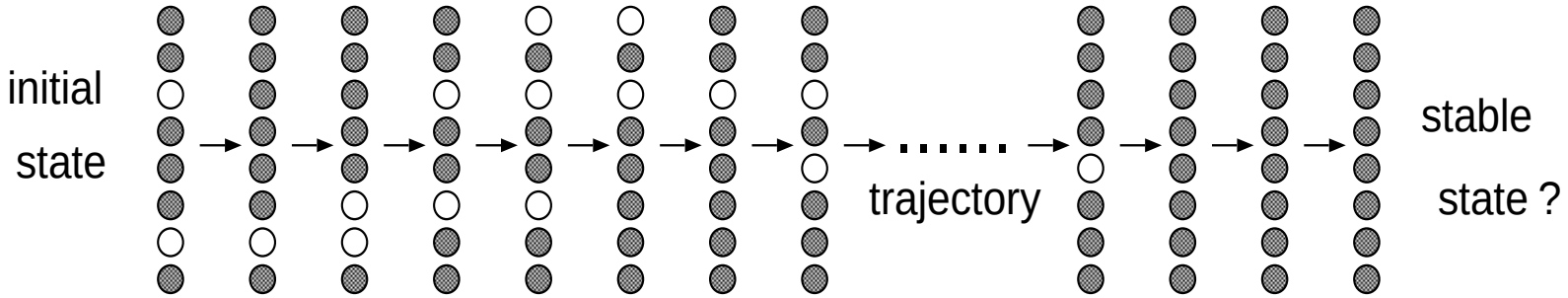
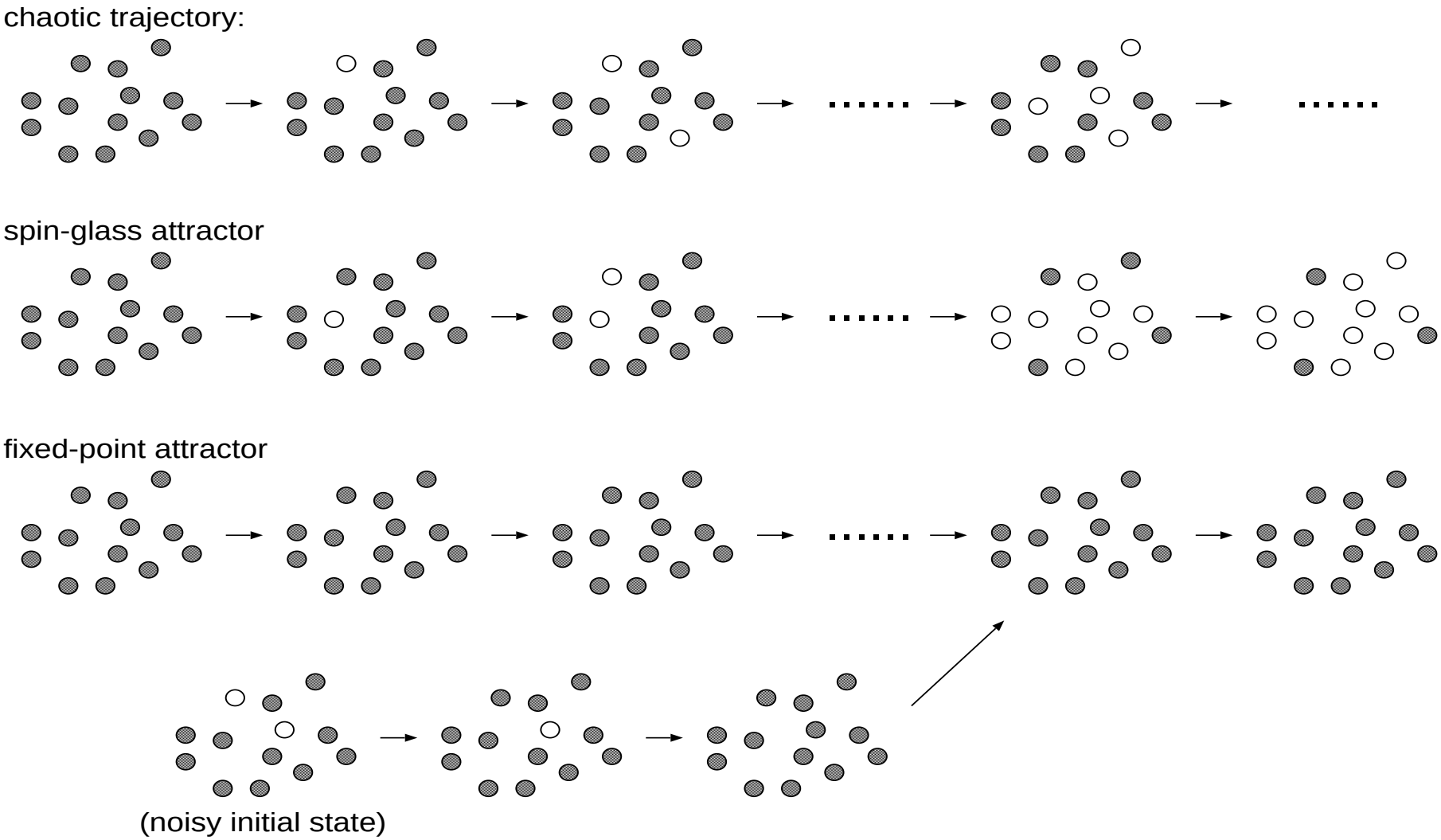
associative memory = dynamical system



