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Multi-Agents Systems and environment modelling…

NetBioDyn, an easy to use multi-agents engine for ecosystems simulation

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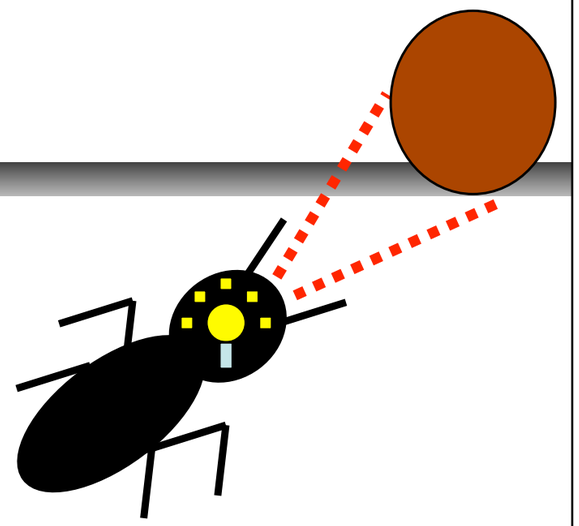
Road map

- Multi-Agents Systems (MAS)
- From Biological environment simulation
- Towards Ecosystems simulation
- NetBioDyn software
- Conclusions and futur works

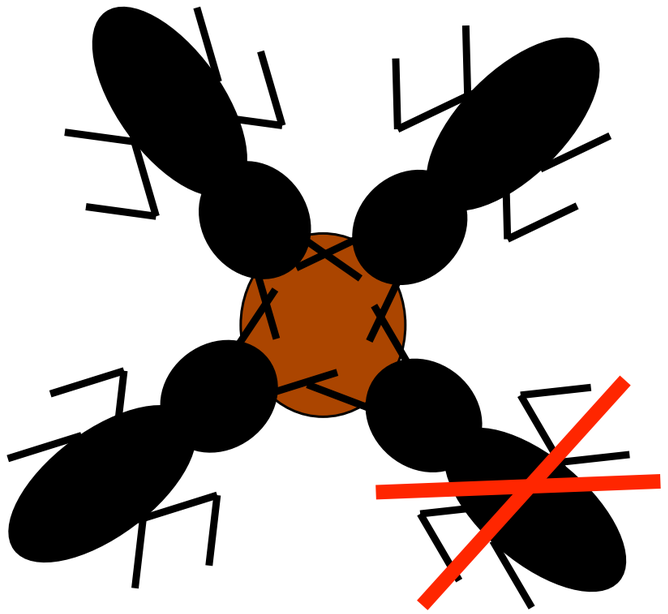
Multi-Agents systems properties



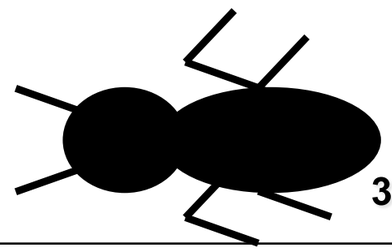
Agent : perception-decision-action

Multi-agents System :

- **auto-organisation**
- **emergence**
- **robustness**
- **adaptability**



Models' autonomy

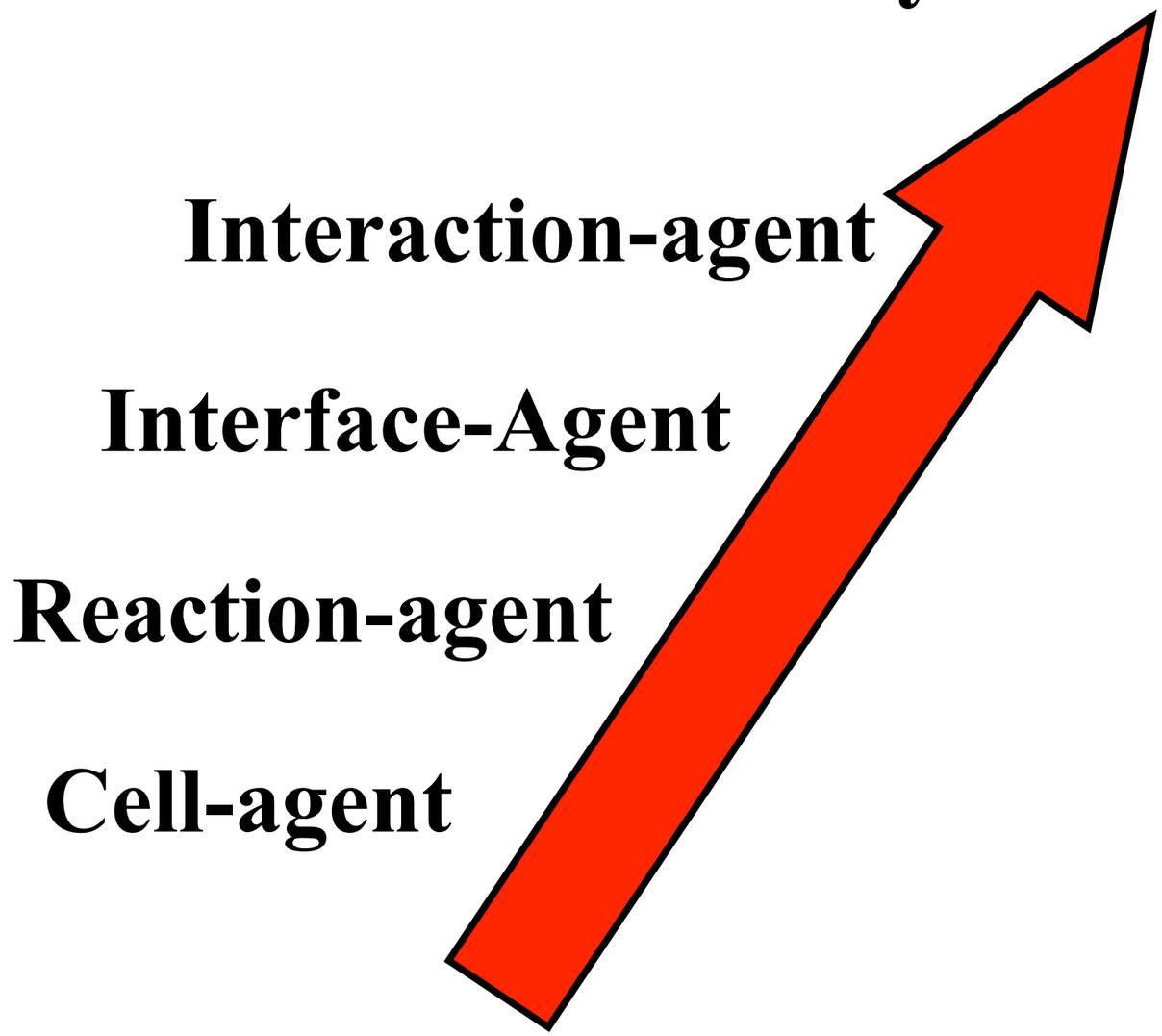


Road map

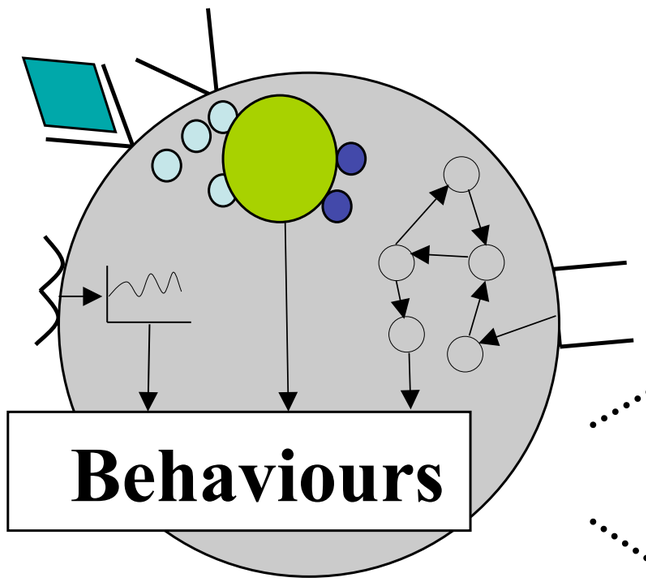
- ☑ **Multi-Agents Systems (MAS)**
- ❑ **From Biological environment simulation**
- ❑ **Towards Ecosystems simulation**
- ❑ **NetBioDyn software**
- ❑ **Conclusions and futur works**

Multi-Agent Systems and Biological modelling & simulation

From cell-agent To systemic approach



Cell-agent model



Basic behaviours

- Mitosis
- Activation
- Internalisation
- Expression of receptor
- Apoptose

Model of located agents with complex behaviors

Cell-agent model:
An exemple of application

Simulation of physiologic coagulation:

Cell

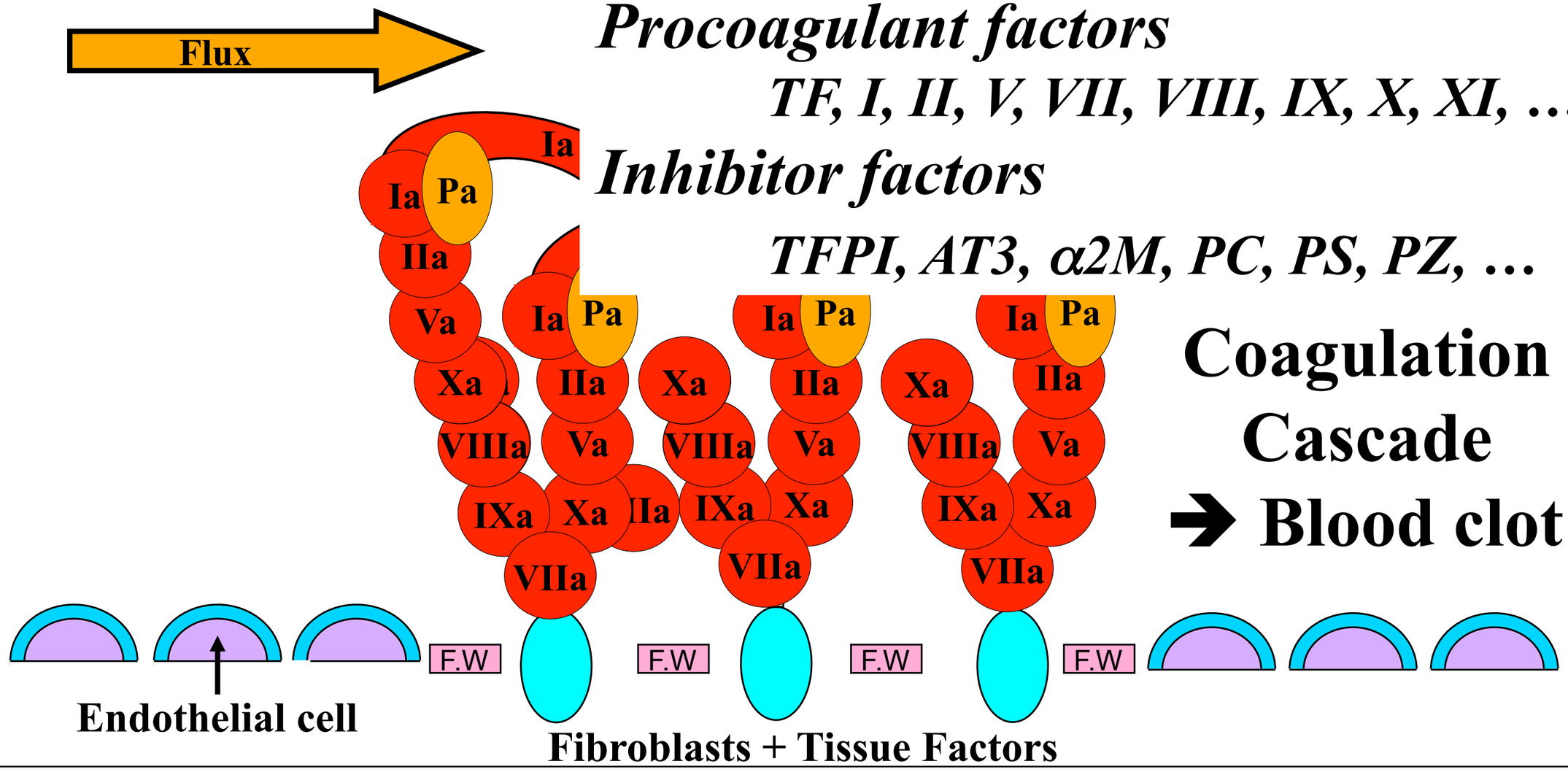
Fibroblasts cells, endothelial cells, platelet

