Tentative delineation of an agent-based project for vertical integration of multi-scale knowledge

A case study on small rodents hosts and their parasites bio-ecology.

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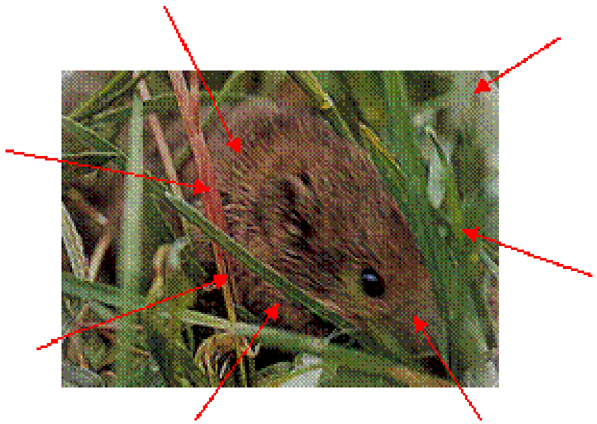
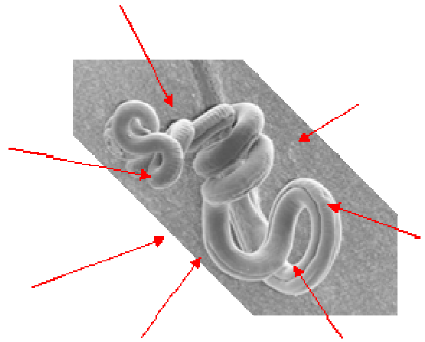
1. Context

Purpose: knowledge integration

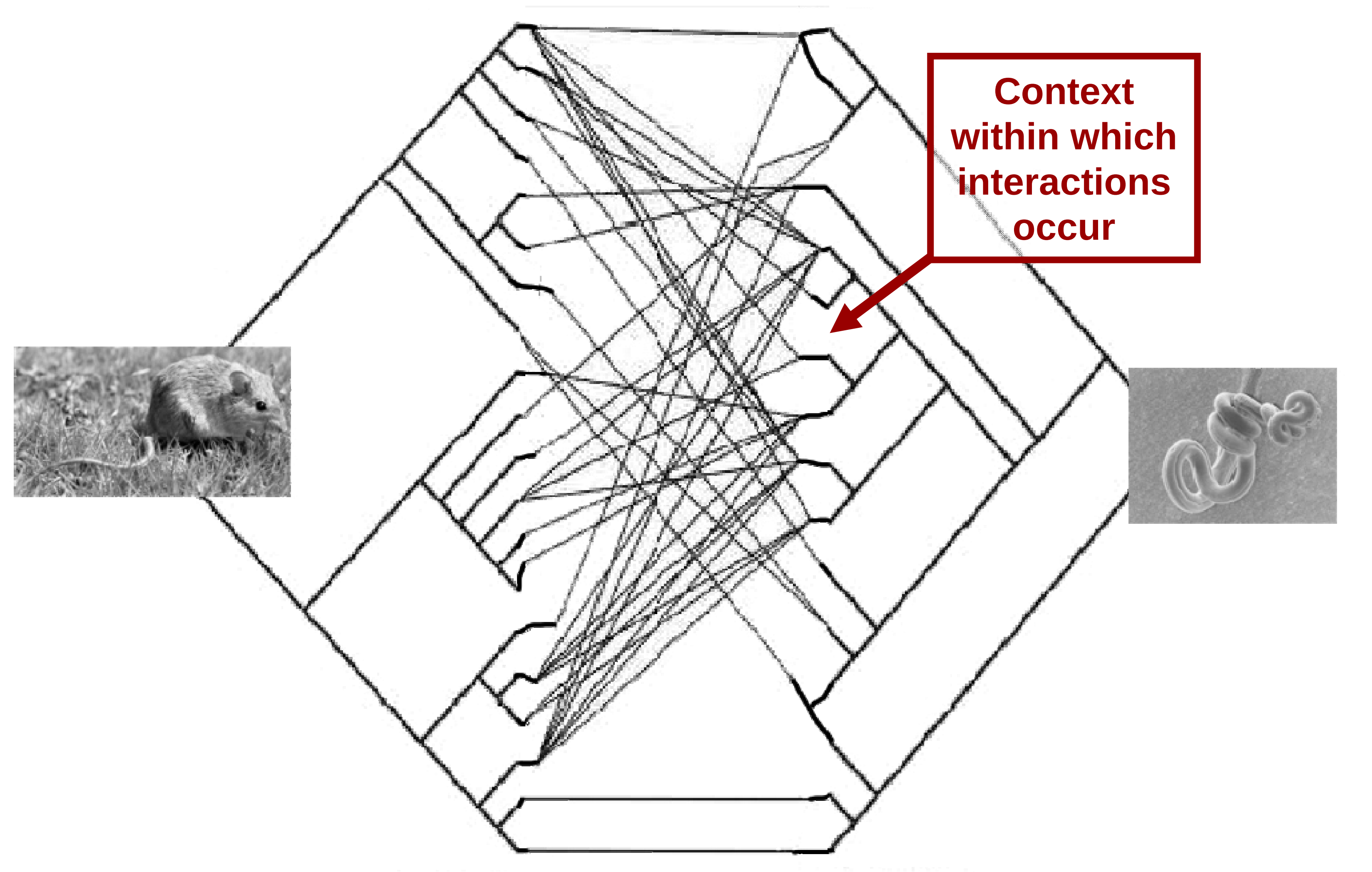
- Research on small rodents hosts and their parasites is composite:
  - multi-fields, multi-scale, multi-purpose