converge

initial state
$u+\delta u$

equilibrium state
u

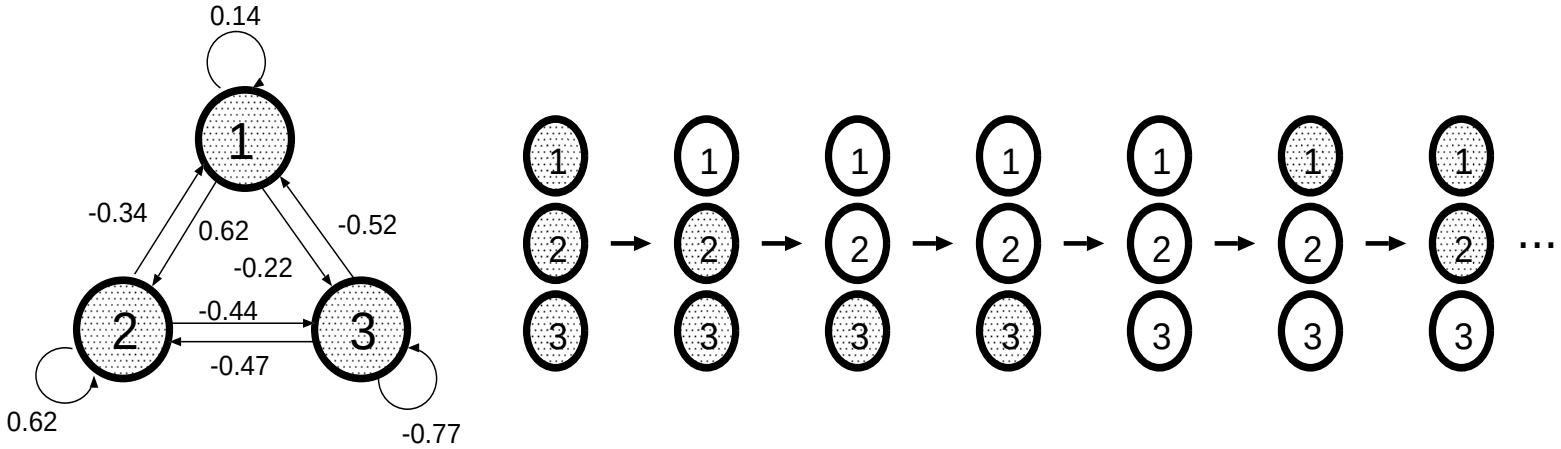

chaotic trajectory:
spin-glass attractor
fixed-point attractor
(noisy initial state)

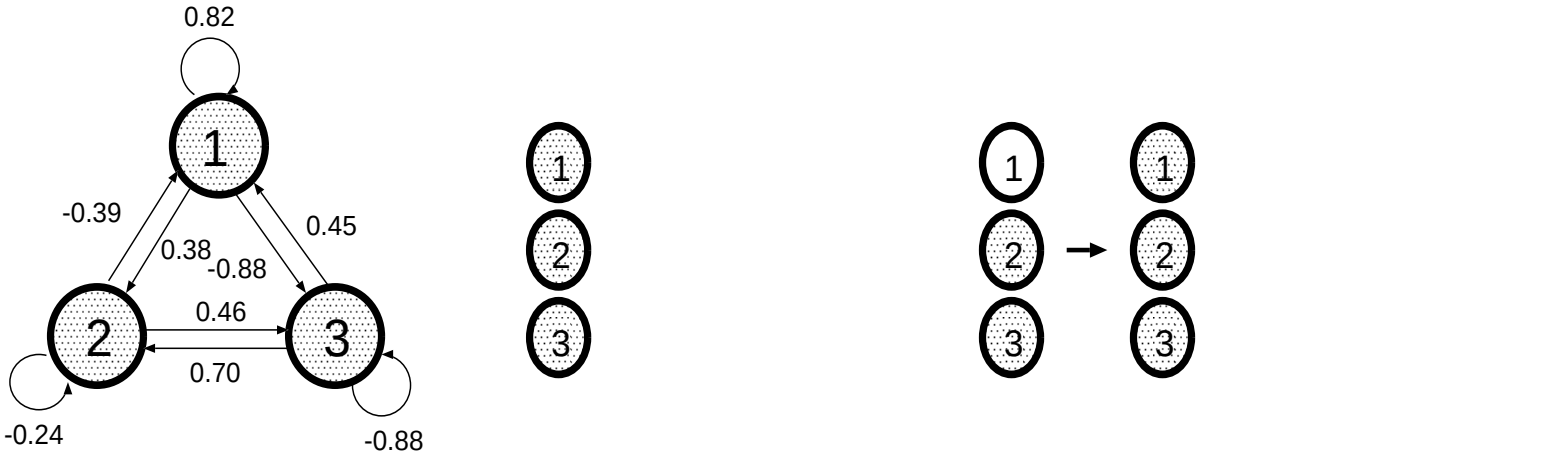
A Genetic Algorithm using an Entropy based Selection Scheme

