# Sea Shell pattern formation using discrete and continuous approach of modelling

Workshop on Flag,Landscape and signalling,
IMSc

–**Ananta Dutta**–

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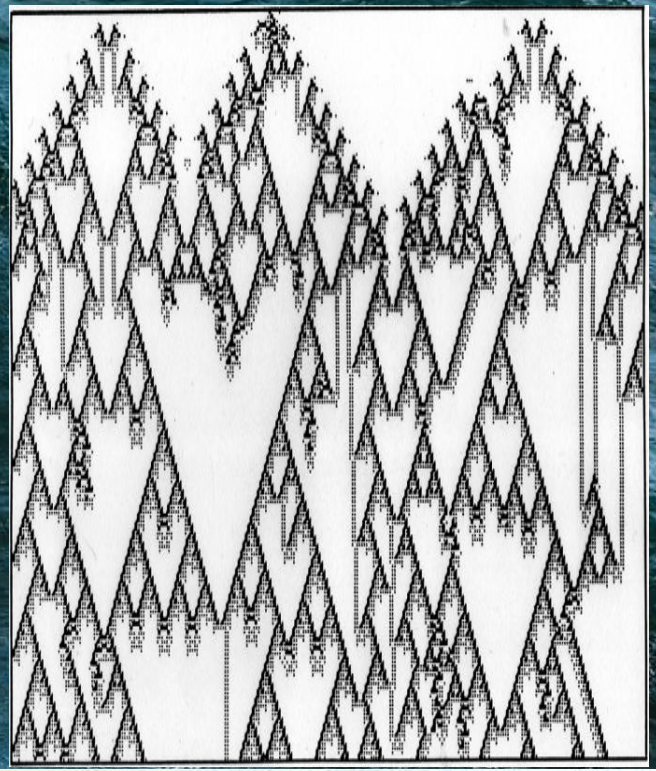


THE VIRTUAL LABORATORY

HANS MEINHARDT

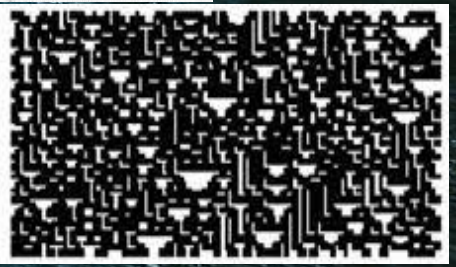
# THE ALGORITHMIC BEAUTY OF SEA SHELLS

FOURTH EDITION

Springer

STEPHEN WOLFRAM

A NEW KIND OF SCIENCE

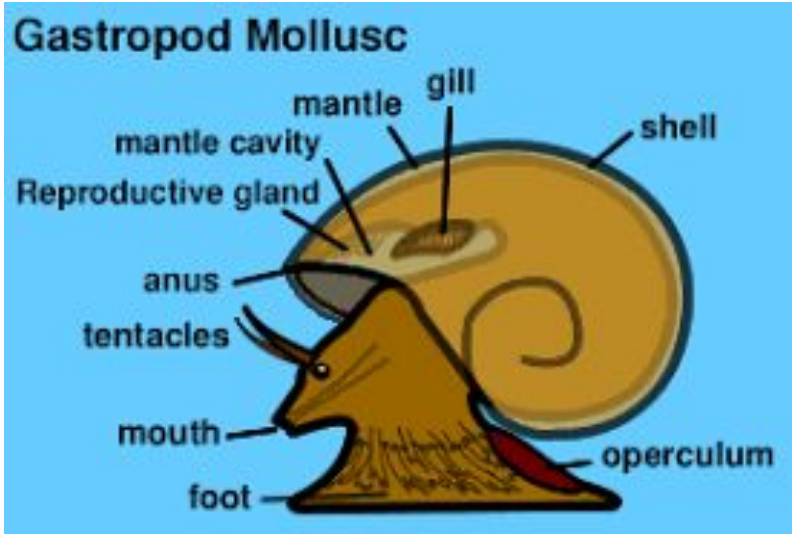


# Outline

- Sea shell development
- Continuous Approach
- Discrete Approach
- Results and comparison
- Future work