  - Clear ranking of underlying causes (Broëckling et al., 2006) may be under debate
  - Making a global picture would disentangle the field's complexity

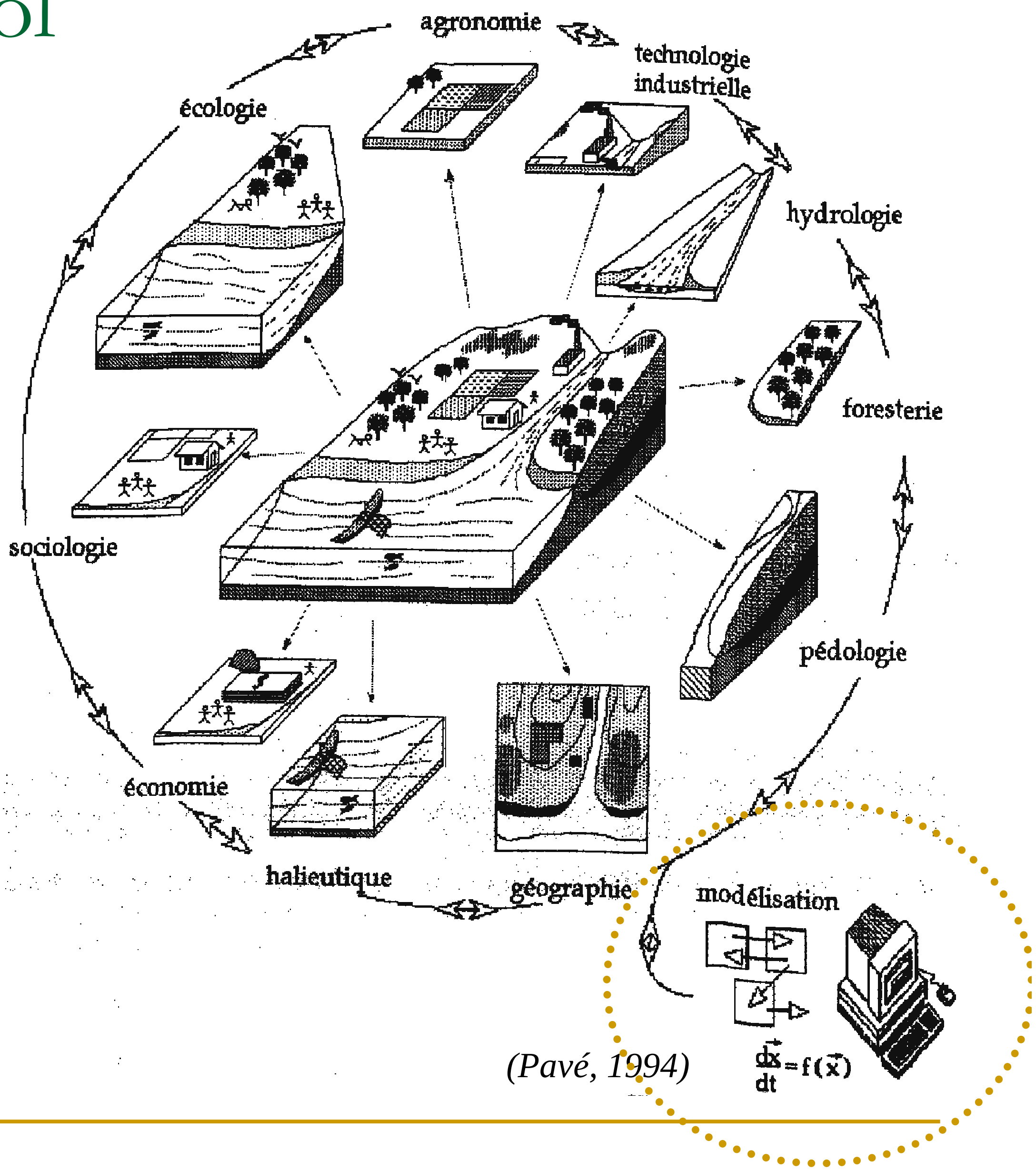
How to progress toward a global picture ?