Akira Imada
Nara Institute of Science and Technology
(akira-i@is.aist-nara.ac.jp)

□ Introduction:

- We apply
  - ECs to neural network model of Associative Memory.
- We study
  - basic behaviors of the model under simple evolutionary processes.
- Here,
  - we use a selection scheme based on entropy of the population.
    (Lee and Han, 1997)


0.14
1
-0.34
0.62
-0.52
-0.22
2
-0.44
3
-0.47
0.62
-0.77
1
2
3
1
2
3
1
2
3
1
2
3
1
2
3
1
2
3
1
2
3
...


0.82
1
-0.39
0.38
0.45
-0.88
2
0.46
3
0.70
-0.24
-0.88
1
2
3
1
2
3
1
2
3

Fitness Landscapes on Weight Space

- all the possible configurations of w_{ij} of a network with N

$\Downarrow$

- an N^2-dimensional Euclidean space

$\Downarrow$

- a specific configuration is represented as a point in the space

$\Downarrow$

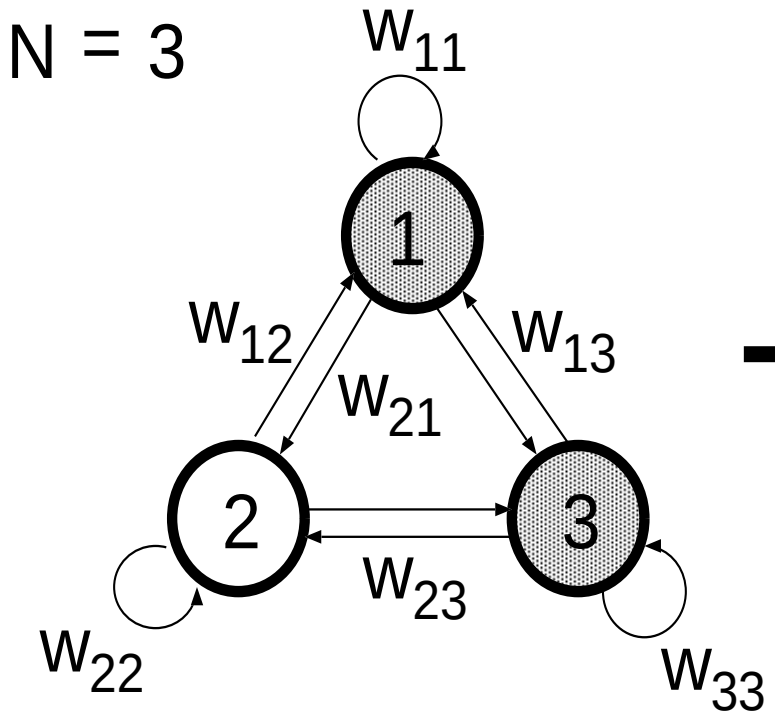
- "fitness landscape" can be defined on the space