Procoagulant factors

TF, I, II, V, VII, VIII, IX, X, XI, …

Inhibitor factors

TFPI, AT3, α2M, PC, PS, PZ, …

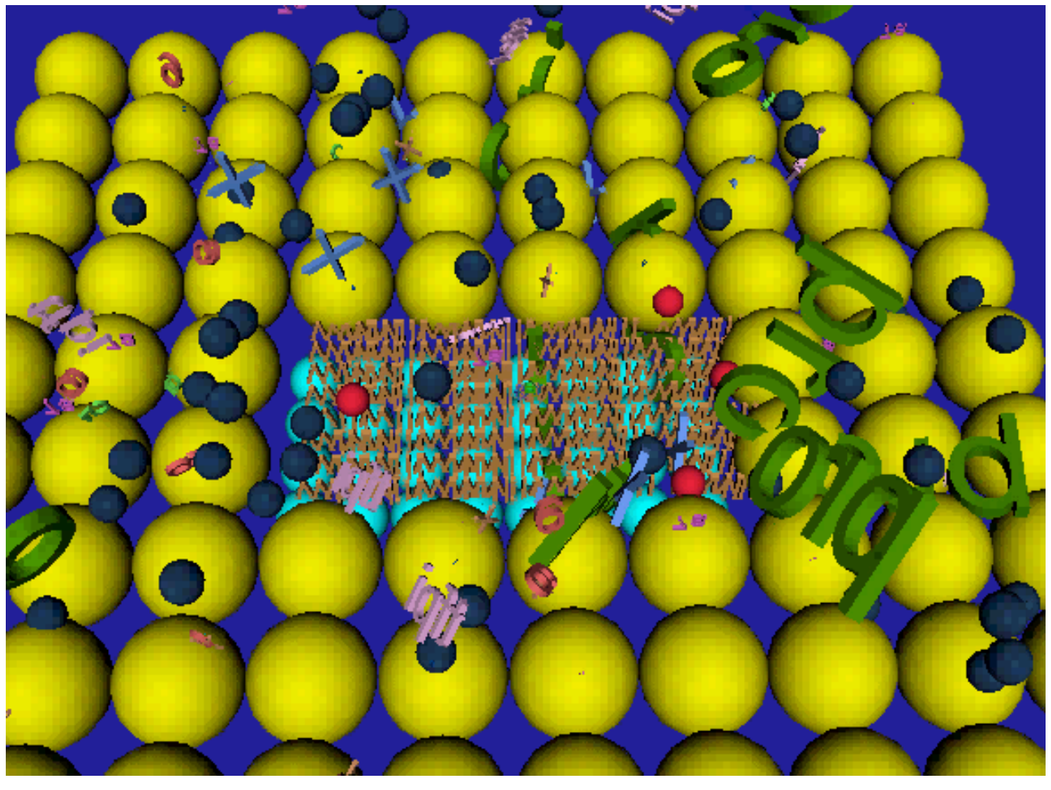


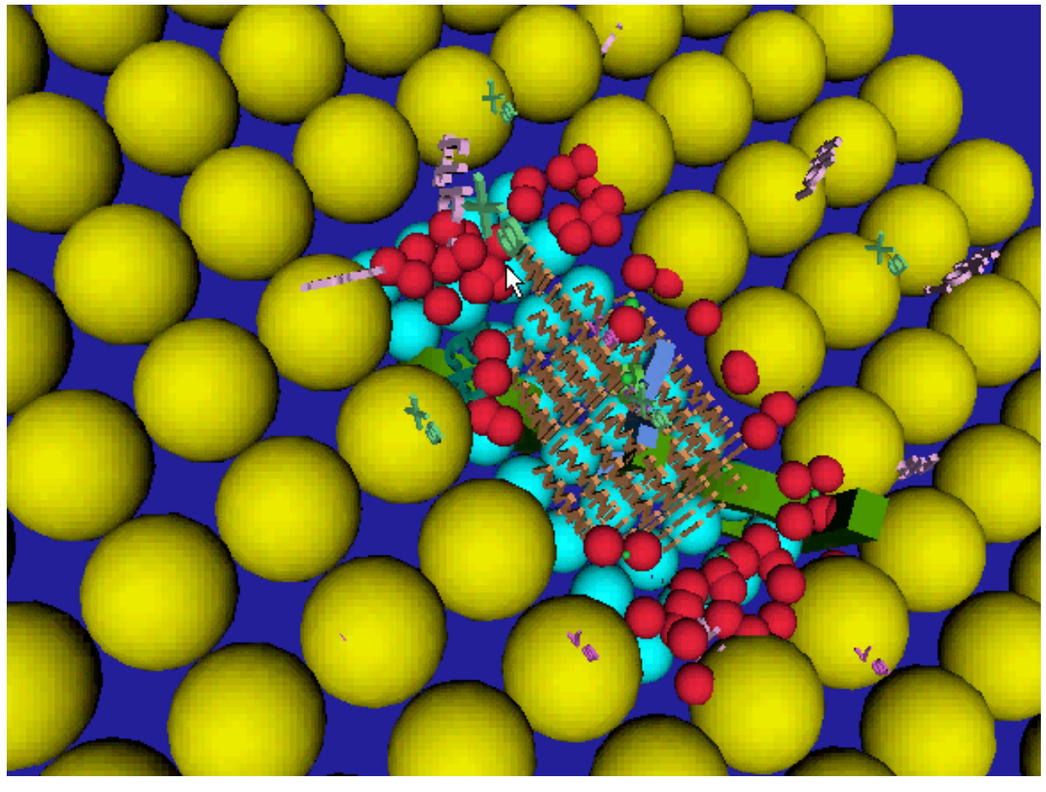
Coagulation Cascade

➔ Blood clot

Cell-agent model: An exemple of application

Simulation of physiologic coagulation: ➔ blood clot…

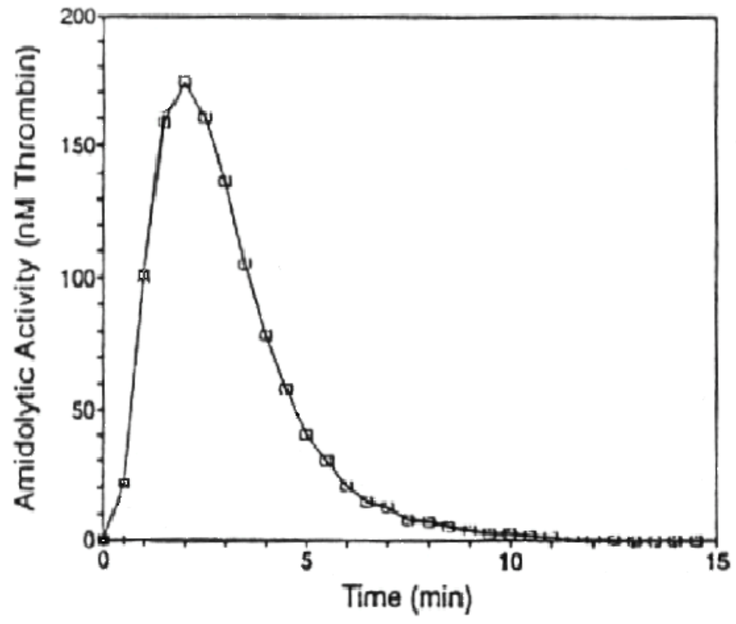




Cell-agent model: An exemple of application

Elements of validation of the coagulation multiagents model :

- **Comparison with Biological experiment**



Curve of thrombin Generation [Hemker, 1995]

- **Coherence with respect to pathologies**

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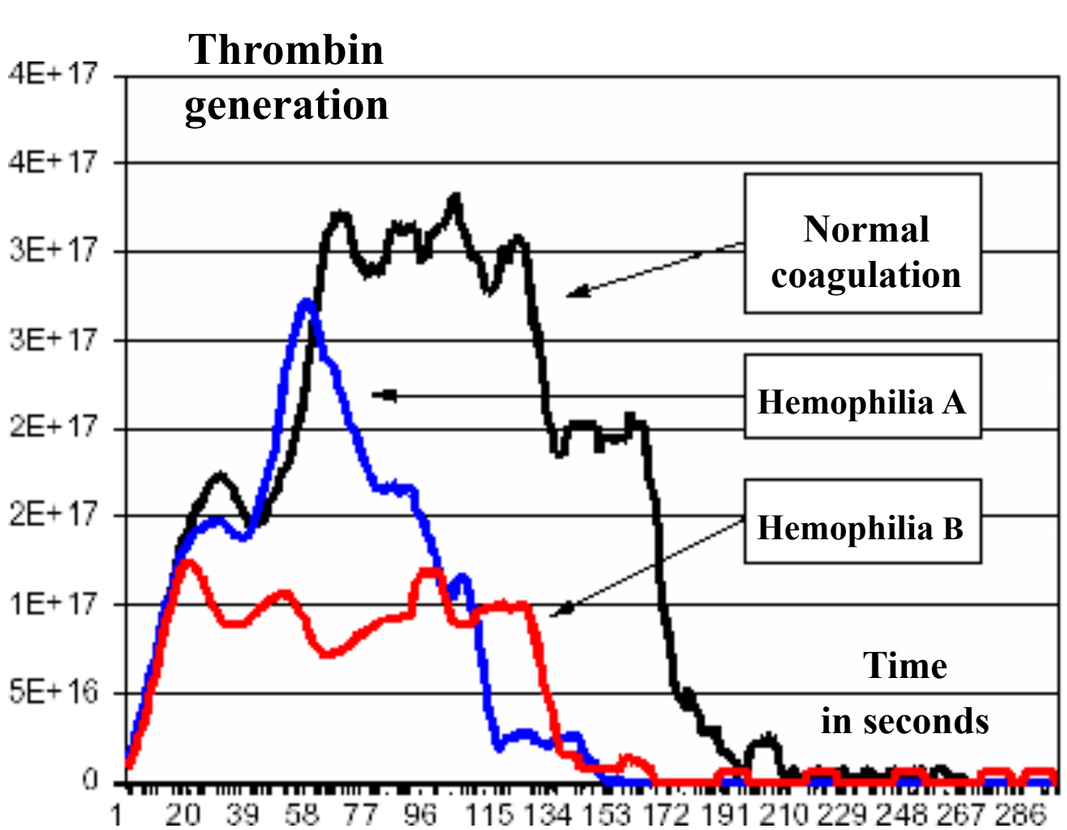
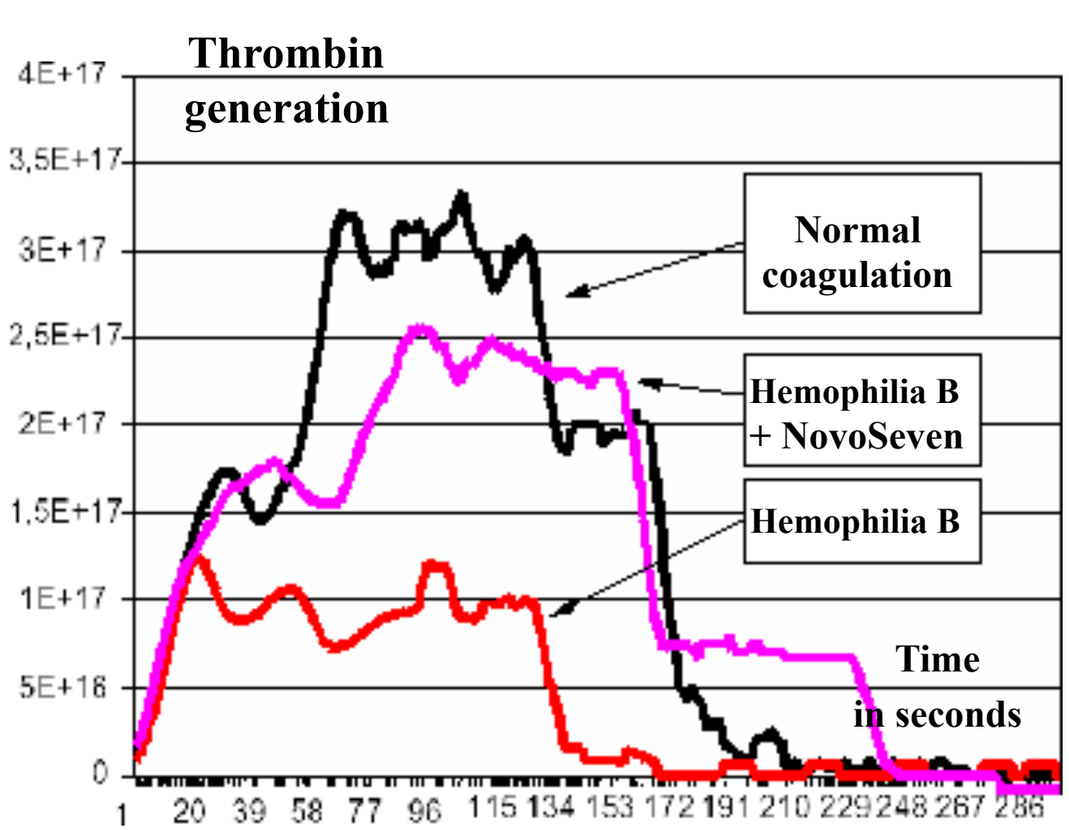
Cell-agent model: An exemple of application

Simulation of physiologic coagulation:

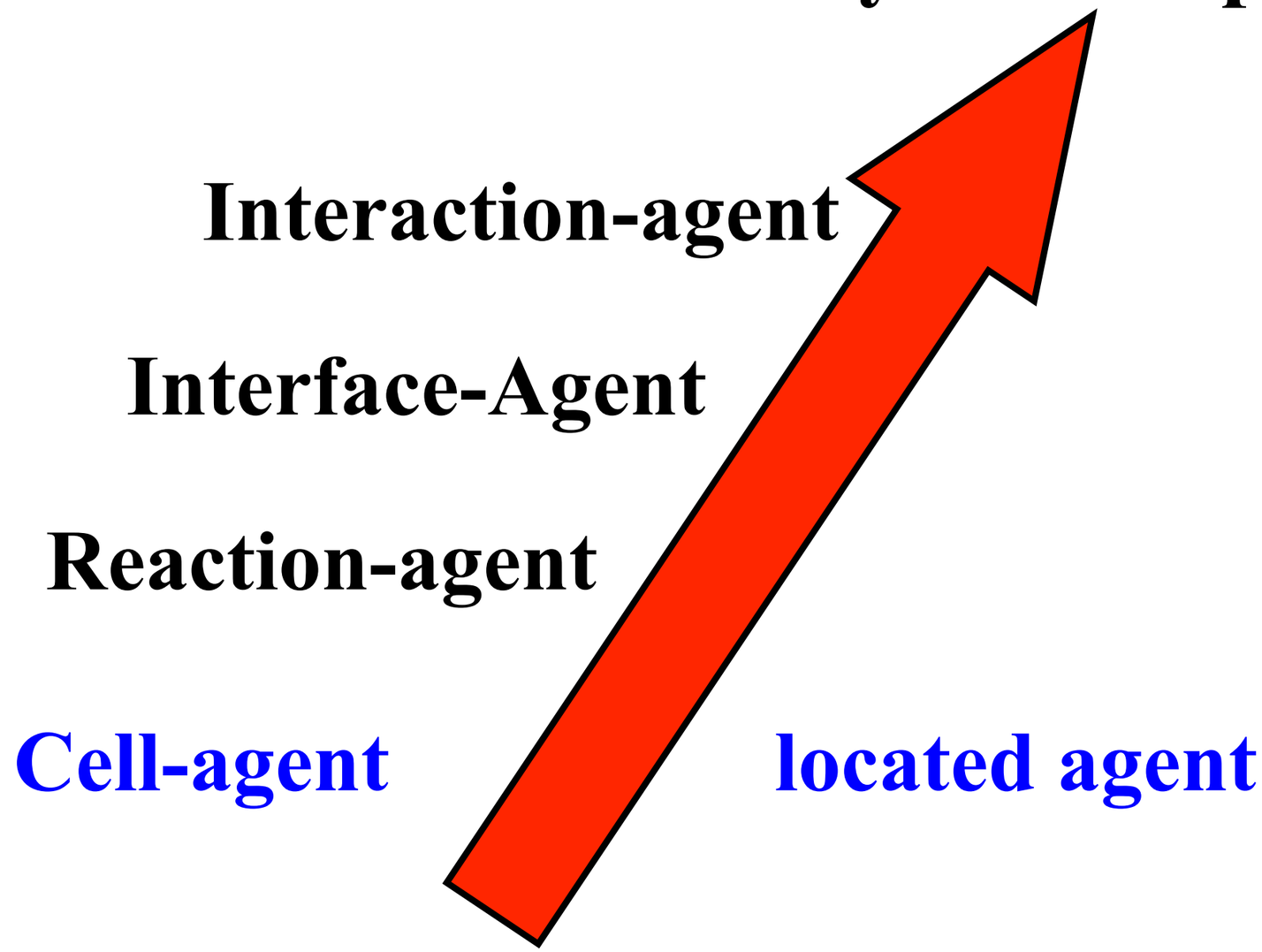
Healthy patient, hemophiliac, hemophiliac with treatment





Multi-Agent Systems and Biological modelling & simulation

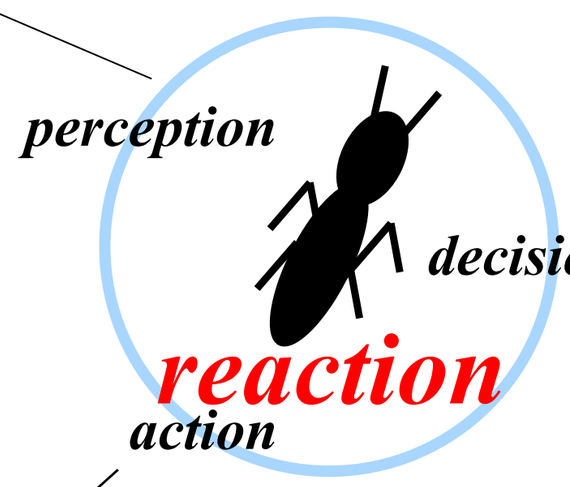
From cell-agent To systemic approach



Reaction-agent model

- « microscopic » level : *agent = cell/molecule*
- « macroscopic » level : *agent = reaction*

1: reading of the concentrations in reactants



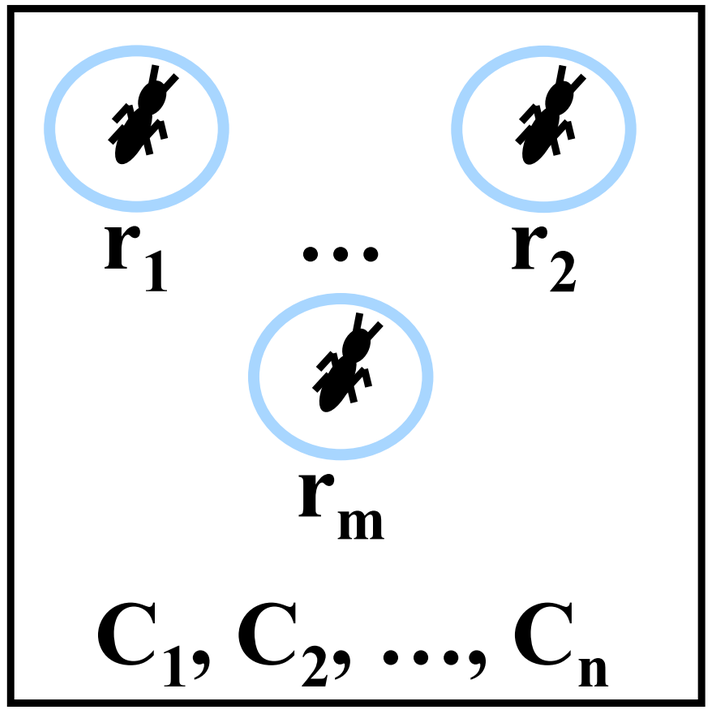
2:calculation the reaction speed and then the quantity of reactant to be reacted

3: consequently, modification of the concentrations in reactants and products

Reaction-agent model

Spatial indiscernibility

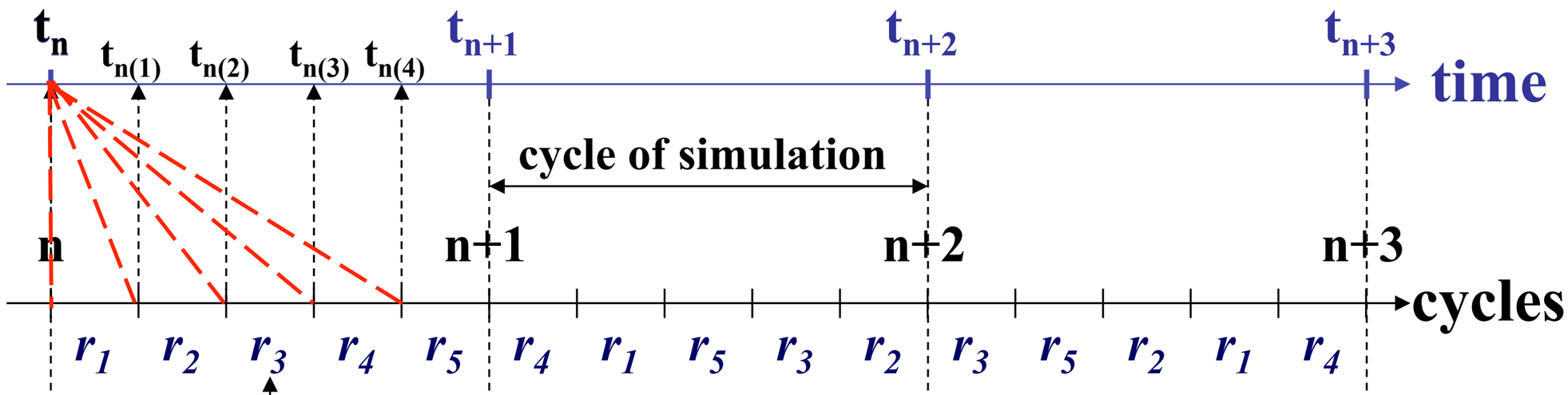
Non located agents



Chemical reactor

- **Asynchronous phenomena and chaotic order**
- **No Ordinary Differential Equation**

Reaction-agent model



Asynchrony of MAS ⟶ ***Random permutation***

Traditional approaches
Asynchronous and chaotic iterations

Reaction-agent model

$$d[S_1]/dt = -kcat_1[E_1][S_1]/(Km_1+[S_1]) - kcat_3[E_1][S_1]/(Km_3+[S_1])$$

$$d[S_2]/dt = +kcat_2[E_2][S_2]/(Km_2+[S_2])$$

$$d[P_1]/dt = -kcat_1[E_1][S_1]/(Km_1+[S_1]) - kon_3[P_1][P_2] + kcat_3[E_1][S_1]/(Km_3+[S_1])$$

$$d[P_2]/dt = +kcat_2[E_2][S_2]/(Km_2+[S_2]) - kon_3[P_1][P_2]$$

$$d[P_1P_2Complex]/dt = kon_3[P_1][P_2]$$

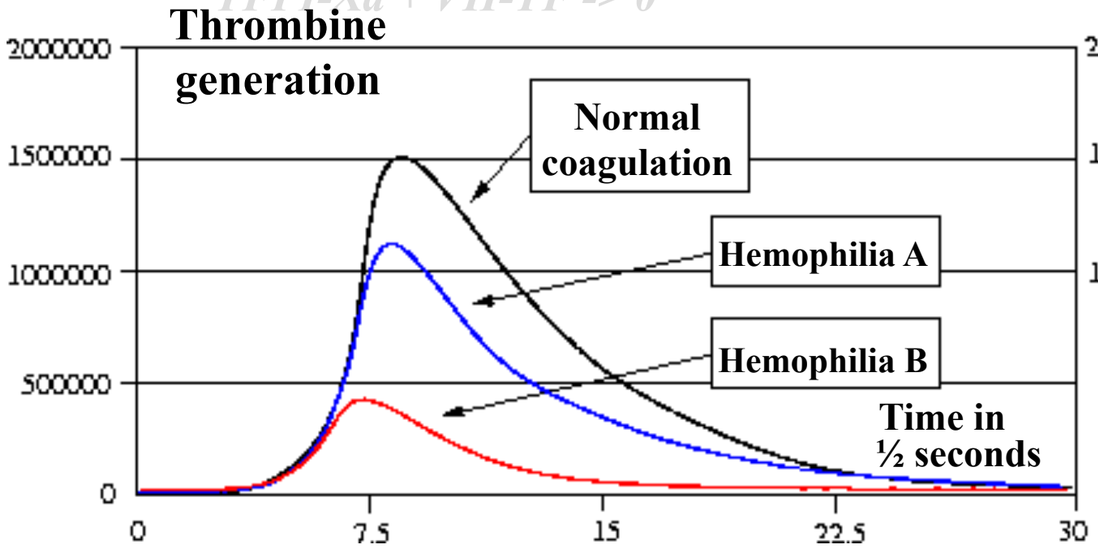
$$E_1 + S_1 \rightarrow E_1 + P_1$$
$$E_2 + S_2 \rightarrow E_2 + P_2$$
$$P_1 + P_2 \rightarrow P_1P_2Complex$$
$$E_3 + S_1 \rightarrow E_3 + P_1$$

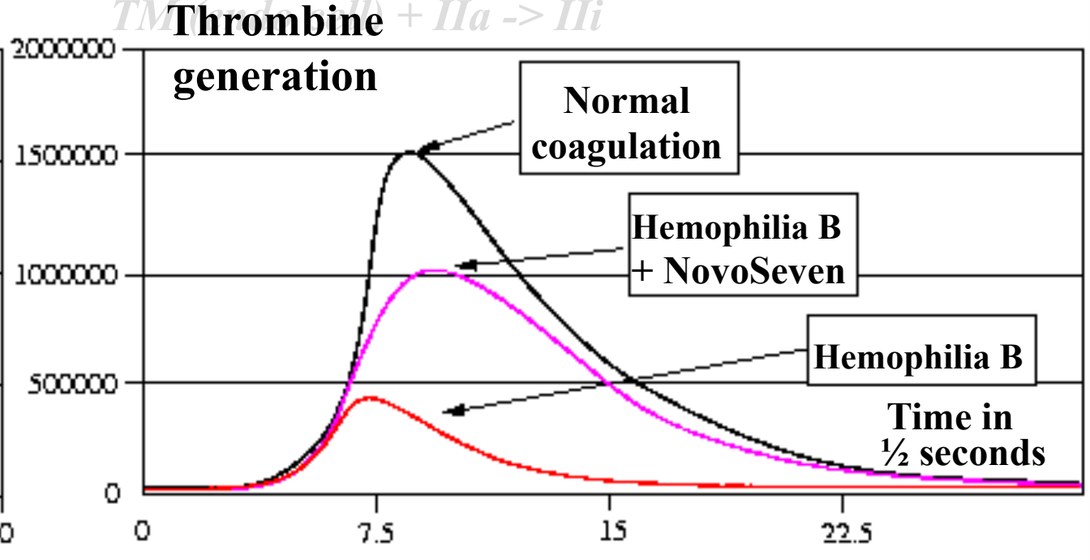
```
new EnzimaticReaction(plasma, E1, S1, P1, kcat1, Km1);
new EnzimaticReaction(plasma, E2, S2, P2, kcat2, Km2);
new ComplexFormationReaction(plasma, P1, P2, P1 P2Complex, kon3);
new EnzimaticReaction(plasma, E3, S1, P1, kcat3, Km3);
```