Aim: integration tool

- Develop a framework devoted to the integrative articulation of knowledge on this field (example on coastal management)

- Model structure considered as :
  - a medium for exchange of disciplinary knowledge
  - canvas for field integration

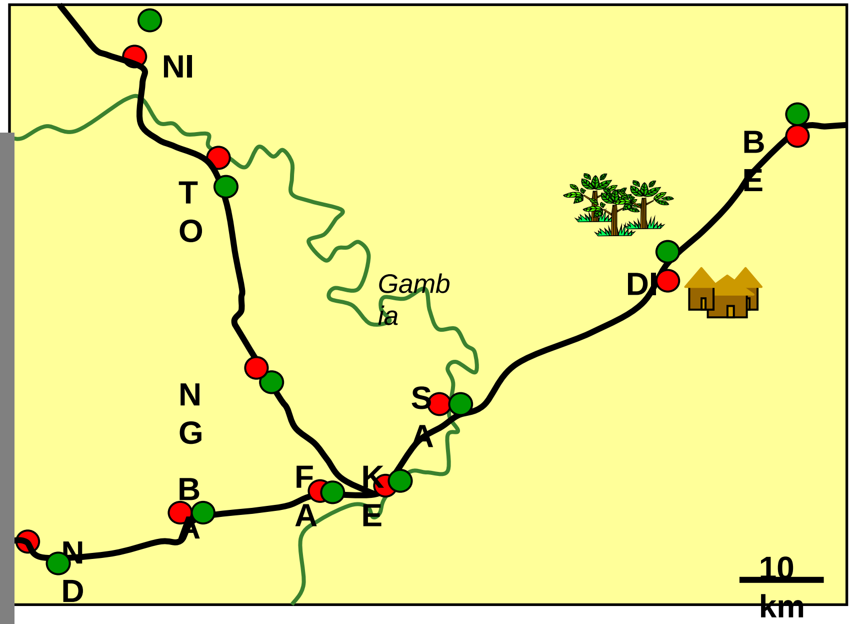


(Pavé, 1994)