# How they make it

- The initial formation of the molluscan shell occurs at the end of gastrulation
- controlled deposition of calcium carbonate
- The transcription factor “engrailed” is likely a key member of this GRN
- The molluscan protein perlucin contains a C-type lectin domain and has a carbohydrate binding ability

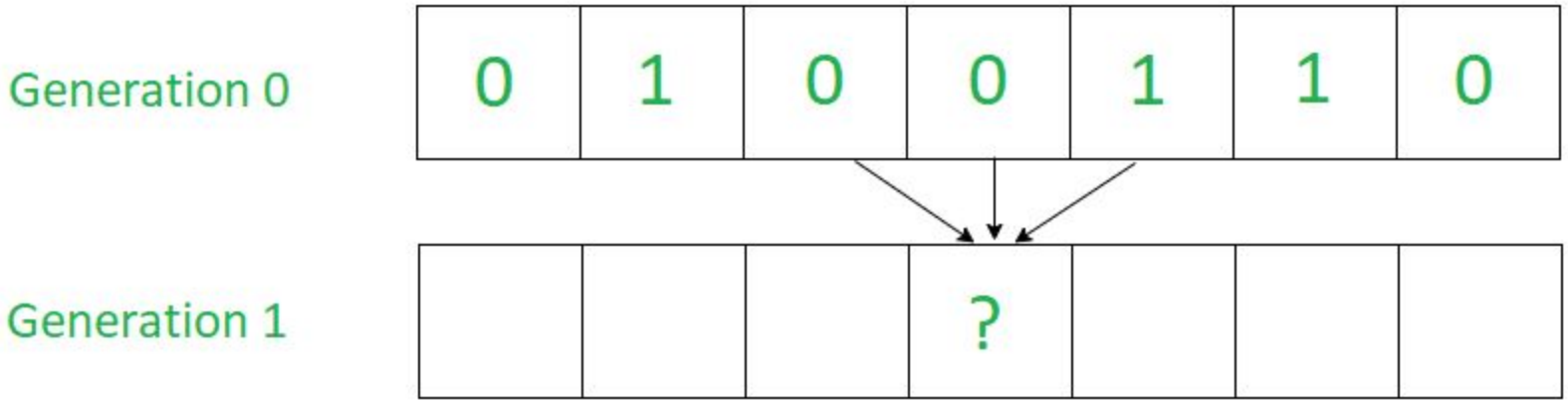


# Discrete Approach

- Stephen Wolfram came up with this approach in 80’s
- Cellular Automata
- In seashells, pigment cells in a narrow band on the shell's lip secrete pigments based on what the cells around them are doing.

  Rule 90: "the simplest non-trivial cellular automaton",

| 111 | 110 | 101 | 100 | 011 | 010 | 001 | 000 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 |