Reaction-agent model: An exemple of application

Simulation of physiologic coagulation:

Healthy patient, hemophiliac, hemophiliac with treatment





42 reactions

Multi-Agent Systems and Biological modelling & simulation

From cell-agent To systemic approach

Interaction-agent

Interface-Agent

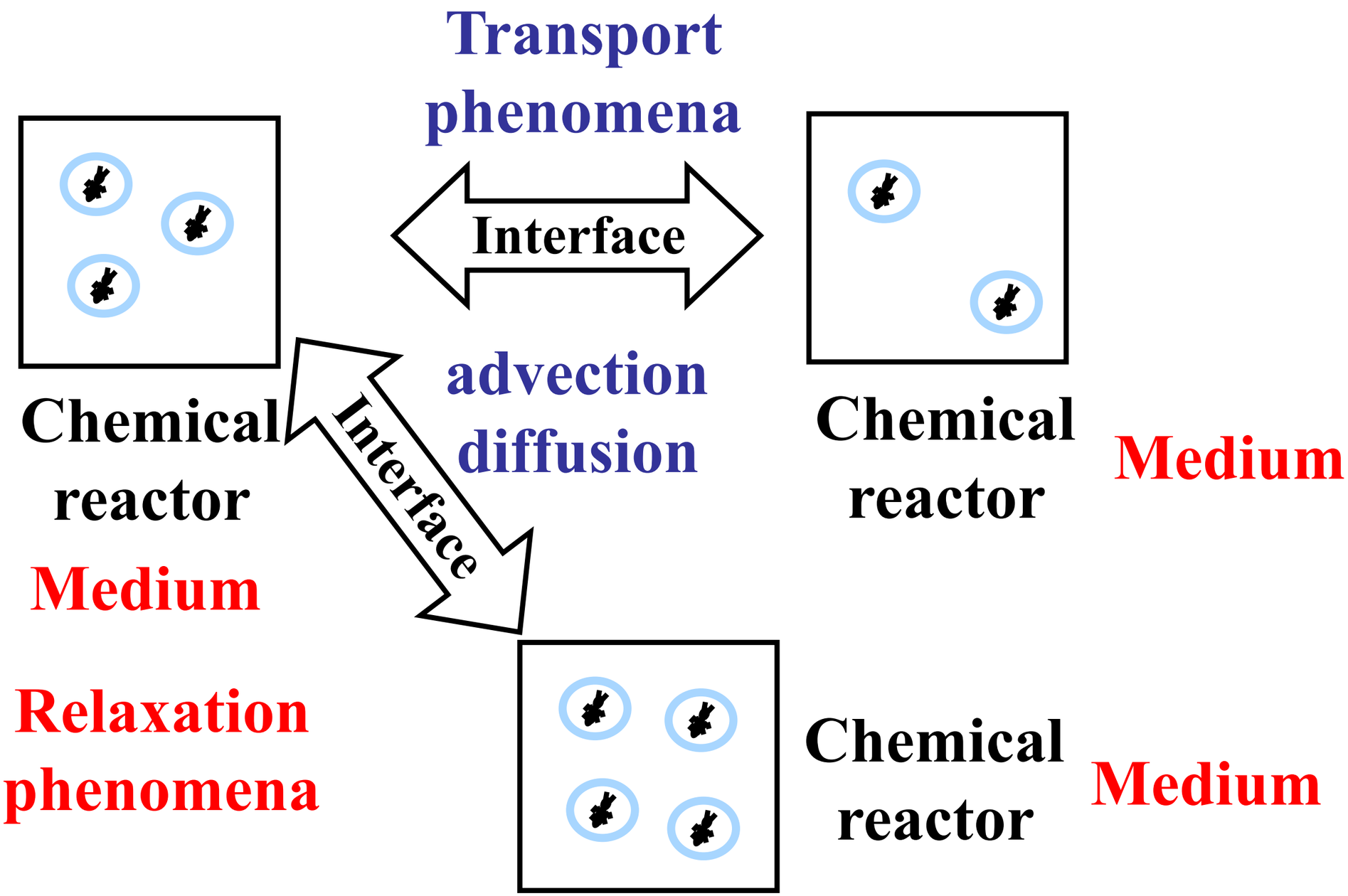
Reaction-agent

non located agent

Cell-agent

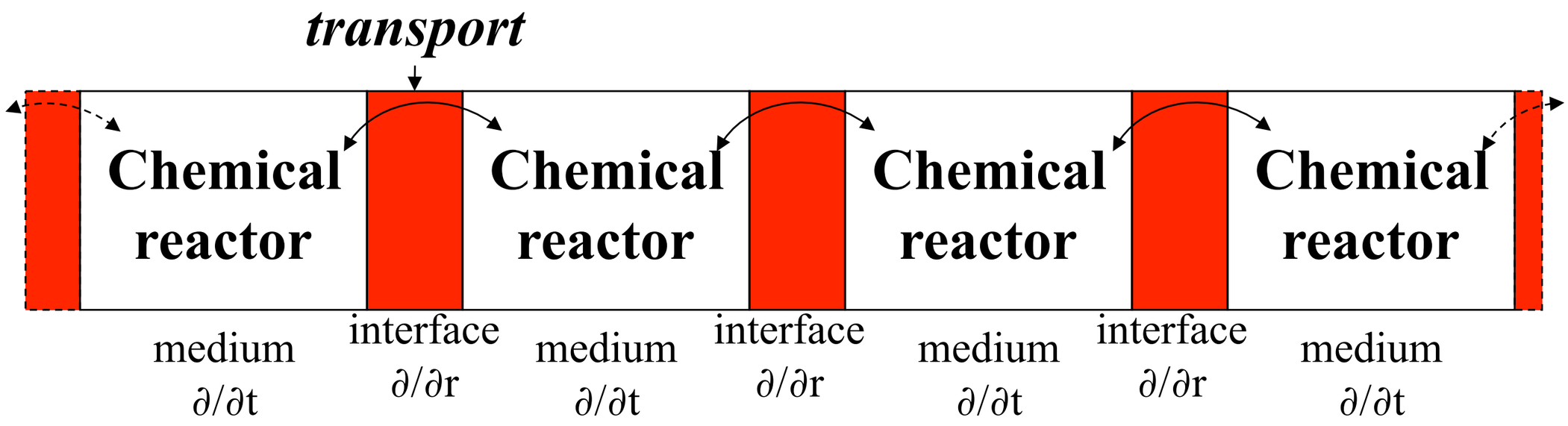
located agent

Interface-agent model



Interface-agent model

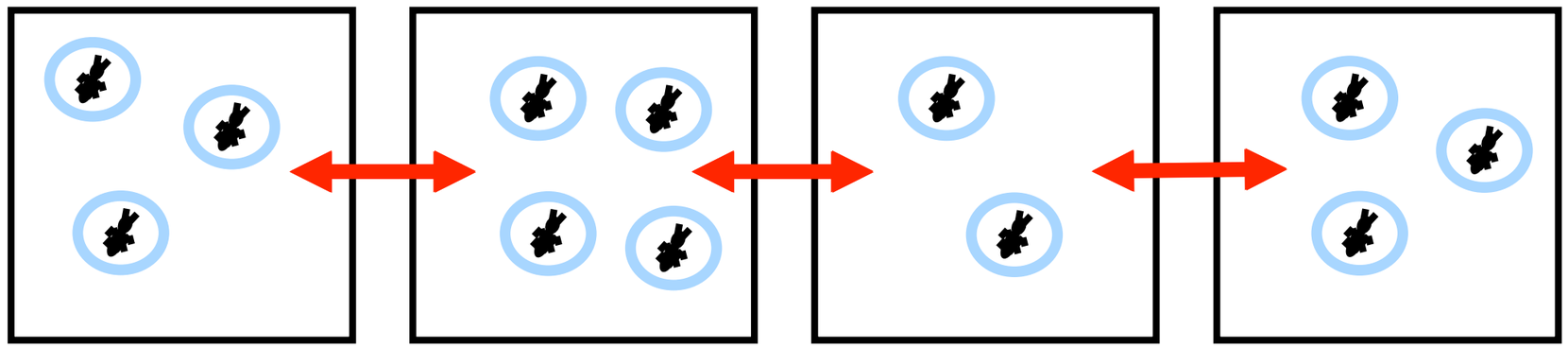
« Classical » point of view:



- **Variables = concentrations in reactants in each chemical reactor (mesh of the medium)**
- **All the phenomena are supposed simultaneous**
- **Resolution of partial differential equations**

Interface-agent model

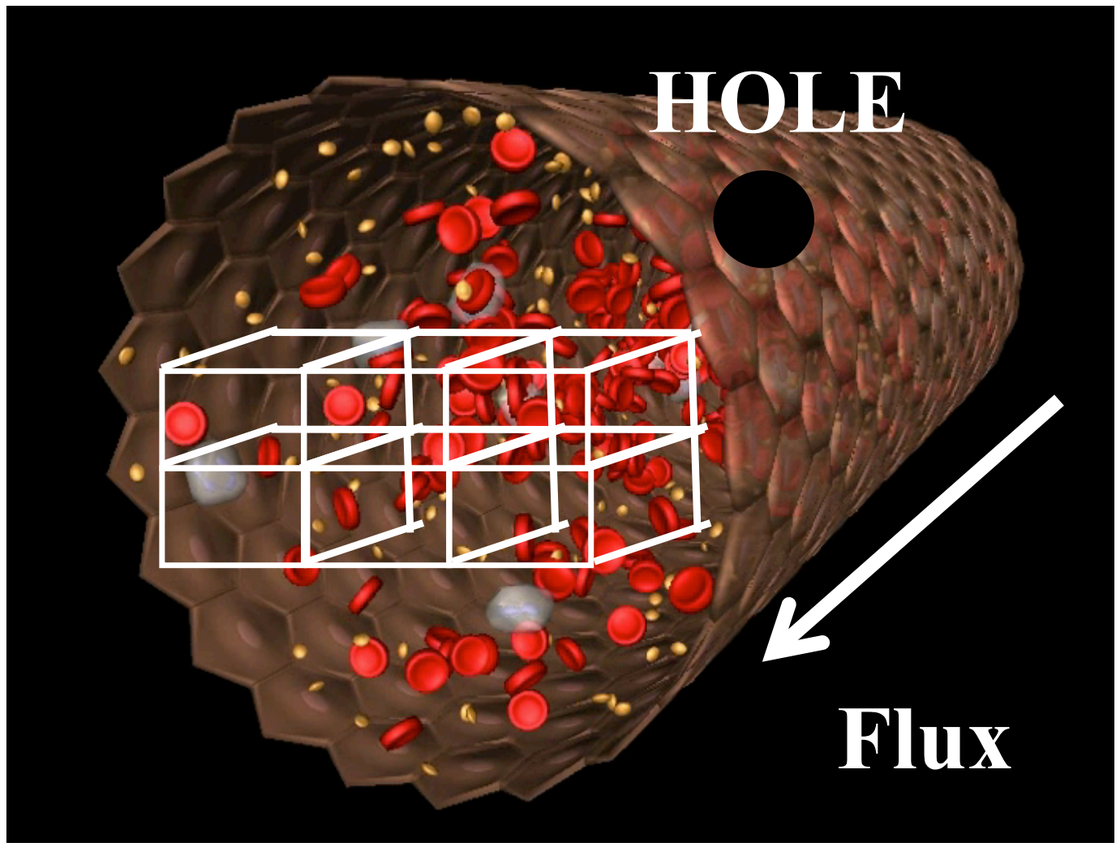
An « agent » point of view:



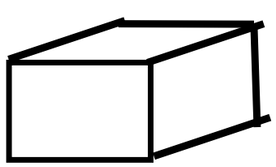
- Interface-agent
  - ➡ interaction between the mediums
- Asynchronous phenomena and chaotic order
- No Partial Differential Equation

Interface-agent model: An exemple of application

Coagulation :