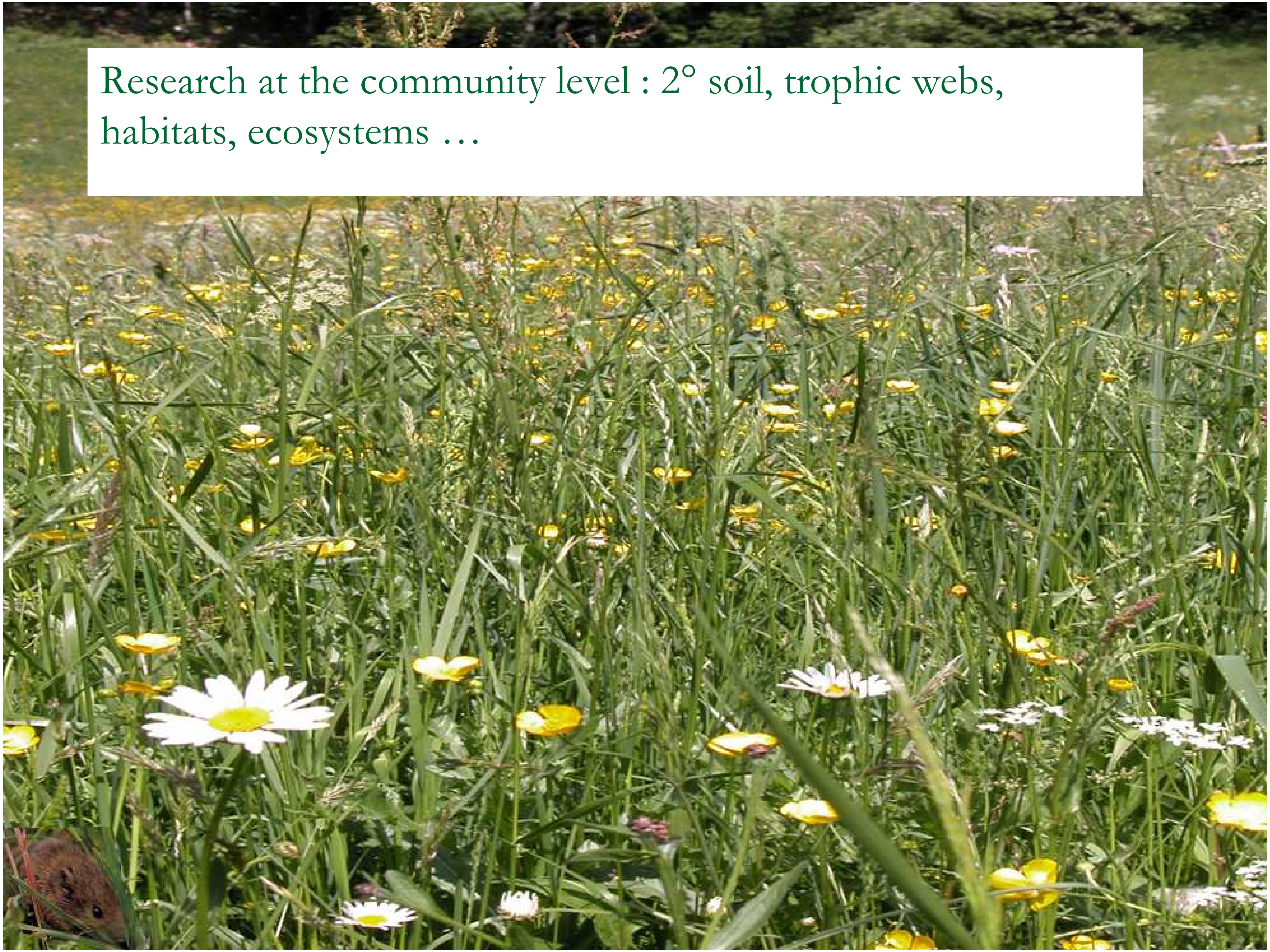
2. Field overview

(just snapshots)