Generation 0
0
1
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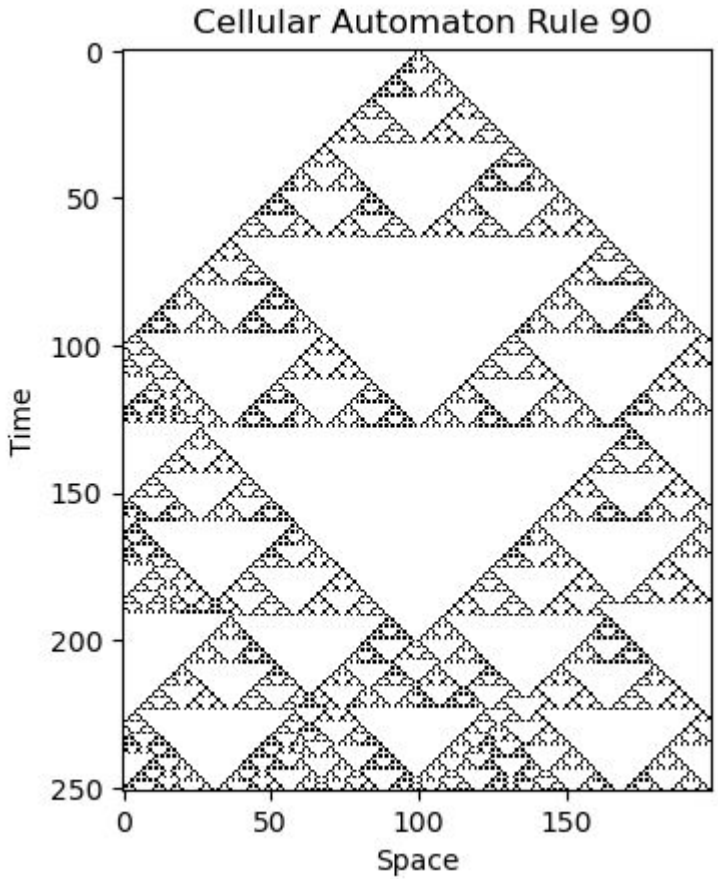
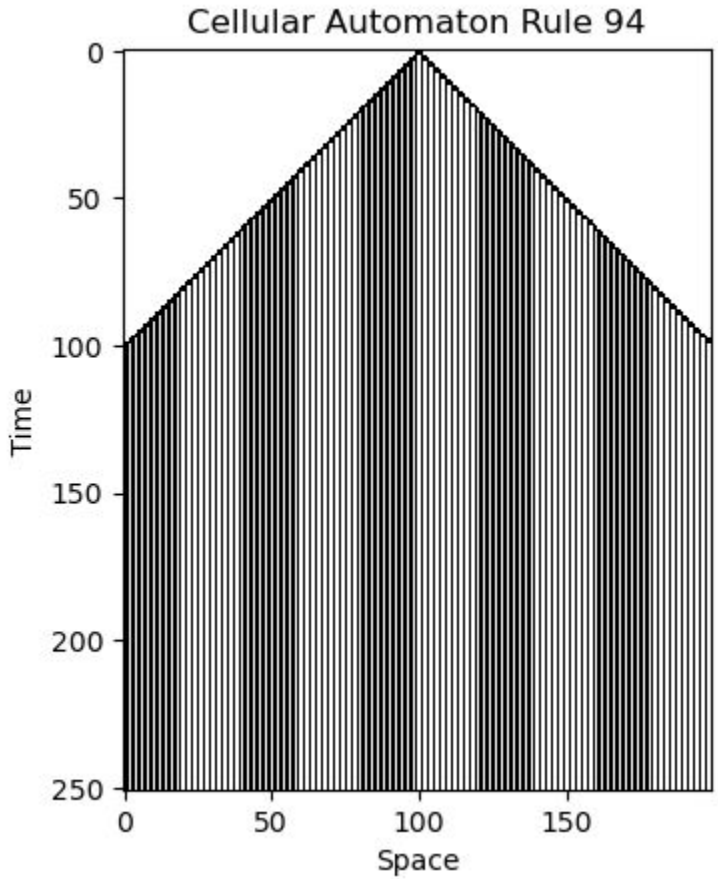
0
1
1
0
Generation 1
?


Cellular Automaton Rule 90
Time
Space
0
50
100
150
200
250
0
50
100
150


Cellular Automaton Rule 94
Time
Space
0
50
100
150
200
250
0
50
100
150

# Continuous Approach

Activation-Inhibition approach

Pigment deposition is under the control of a substance called the activator

$$\frac{\partial a}{\partial t} = \frac{\rho}{h + h_0}\left(\frac{a^2}{1 + \kappa a^2} + \rho_0\right) - \mu a + D_a \frac{\partial^2 a}{\partial x^2}$$

$$\frac{\partial h}{\partial t} = \sigma + \rho \frac{a^2}{1 + \kappa a^2} - \frac{\nu}{c} h + D_h \frac{\partial^2 h}{\partial x^2}$$

$$\frac{dc}{dt} = \frac{\rho'}{x_{max} - x_{min}} \int_{x_{min}}^{x_{max}} a dx - \eta c$$

(By Hans Meinhart, 1987)