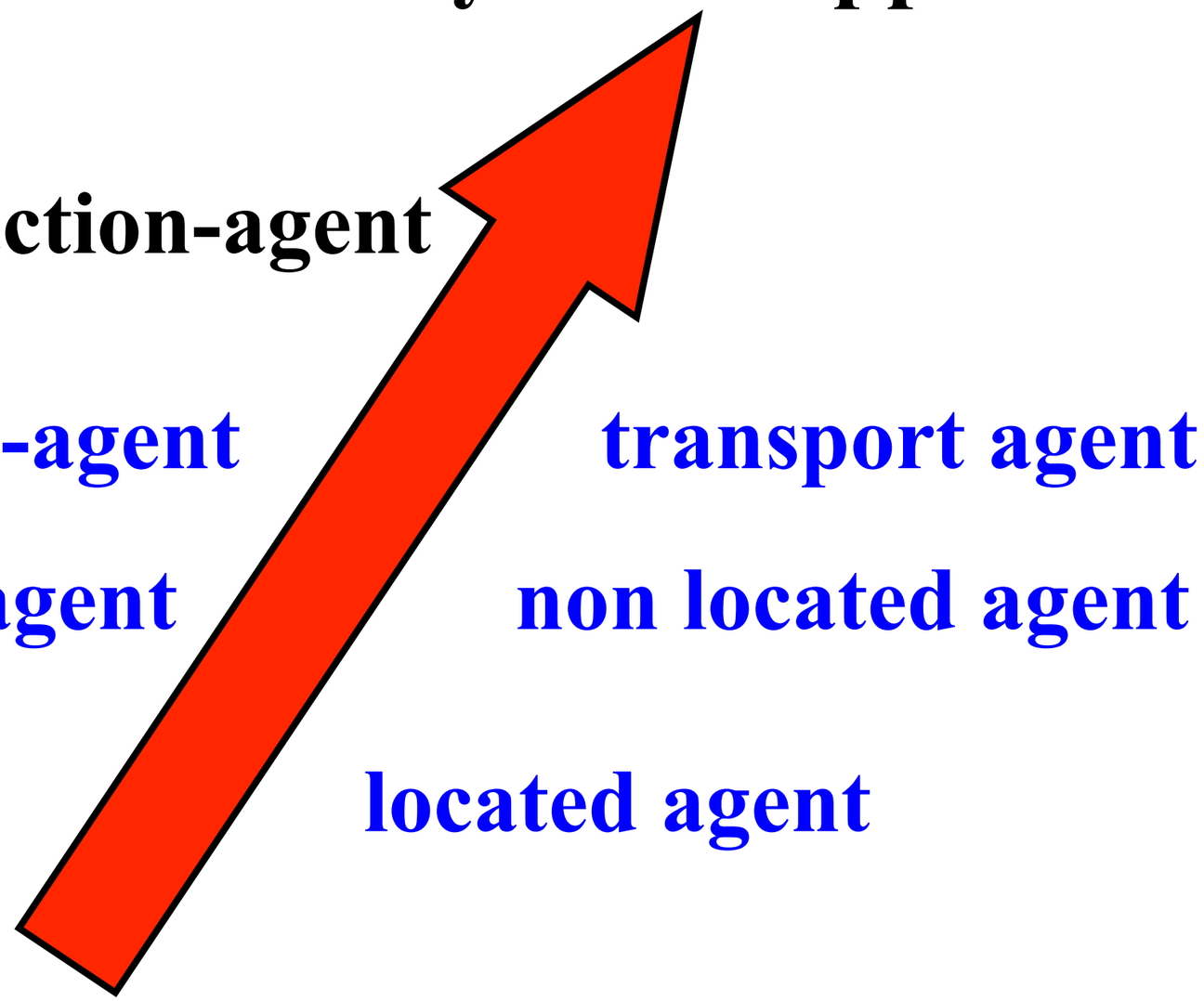
3D Vessel



Chimical Reactors : 42 reactions (coagulation)

Multi-Agent Systems and Biological modelling & simulation

From cell-agent To systemic approach

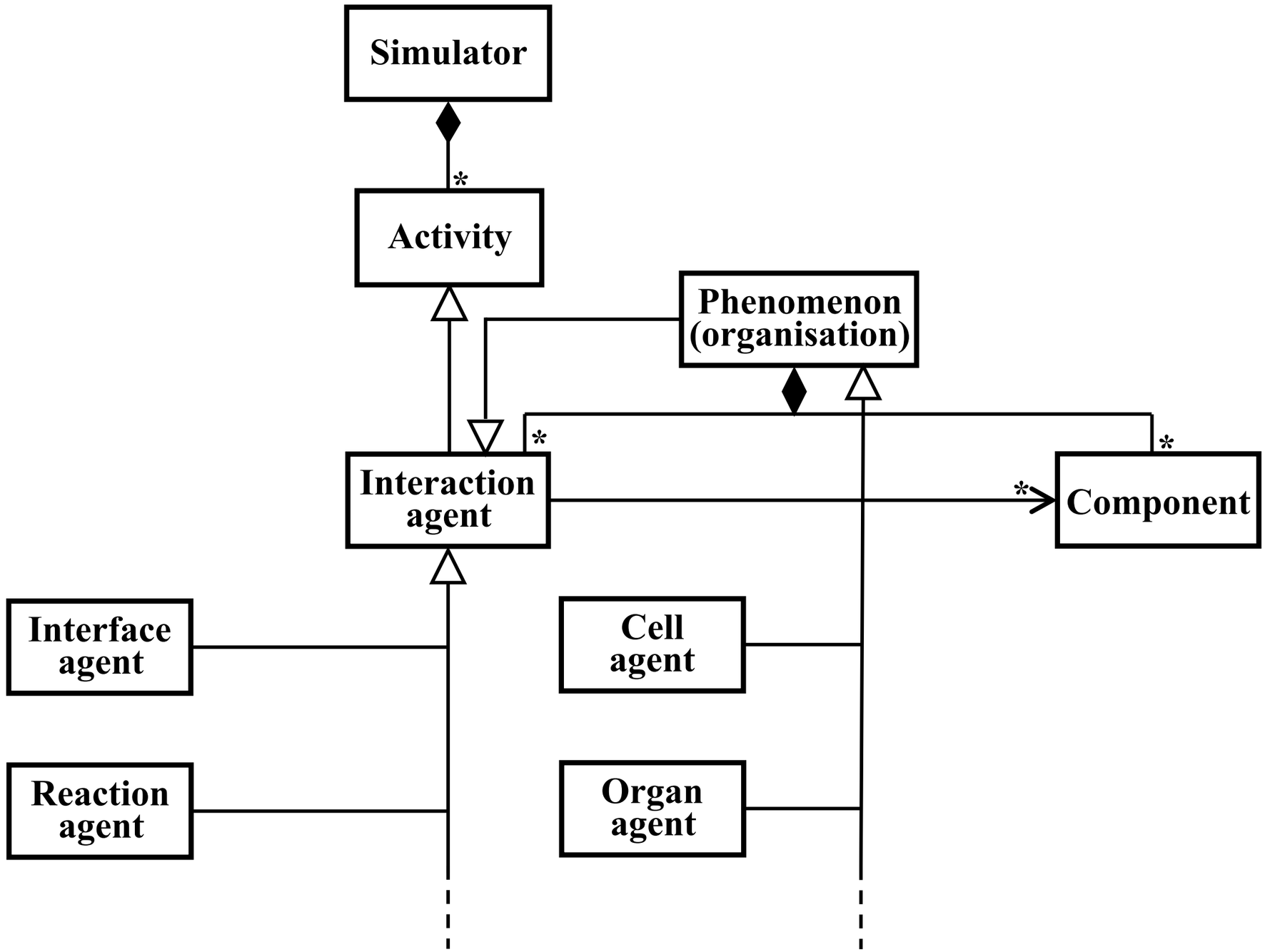


Generic model of interaction-agent

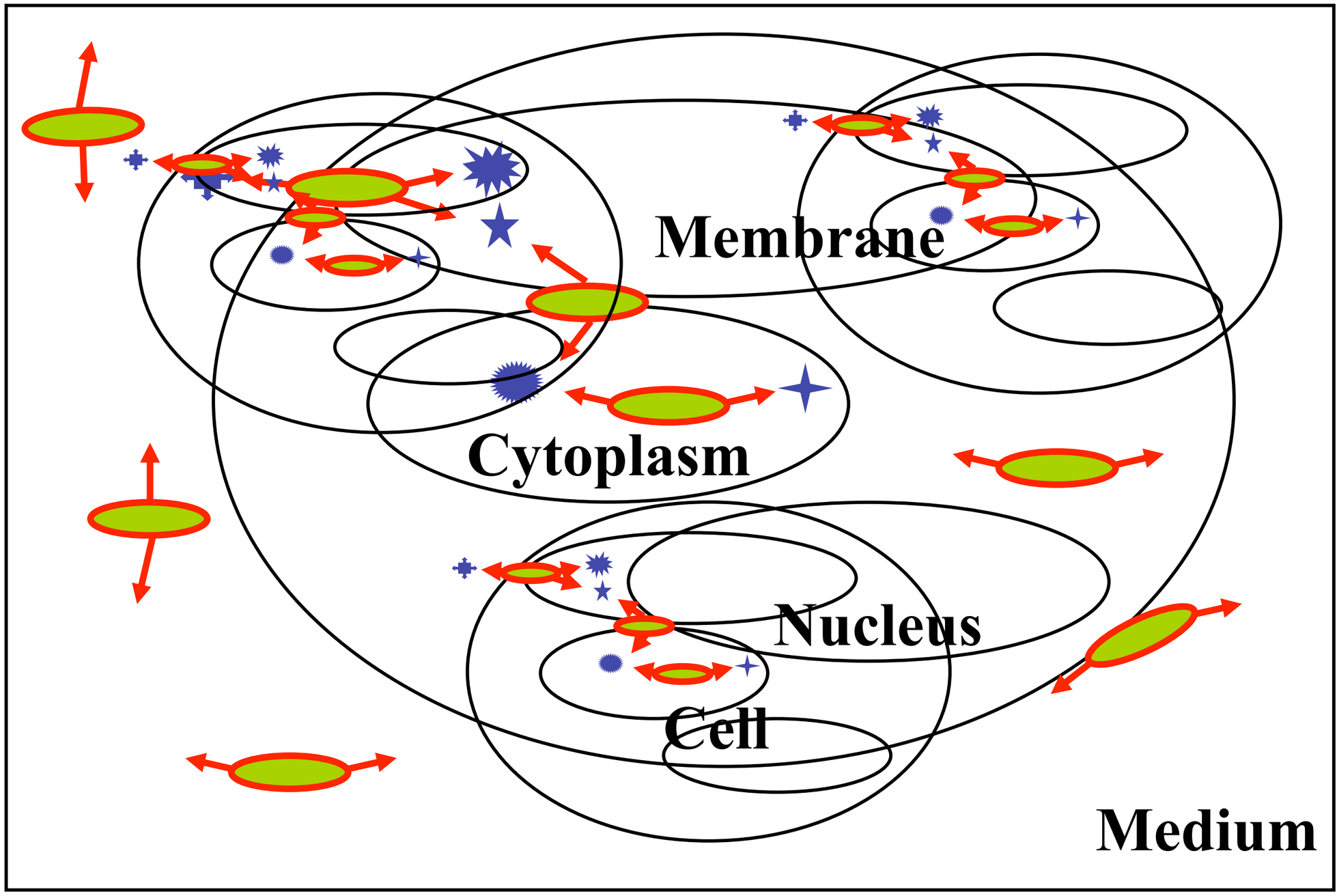
Main principle :
Models' autonomy

- **Interaction between models of different natures**
- **Multi-modeling Simulation**
- **Systemic paradigm**
- **Data Matter exchange between organisations**