$\Downarrow$

- where we can imagine the optima as peaks

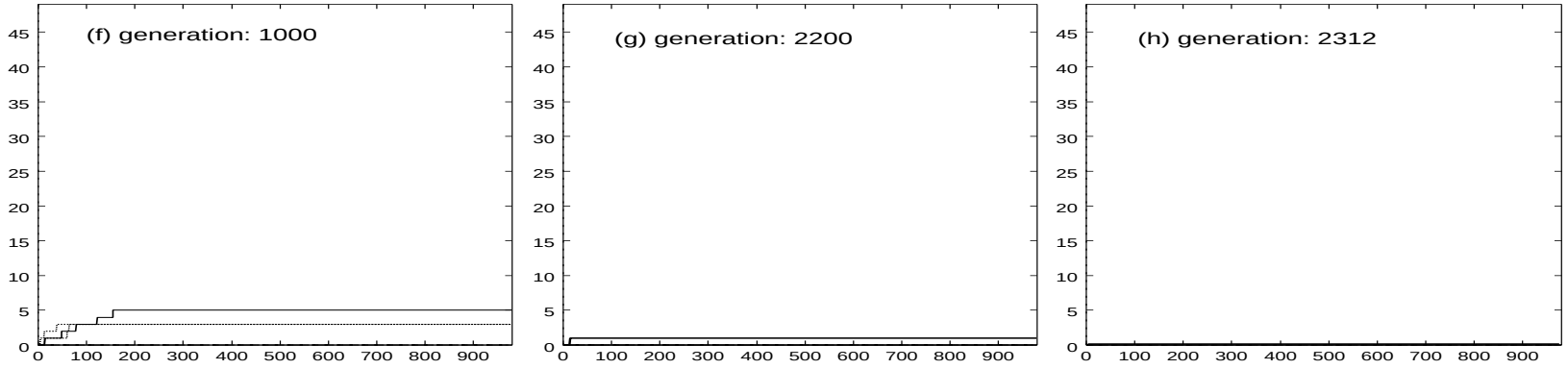
The Associative Memory can be realized with:

- **fully-connected neural network model (Hopfield model)**
- **immune system model**
- **etc**



weight matrix

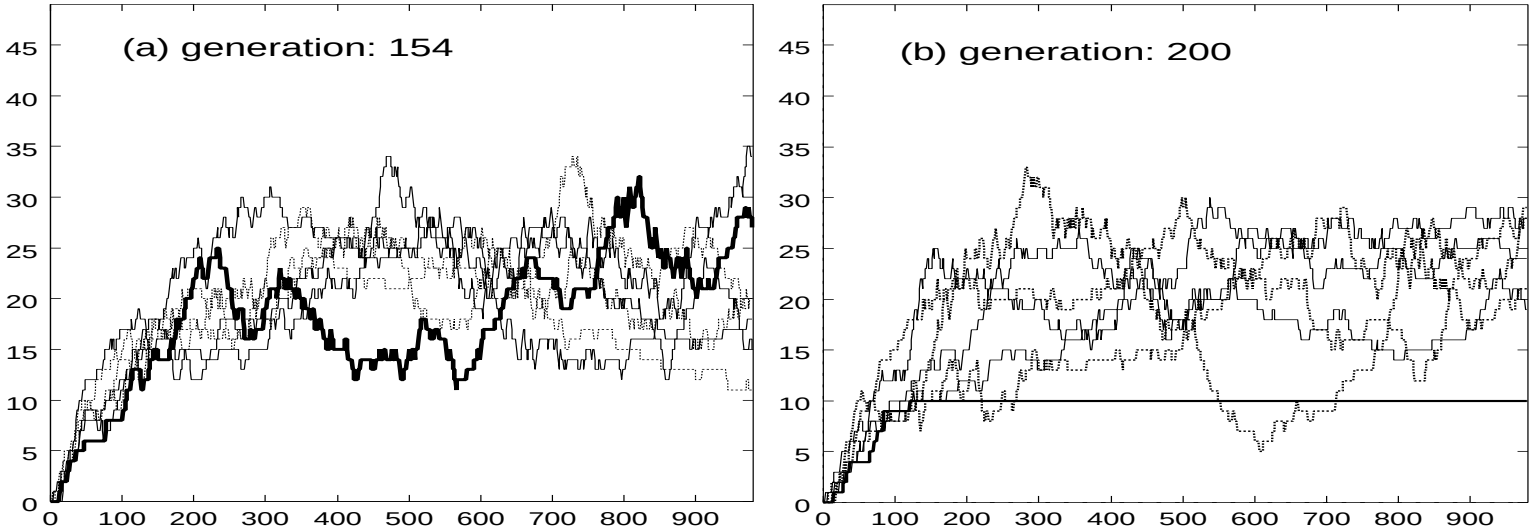
$$\begin{pmatrix} w_{11} & w_{12} & w_{13} \\ w_{21} & w_{22} & w_{23} \\ w_{31} & w_{32} & w_{33} \end{pmatrix}$$