# Continued…

Observation of the shell indicates that the number of traveling waves

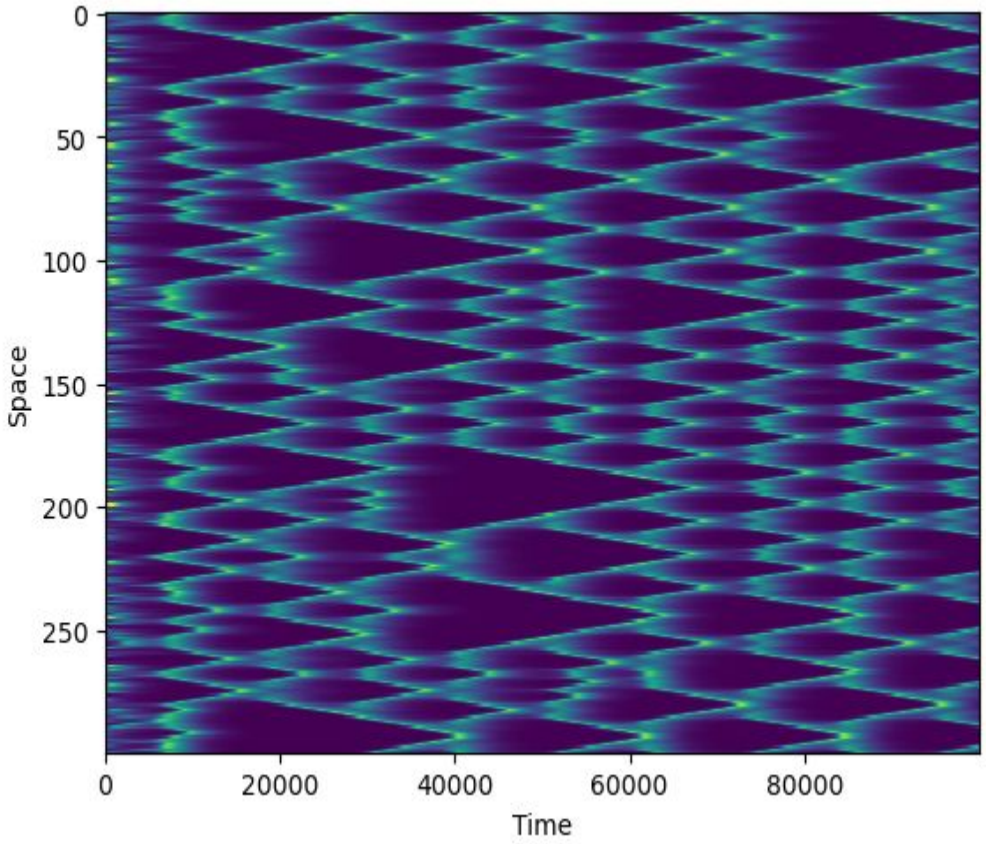
is approximately constant over time.

C is a global hormone which monitors the total amount of activator along the growing edge.