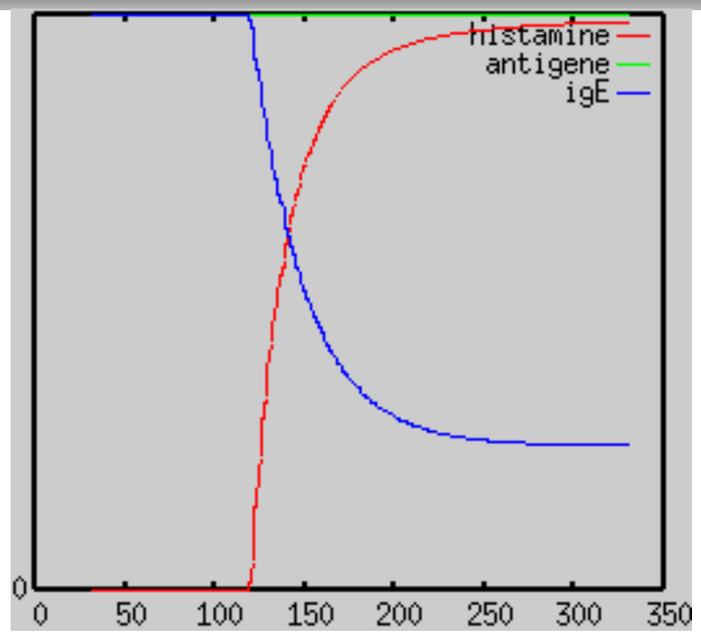
Generic model of interaction-agent



Generic model of interaction-agent : An exemple of application



Generic model of interaction-agent : An exemple of application

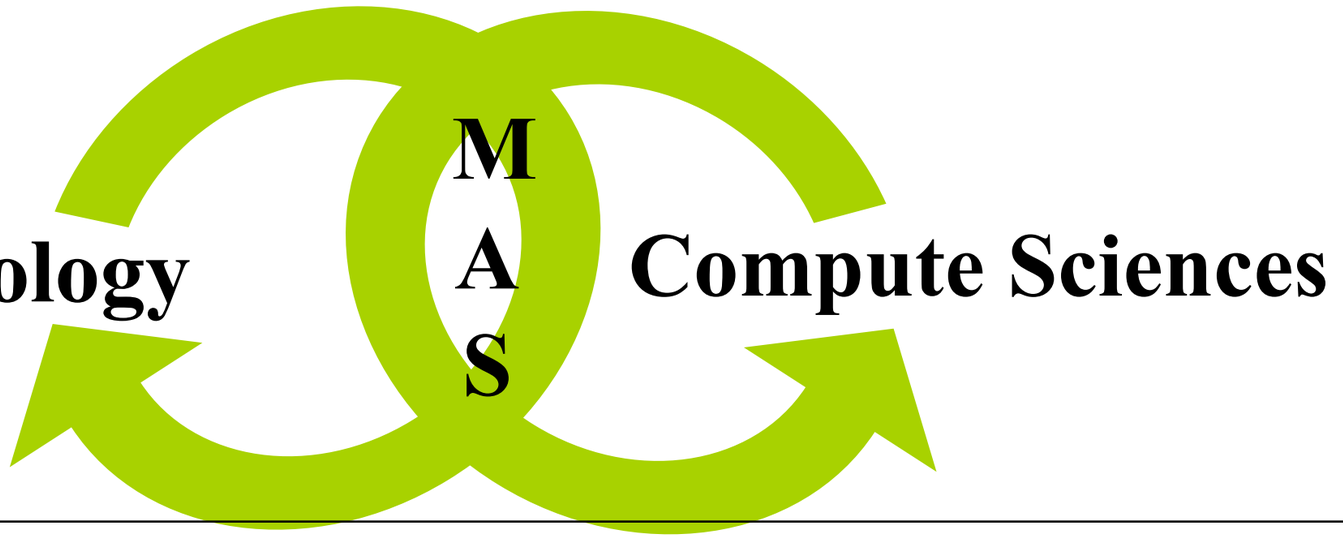


Multi-Agent Systems and Biological modelling & simulation

From cell-agent To systemic approach

Interests in the field of biology

- **To help the reflection**
  - **Test and validate hypotheses**
  - **Analyse parameters influence**
  - **Understand complex phenomena**
- **To prepare experiments**
- **To accelerate the drug discovery**



Road map

☑ **Multi-Agents Systems (MAS)**

☑ **From Biological environment simulation**

❑ **Towards Ecosystems simulation**

❑ **NetBioDyn software**

❑ **Conclusions and futur works**

Towards Ecosystems simulation

Cells ➔ Entities (insects, etc.)

&

Low level interaction

Reaction ➔ High level interaction between entities

Interface/Interaction ➔ Physical environment

Road map

☑ **Multi-Agents Systems (MAS)**

☑ **From Biological environment simulation**

☑ **Towards Ecosystems simulation**

❑ **NetBioDyn software**

❑ **Conclusions and futur works**

NetBioDyn software :
an easy to use multi-agents engine

Goal:
Rapid prototyping of
biological & ecosystem simulations

http://virtulab.univ-brest.fr/netbiodyn.html

http://virtulab.univ-brest.fr/netbiodyn3D.html

NetBioDyn software : an easy to use multi-agents engine

Key concepts:

➔Environment: a grid

➔Entities: colored squares

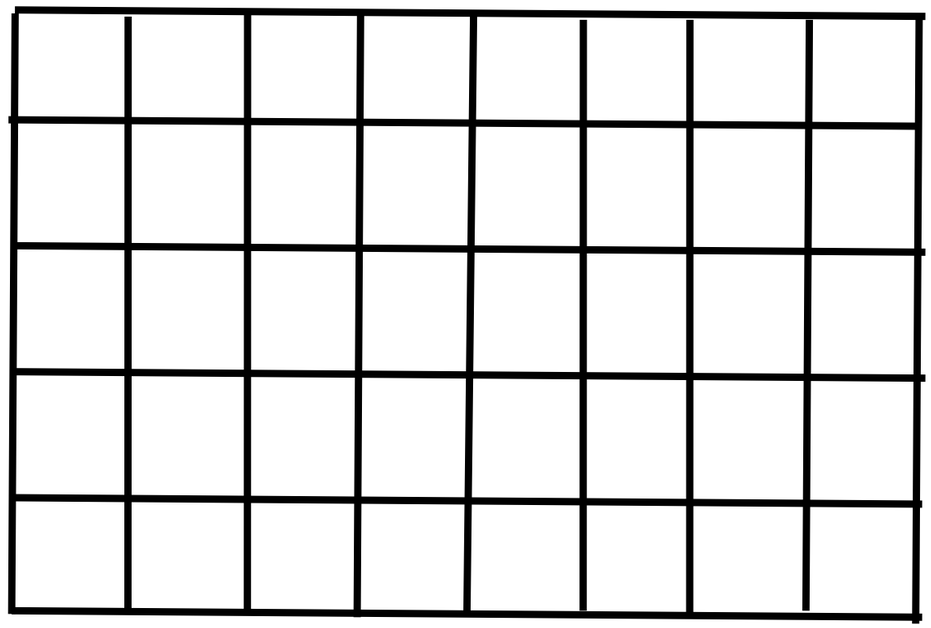
➔Interaction with environment : simple rules

➔Interaction between entities : simple rules

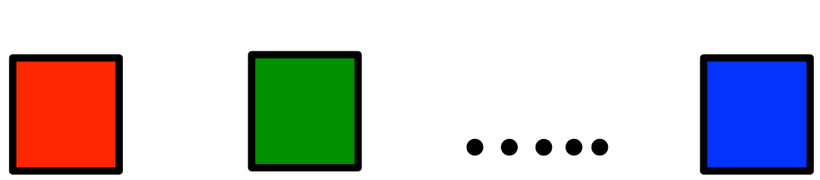
Easy to use… No programming skill requires !!!!

NetBioDyn software : How to model…?

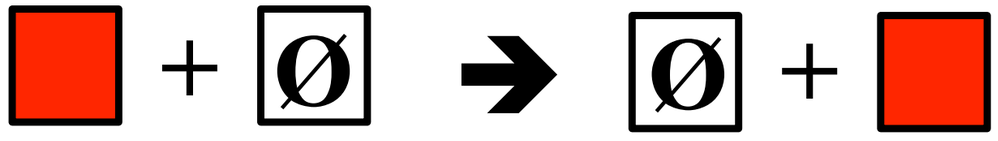
1st : take a grid



2nd : decide which entities to use



3rd : define rules (with a probility of activation) to give entities movements and interactions



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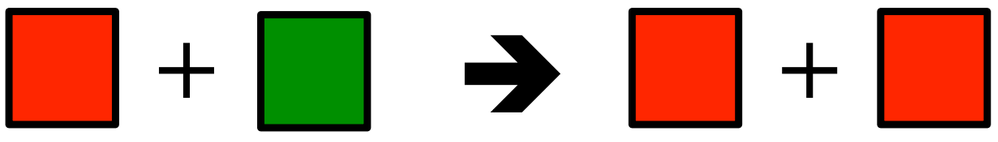

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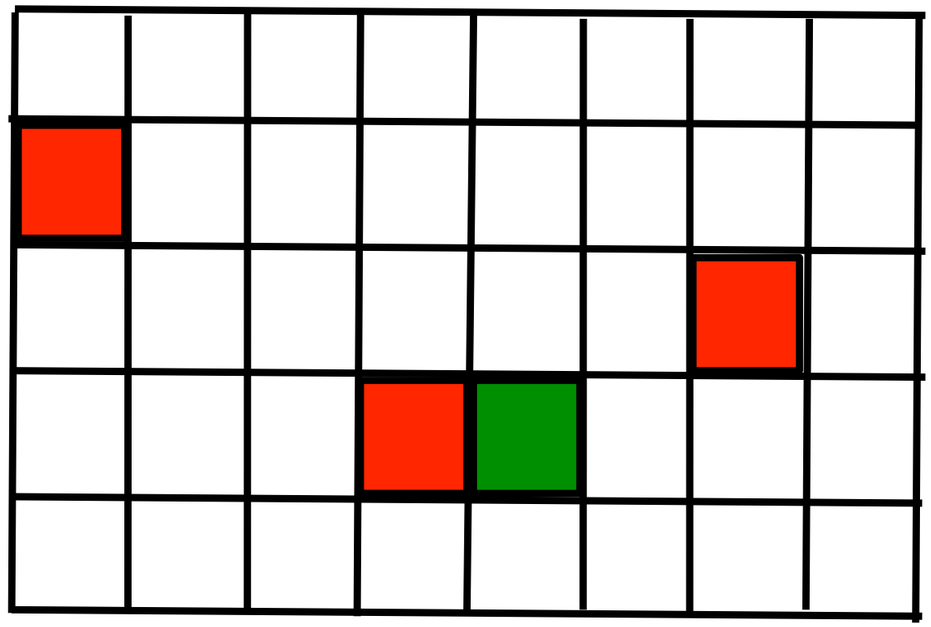
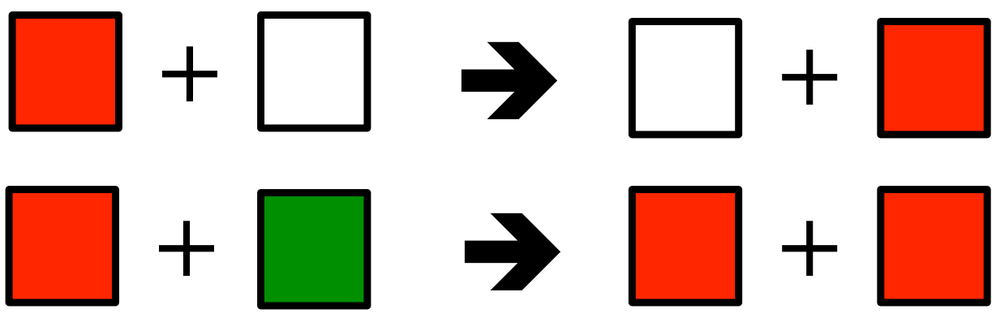
NetBioDyn software : How to model…?

4th : place entities

and : run





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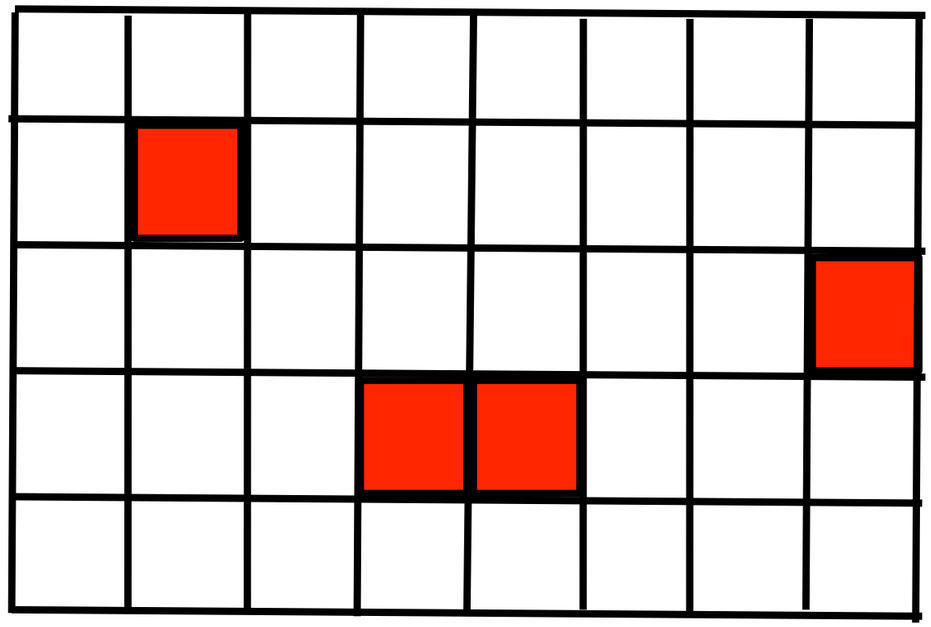
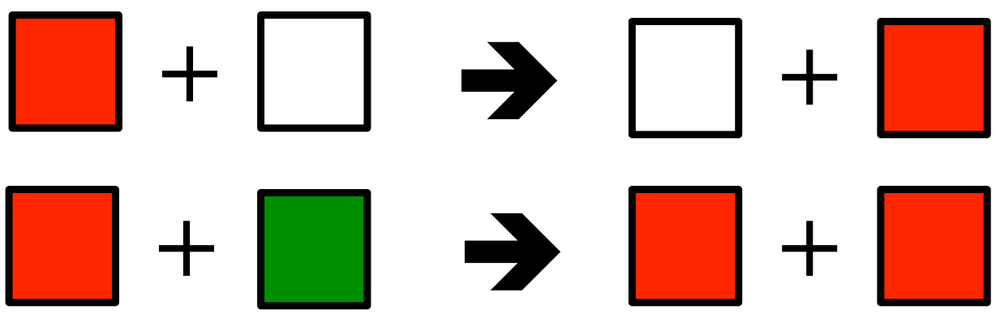
…..