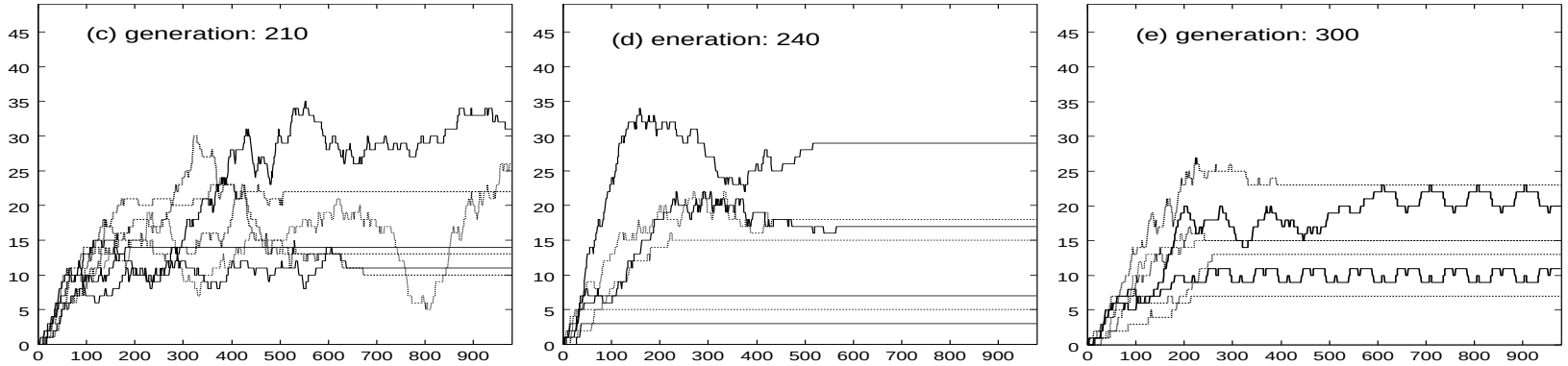

(f) generation: 1000
(g) generation: 2200
(h) generation: 2312
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400
500
600
700
800
900

□ Weight Space and String Space:

- weight space
  - a given set of patterns to be memorized: fixed
  - N^2-dimensional; real-valued genes

- string space
  - a configuration of weights: fixed
  - N-dimensional; binary genes


(a) generation: 154
(b) generation: 200
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400
500
600
700
800
900


(c) generation: 210
(d) eneration: 240
(e) generation: 300
0
5
10
15
20
25
30
35
40
45
0
100
200
300
400
500
600
700
800
900

Entropic Sampling:

- Fitness level is devided into 21 classes (from row to high).

$\Downarrow$

- The last class is only for perfect fitness.