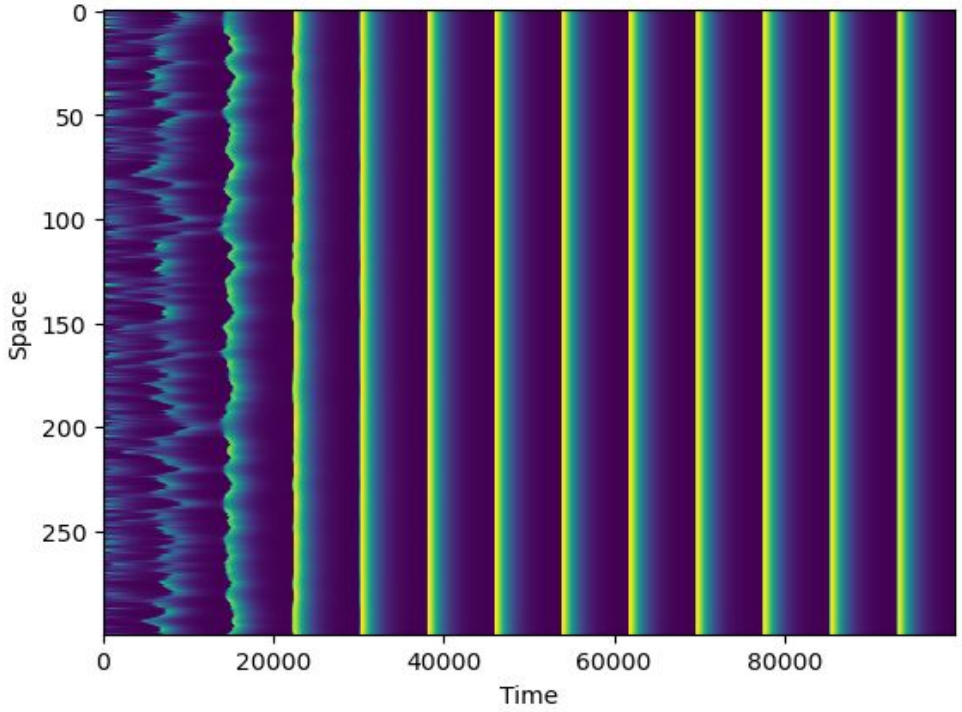
Decay associated to the growing edge in constant.

The hormone c provides a negative feedback maintaining the number of traveling waves at an approximately constant level.

# Simulations



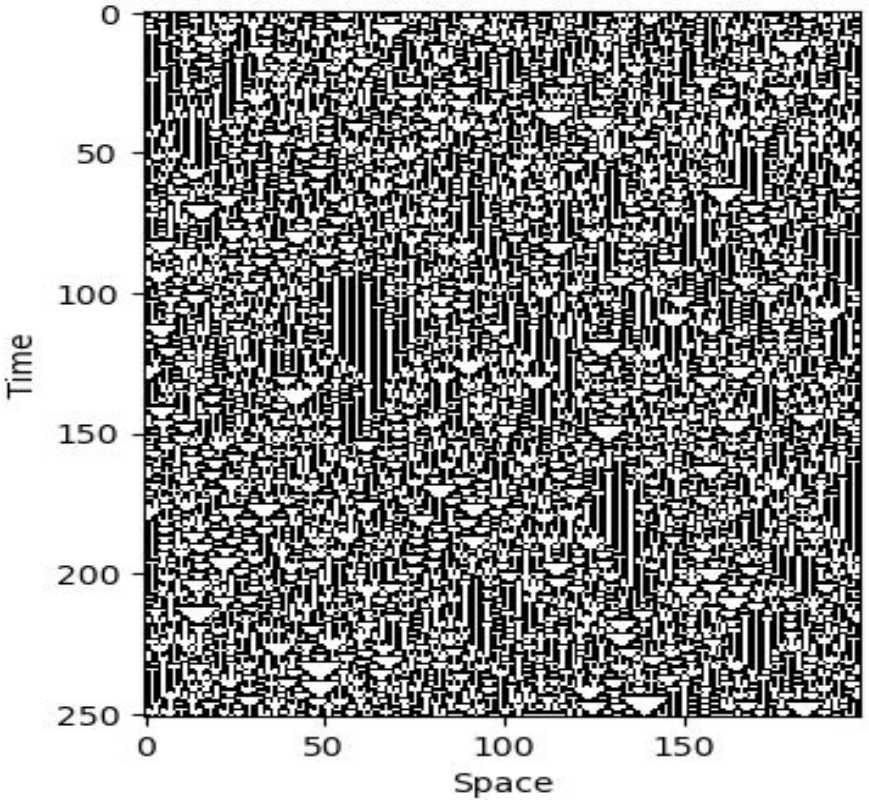

***Oliva porphyria***.




*Changing h0  gives different pattern.(h0=0.001)