NetBioDyn software : How to model…?

4th : place entities

and : run





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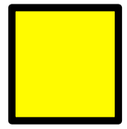
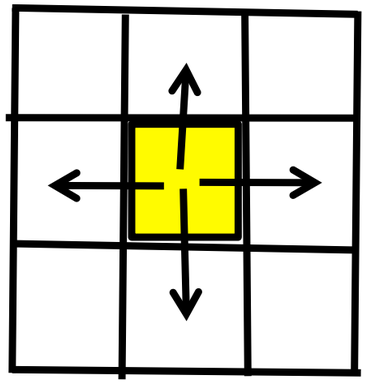
NetBioDyn : 1st example, randomwalk

➔**Entities:** 



Rd_Walk

➔

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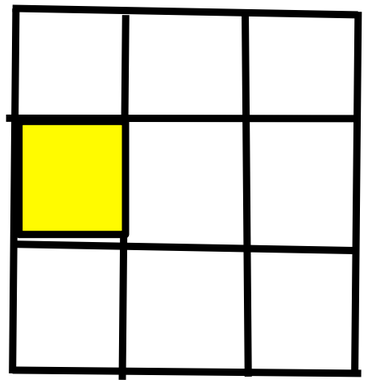

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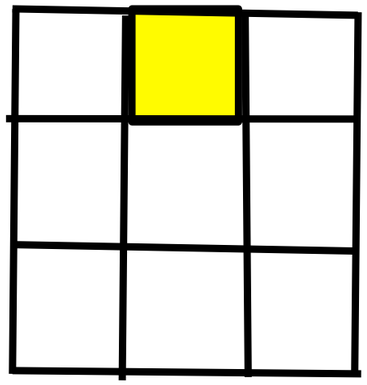

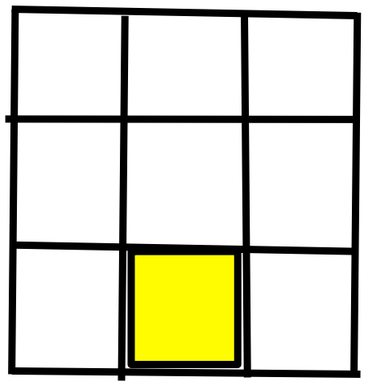

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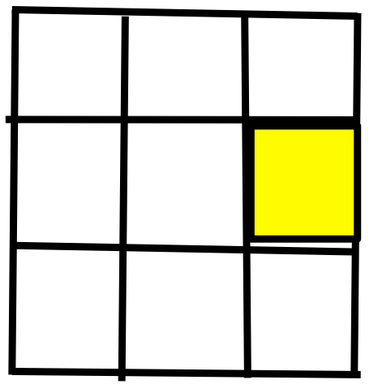
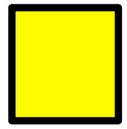
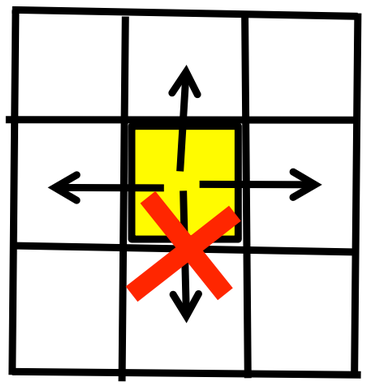


NetBioDyn : 1st example, randomwalk

➔**Entities:** 



Rd_Walk

➔

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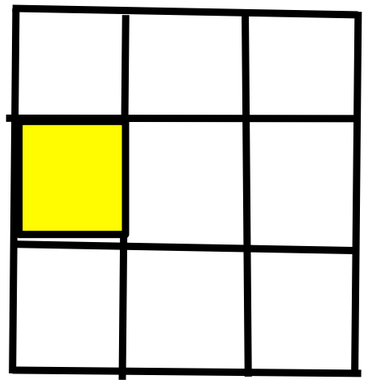

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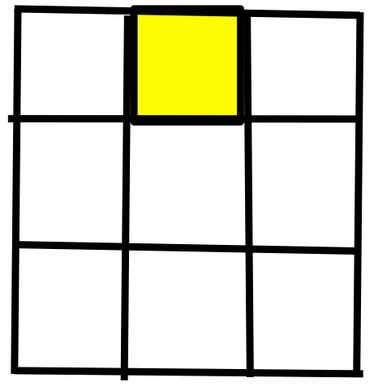
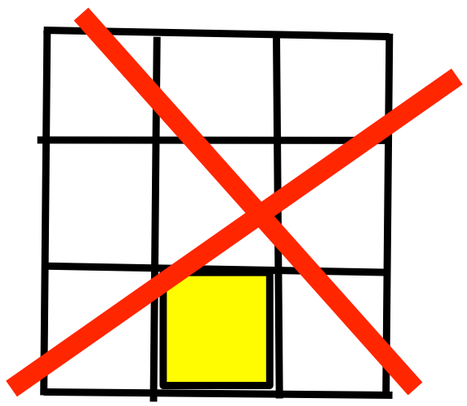
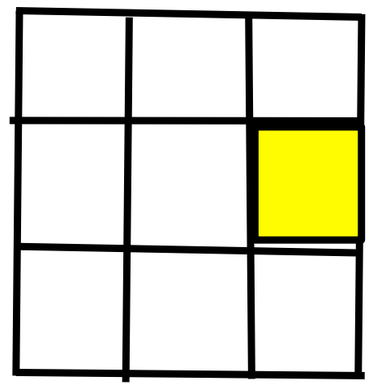


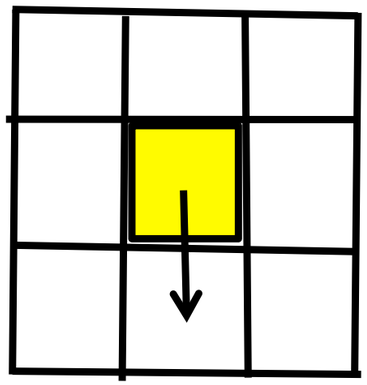


or



NetBioDyn : 2nd example, sandglass

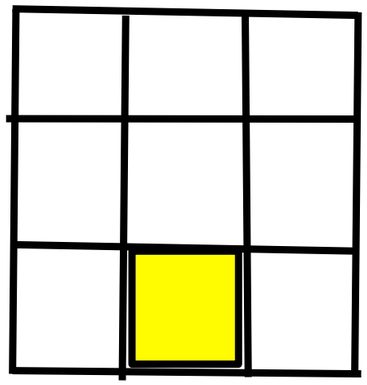
➔Entities: grain ■ and border ■

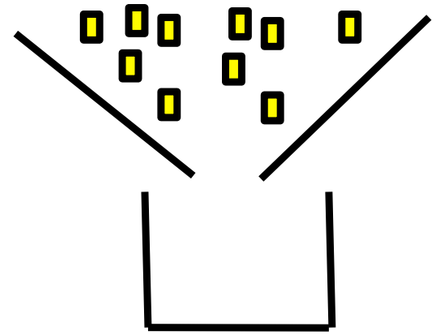


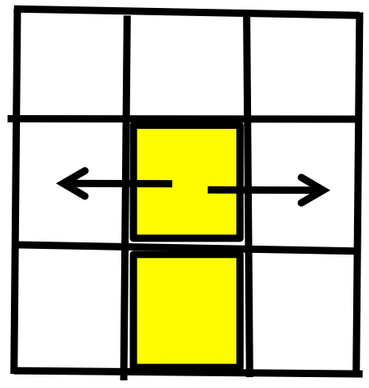
Go_Down

➔

P=1



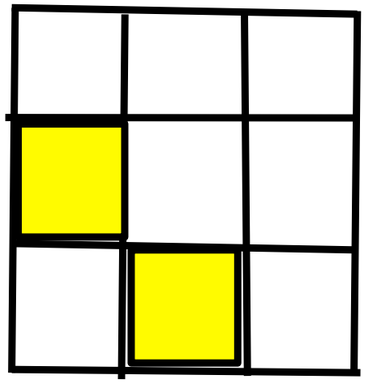




Go_LeftRight

➔

P=0.5



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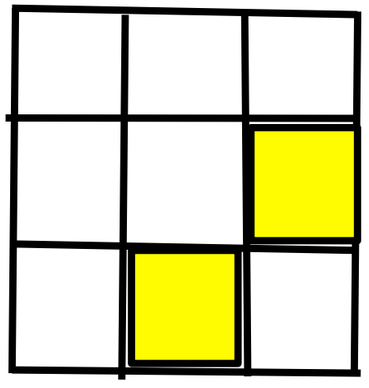
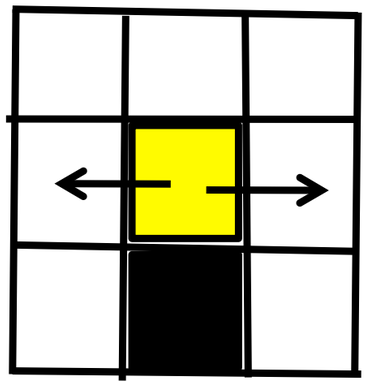
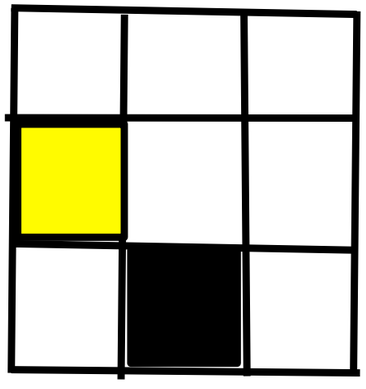




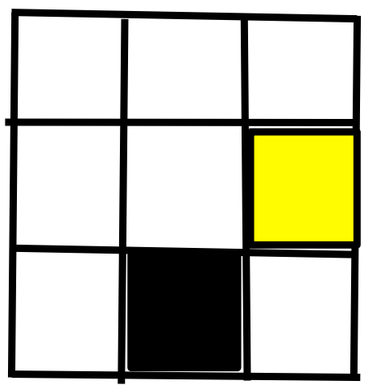
Go_Border

➔

P=0.75



or

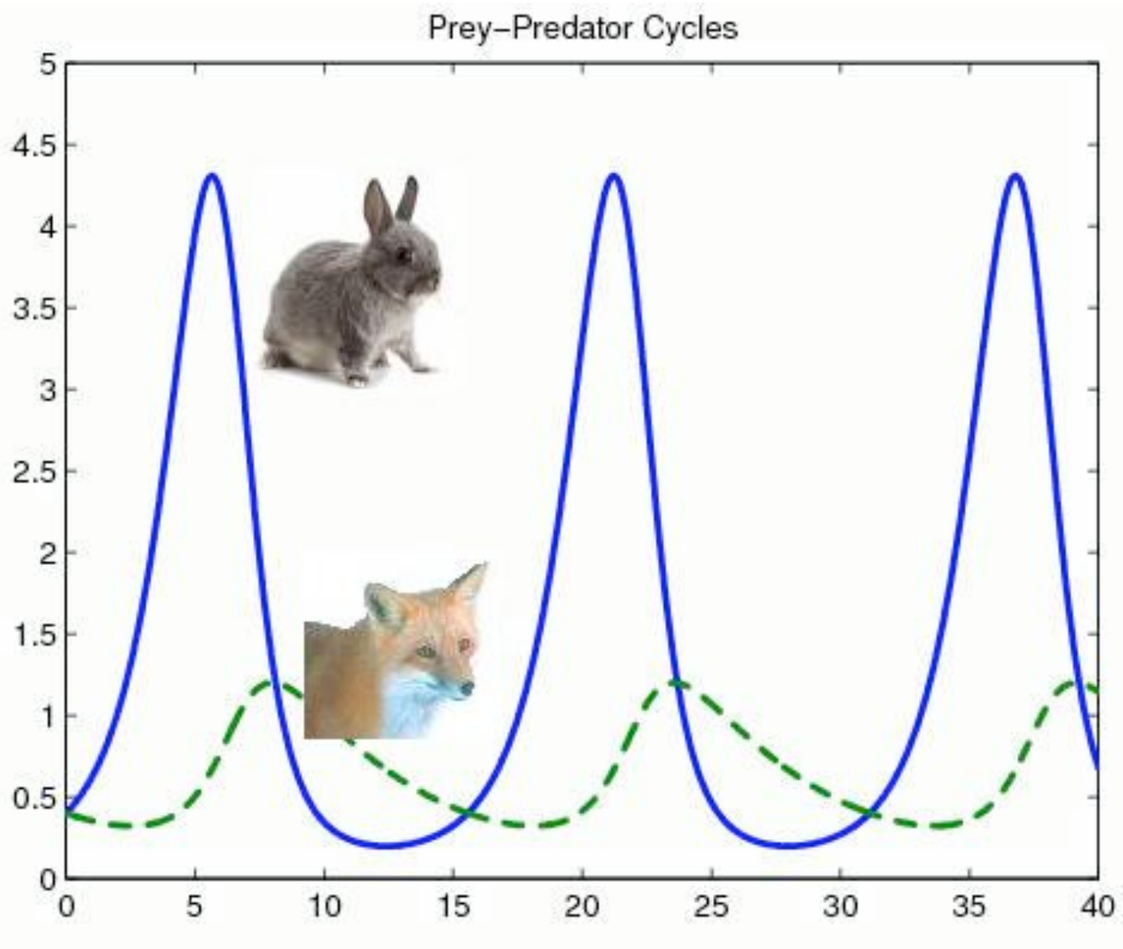


NetBioDyn : 3rd example, prey-predator

➔Entities: prey and predator

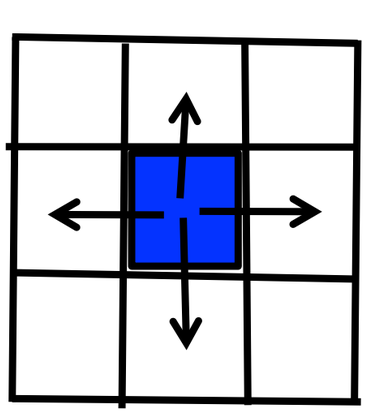
Prey ½ life time : 2000 cycles + **Rd_Walk**