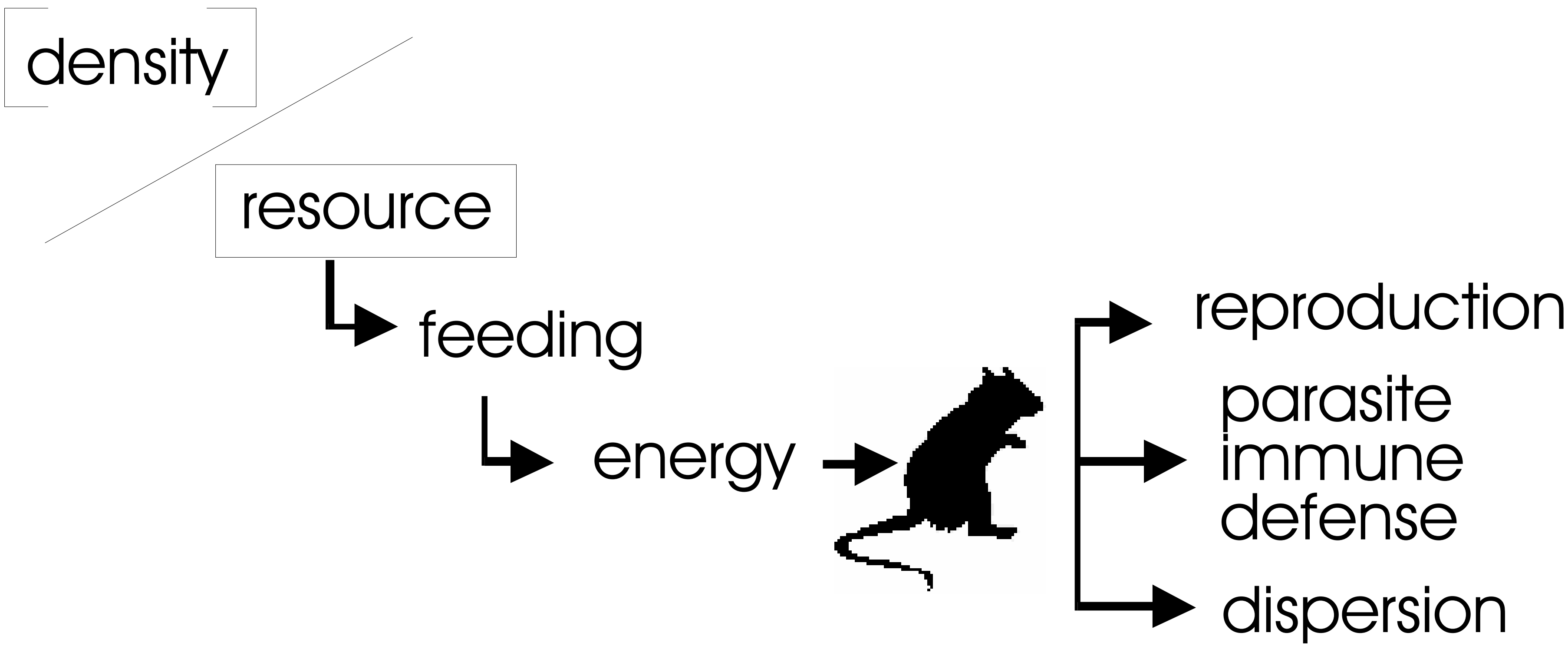
Research at the population level : 1° biotopes, ecotones