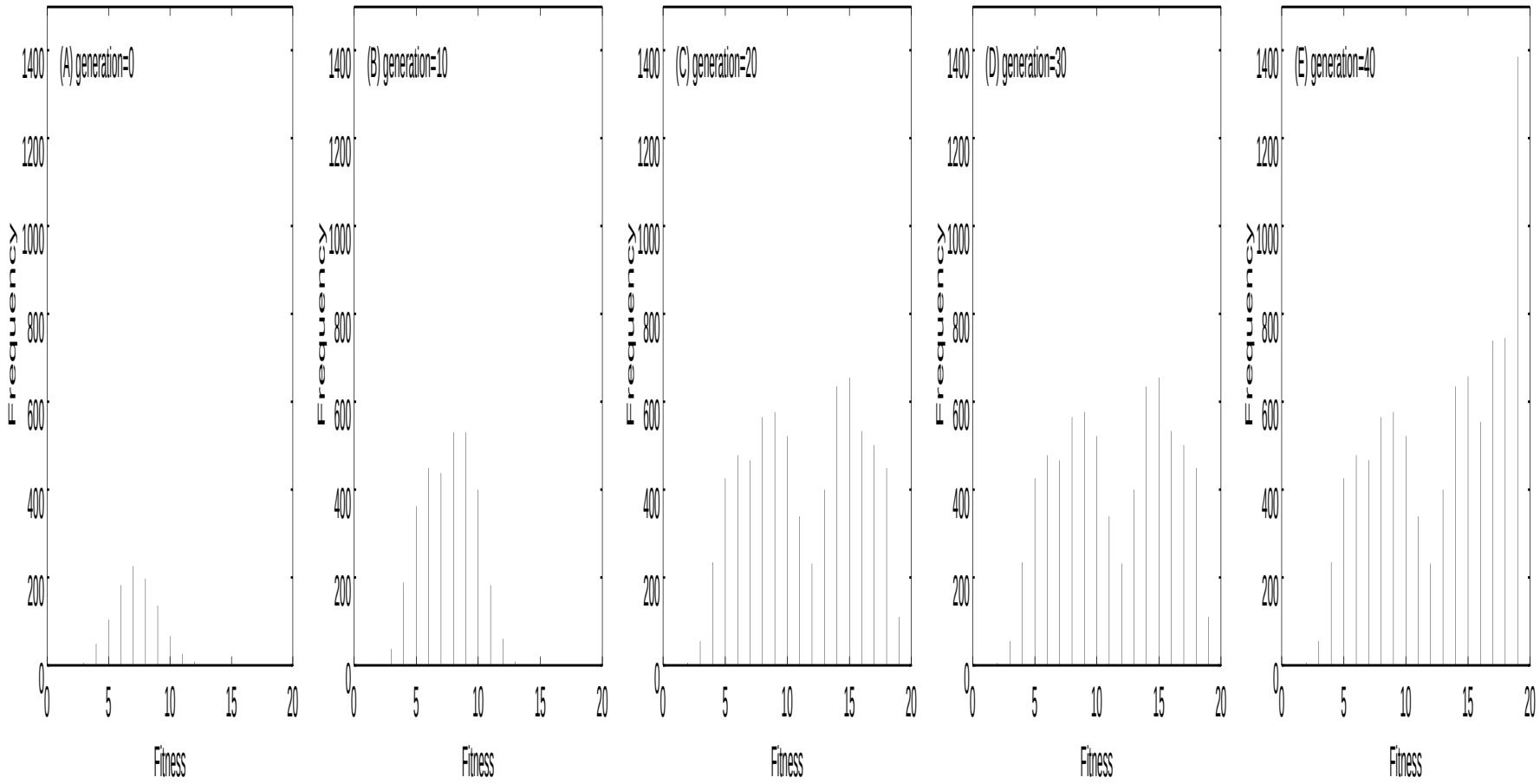
$\Downarrow$

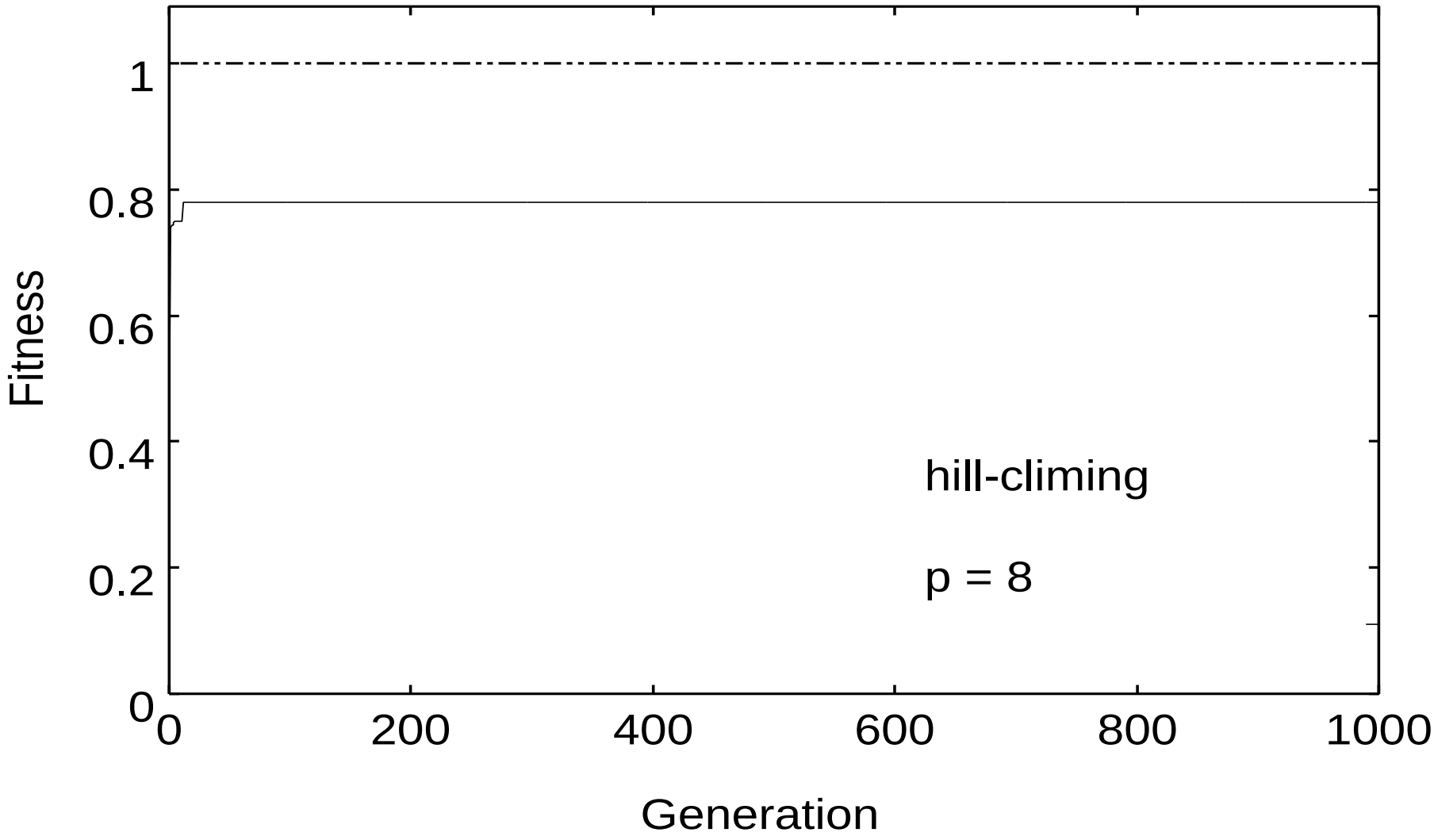
- The fewer the indivisuals are, the higher the probability to be selected.

