Boolean Networks II

State of the system: described by **vector** of **discrete** values

$$S_i = \{0, 1, 1, 0, 0, 1, \ldots\}$$

$$S_i = \{x_1(i),\ x_2(i),\ x_3(i), \ldots\}$$

fixed number of species with **finite number** of states each

→ finite number of system states

→ periodic trajectories

→ **periodic** sequence of states = **attractor**

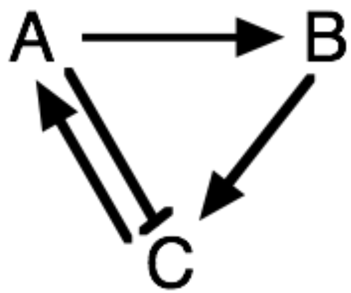
→ all states leading to an attractor = **basin of attraction**

Propagation:

$$S_{i+1} = \{x_1(i+1),\ x_2(i+1),\ x_3(i+1),\ \ldots\}$$

$$x_1(i+1) = f_1(x_1(i), x_2(i), x_3(i), \ldots)$$ with f_i given by condition tables

A Small Example



State vector S = {A, B, C} → 8 possible states

Conditional evolution:

A is on if C is on

A_{i+1}	C_i
0	0
1	1

A activates B

B_{i+1}	A_i
0	0
1	1

C is on if (B is on && A is off)

C_{i+1}	A_i	B_i
0	0	0
1	0	1
0	1	0
0	1	1

assume here that inhibition through A is stronger than activation via B

Start from {A, B, C} = {1, 0, 0}

#	S_i	A	B	C
0	S_0	1	0	0
1	S_1	0	1	0
2	S_2	0	0	1
3	$S_3 = S_0$	1	0	0

periodic orbit of length 3

Test the Other Starting Conditions

Test the other states

#	A	B	C
0	1	1	1
1	1	1	0
2	0	1	0
3	0	0	1
4	1	0	0
5	0	1	0

A_{i+1}	C_i
0	0
1	1

B_{i+1}	A_i
0	0
1	1

C_{i+1}	A_i	B_i
0	0	0
1	0	1
0	1	0
0	1	1

#	A	B	C
0	1	0	1
1	1	1	0

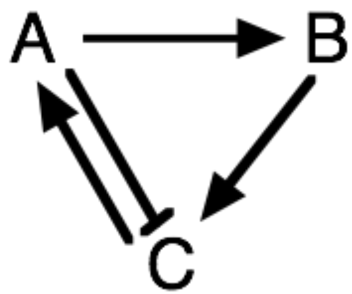
#	A	B	C
0	0	1	1
1	1	0	1

Same attractor as before:

100 → 010 → 001 → 100

is also reached from:

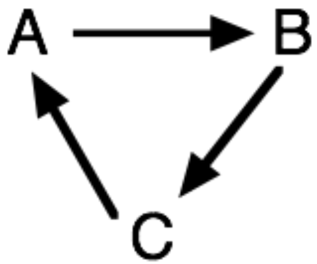
110, 111, 101, 011



#	A	B	C
0	0	0	0
1	0	0	0

→ **Either all off or stable oscillations**

A Knock-out Mutant



A_{i+1}	C_i
0	0
1	1

B_{i+1}	A_i
0	0
1	1

C_{i+1}	B_i
0	0
1	1

Attractors:

#	A	B	C
0	1	0	0
1	0	1	0
2	0	0	1
3	1	0	0

#	A	B	C
0	1	1	0
1	0	1	1
2	1	0	1
3	1	1	0

#	A	B	C
0	1	1	1
1	1	1	1

#	A	B	C
0	0	0	0
1	0	0	0

no feedback

→ no stabilization, network just "rotates"

The Feed-Forward-Loop

External signal determines state of X

→ response Z for short and long signals X

condition tables:

X
↓
Y
↓
Z

Y	X
0	0
1	1

Z	X	Y
0	0	0
0	0	1
0	1	0
1	1	1

X
⊥
Y
⊥
Z

Y	X
1	0
0	1

Z	X	Y
0	0	0
0	0	1
1	1	0
0	1	1

Signal propagation

Left column: external signal

Response to signal X(t)

Short Signal

X	Y	Z
0	0	0
1	0	0
0	1	0
0	0	0
1	0	0
1	1	0
1	1	1
0	1	1
0	0	0
0	0	0

Long signal

X	Y	Z
0	1	0
1	1	0
0	0	0
0	1	0
1	1	0
1	0	0
1	0	1
0	0	1
0	1	1
0	1	0

Can Boolean Networks be predictive?

Generally: → quality of the **results** depends on the quality of the **model**

→ quality of the model depends on the quality of the **assumptions**

Assumptions for the Boolean network description:

(• subset of the species considered → reduced system state space)

• only discrete density levels → dynamic balances lost, reduced to oscillations

• conditional yes–no causality → no continuous processes

• discretized propagation steps → timing of concurrent paths?

"You get what you pay for"