Predator ½ life time : 200 cycles + **Rd_Walk**



NetBioDyn : 3rd example, prey-predator

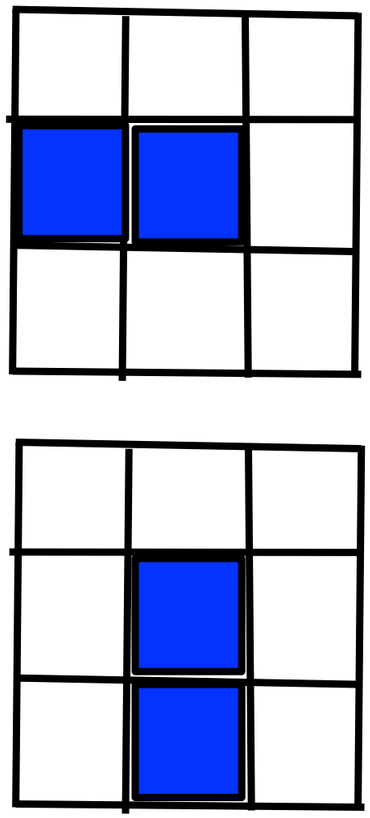
➔Entities: prey ■ and predator ■



Prey_Birth

➔

P=0.01



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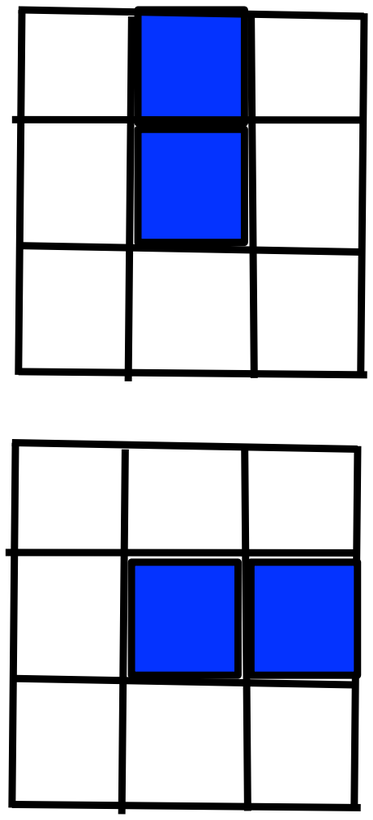


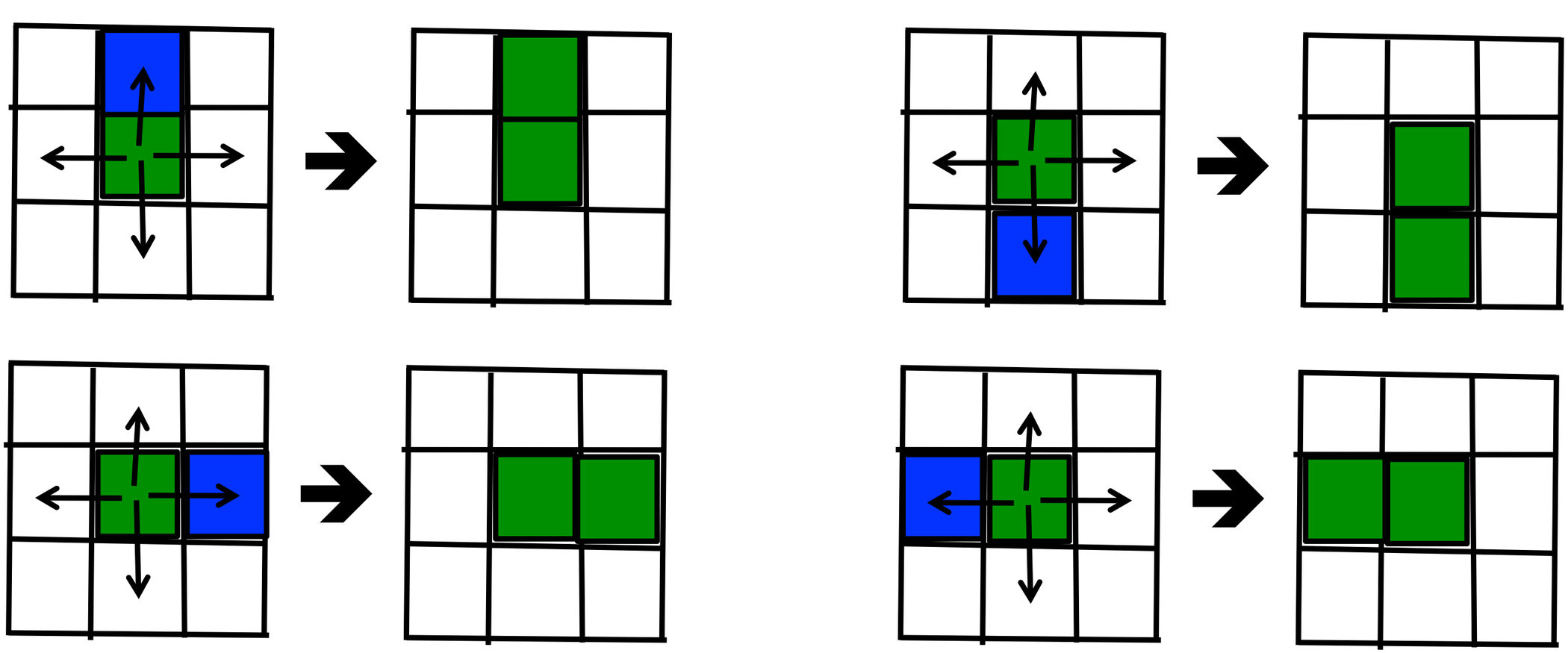
NetBioDyn : 3rd example, prey-predator

➔Entities: prey and predator

Predator_Prey

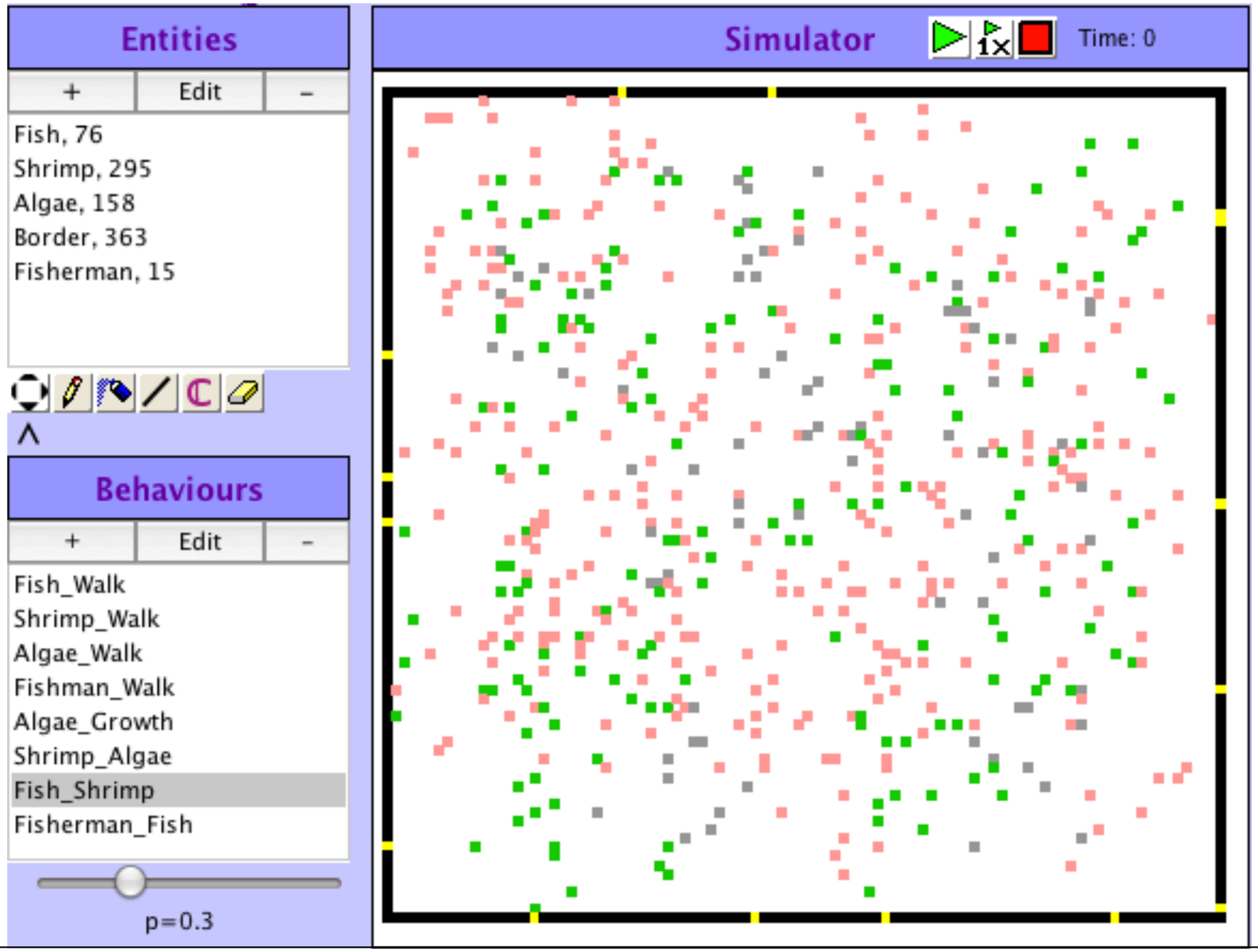
➔

P=0.6



NetBioDyn : 4th example, fish farm

➔Entities: fish , shrimp , algae , fisherman , border



NetBioDyn : 4th example, fish farm

➔Entities: fish , shrimp , algae , fisherman , border

Entities :

Fish:	1/2 Life = 150.0
Shrimp:	1/2 Life = 200.0
Algae:	1/2 Life = infinite
Border:	1/2 Life = infinite
Fisherman:	1/2 Life = infinite

Behaviors :

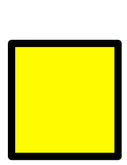
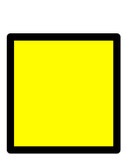
Fish_Walk :	p=1.0, Fish + 0 + *	➔ 0 + Fish + *
Shrimp_Walk :	p=1.0, Shrimp + 0 + *	➔ 0 + Shrimp + *
Algae_Walk :	p=0.3, Algae + 0 + *	➔ 0 + Algae + *
Fishman_Walk :	p=0.1, Fisherman + Border + *	➔ Border + Fisherman + *
Algae_Growth :	p=0.02, Algae + 0 + *	➔ Algae + Algae + *
Shrimp_Algae :	p=0.6, Shrimp + Algae + *	➔ Shrimp + Shrimp + *
Fish_Shrimp :	p=0.3, Fish + Shrimp + *	➔ Fish + Fish + *
Fisherman_Fish :	p=1.0, Fisherman + Fish + *	➔ Fisherman + + *

Road map

- ☑ Multi-Agents Systems (MAS)
- ☑ From Biological environment simulation
- ☑ Towards Ecosystems simulation
- ☑ NetBioDyn software
- ❑ Conclusions and futur works

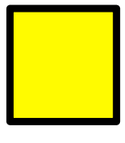
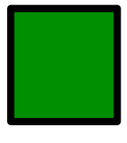
NetBioDyn : Conclusion

➢ **Advantage:** ➔ **very simple (entities, rules)**
➔ **no programming !**

Example:  **+ Ø ➔ Ø +**  **(movement)**

……

➢ **Drawback:** ➔ **very simple (entities, rules)**
➔ **no entity's state !**

Example:  **+ * ➔**  **+ * (new entity's state)**

…… ➔ **new entity !**

NetBioDyn : futur works

- **Self-ajusting parameters…**

  ➔ **a great challenge !**

- **Entity's state (simply an integer)…**

  ➔ **Building a model would be simpler by minimizing the nb of « different » entities**

Road map

- ☑ Multi-Agents Systems (MAS)
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- ☑ Towards Ecosystems simulation
- ☑ NetBioDyn software
- ☑ Conclusions and futur works