Hardest (F3)

Get the model at:
https://github.com/nicolaspayette/sspos