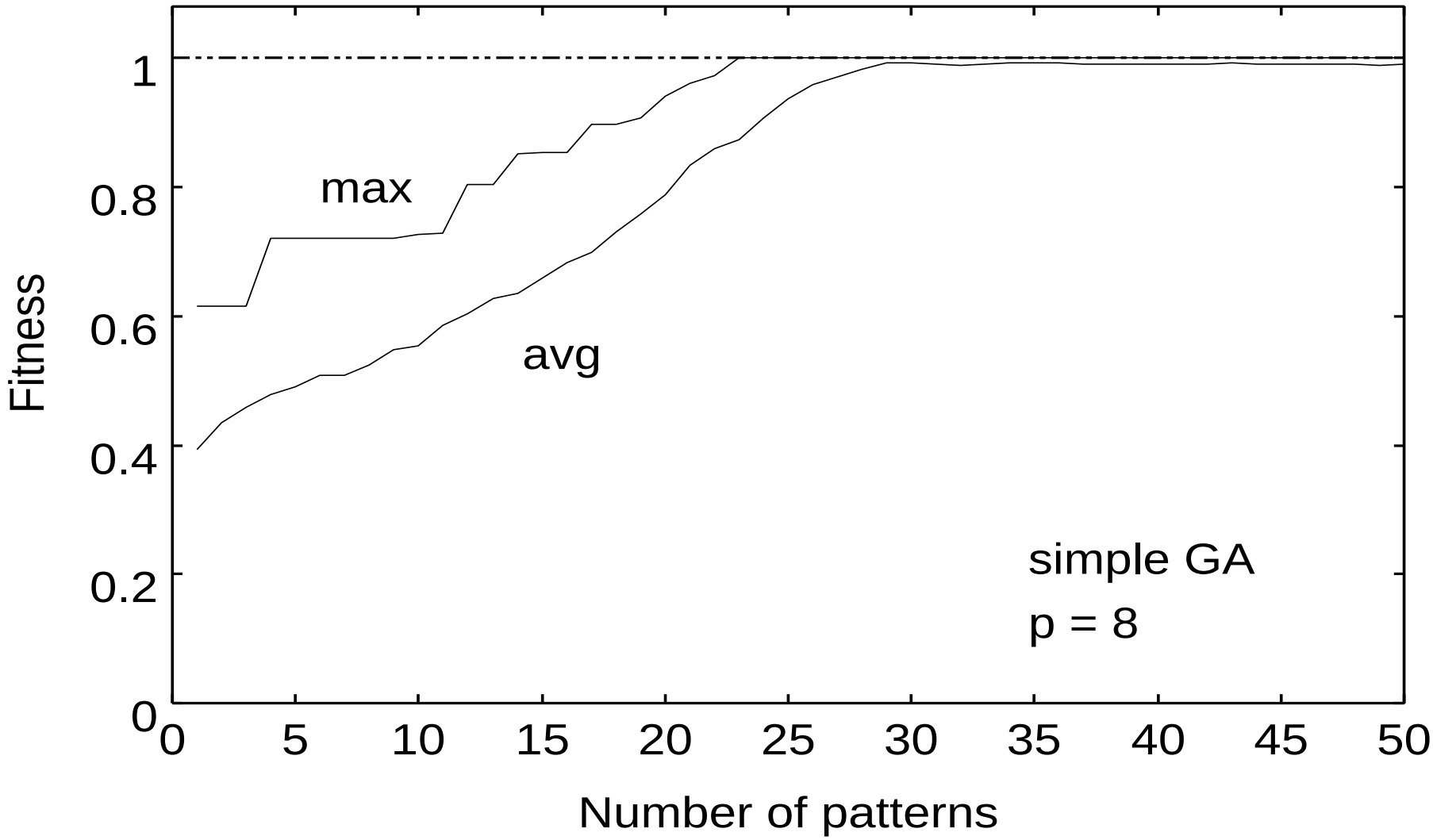
(**cf.** fitness proportionate selection.)