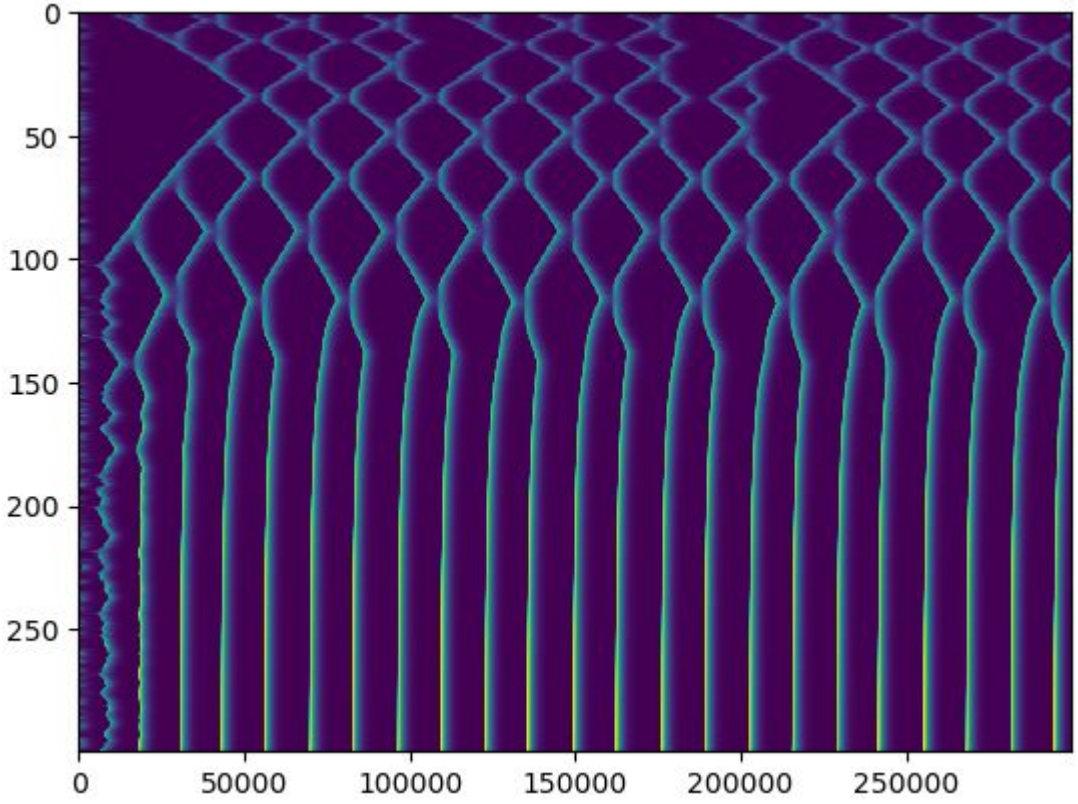
# Mixture in Patterns

# Stochastic Cellular Automata

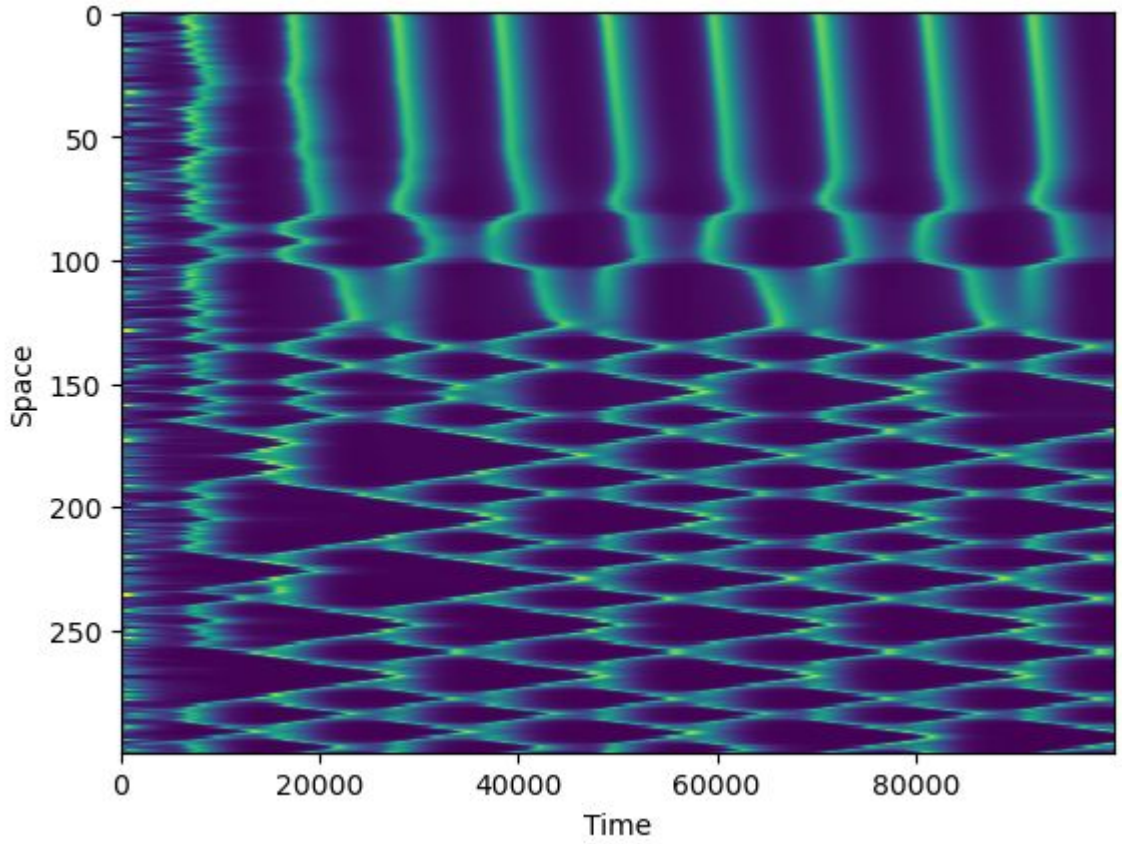



Explaining mixture pattern using Stochastic cellular automata

# Activation-Inhibition to explain mixture




Varying $h_0$ along the row we can get mixture of stripe and Triangle(ranging from 0.1 to 0.001)

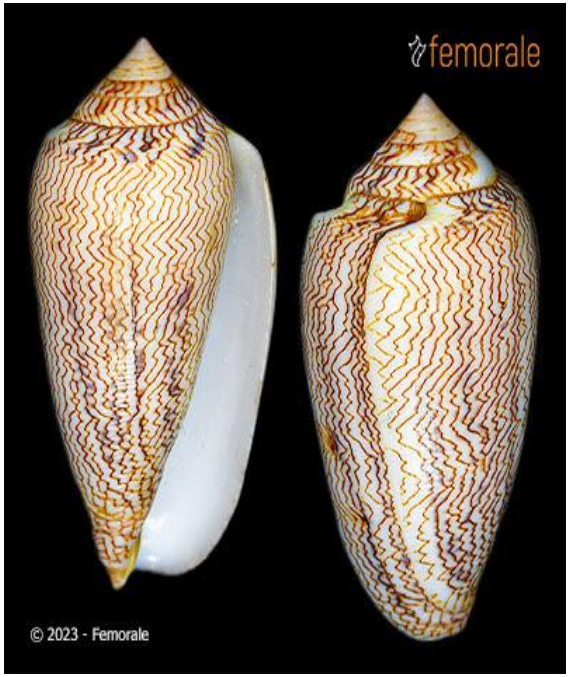



Changing *p*0 gives different pattern formation as well

# Future Work…..

- Starting this comparison from here can leads to explain more generalisation to map between a discrete and continuous system
- This mixture pattern indicate there should be some minimum regulation of activation to get any specific pattern
- Logic Gates implementation of the rules can generate any kind of pattern
- Interesting things starts to come up for many more rule,e.g Rule30.
- Biological relevance of this automata  rules  in gene regulatory networks of the species

# Other patterns




# References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- Kevin M. Kocot1,2†, Felipe Aguilera1,3†, Carmel McDougall1, Daniel J. Jackson4 and Bernard M. Degnan1*

Thanks