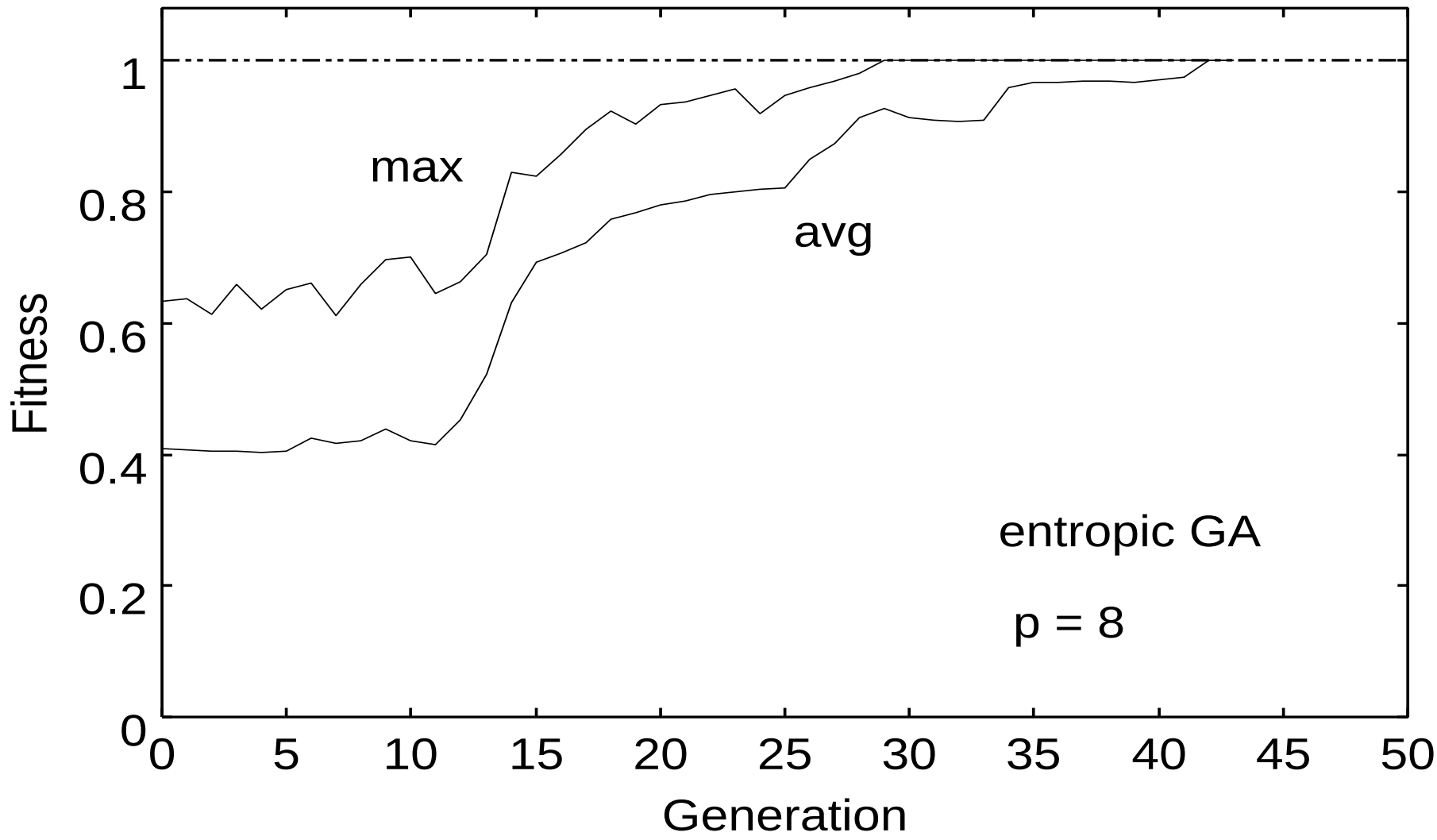
$\Downarrow$

- Can we locate multiple peaks at a run?


(A) generation=0
(B) generation=10
(C) generation=20
(D) generation=30
(E) generation=40
Frequency
Fitness
0
200
400
600
800
1000
1200
1400
0
5
10
15
20


Fitness
1
0.8
0.6
0.4
0.2
0
0
200
400
600
800
1000
Generation
hill-climing
p = 8


Fitness
1
0.8
0.6
0.4
0.2
0
max
avg
simple GA
p = 8
0
5
10
15
20
25
30
35
40
45
50
Number of patterns


Fitness
1
0.8
0.6
0.4
0.2
0
max
avg
entropic GA
p = 8
0
5
10
15
20
25
30
35
40
45
50
Generation

□ Conclusions:

- The "entropic sampling" works as well as simple GA.
  - The more complicated landscape, the more effective?
  - Can we locate multiple solutions simultaneously?

- These studies shed new light on the analysis of the Hopfield model of associative memory.