Research at the community level : 2° soil, trophic webs, habitats, ecosystems …

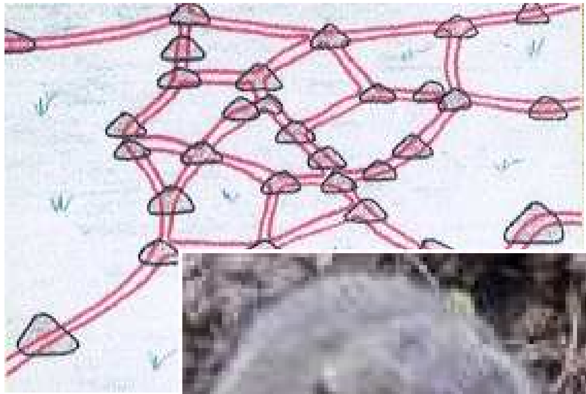


Research at the individual level: 3° eco-physiology & trade offs approach

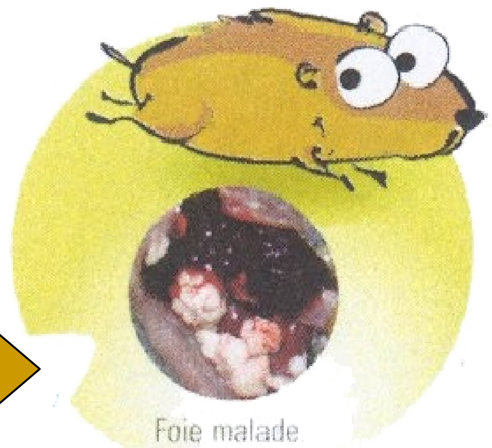


Research at the inter-individual level: 4° host-parasite interaction

Burrow web

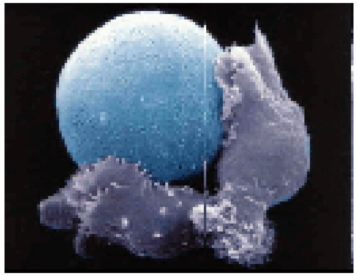


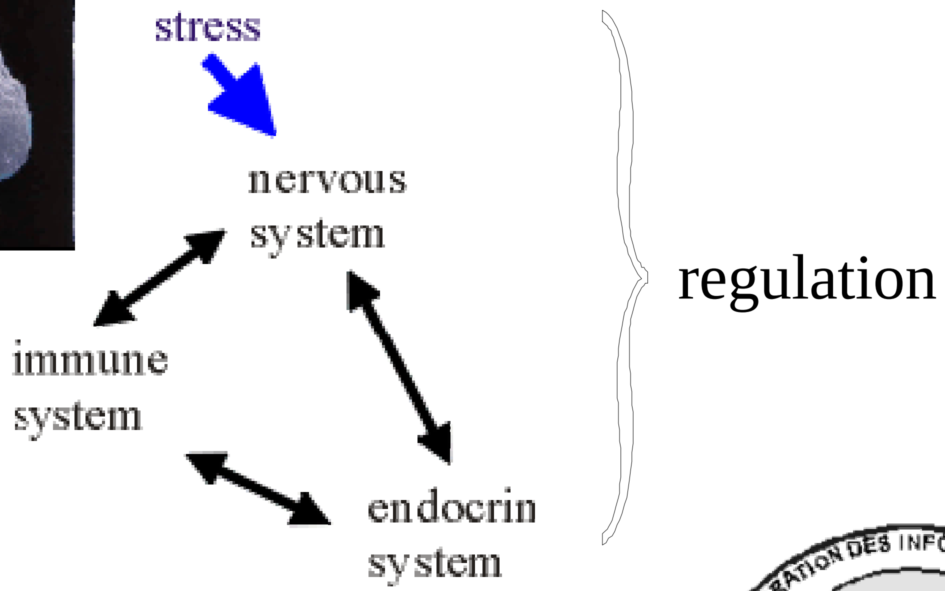
resources,
food, moves
reproduction

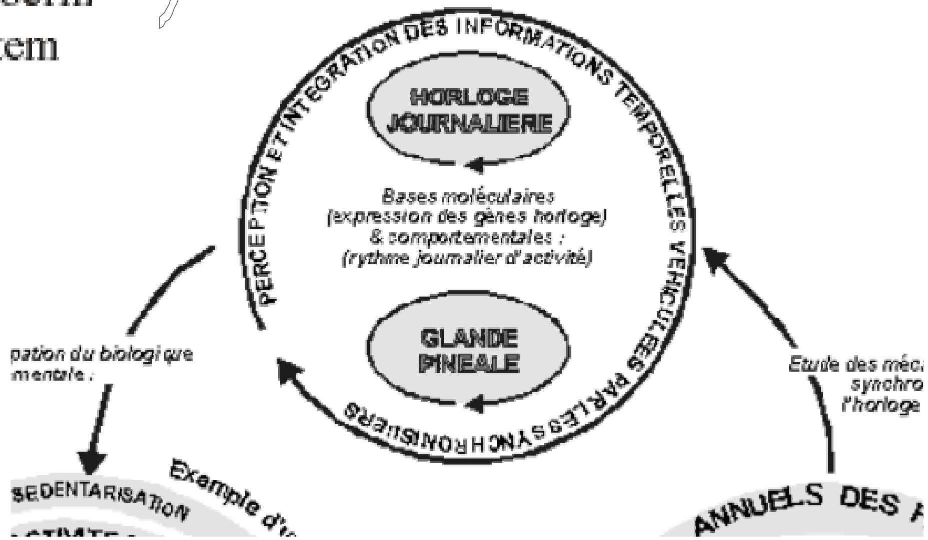


sick liver

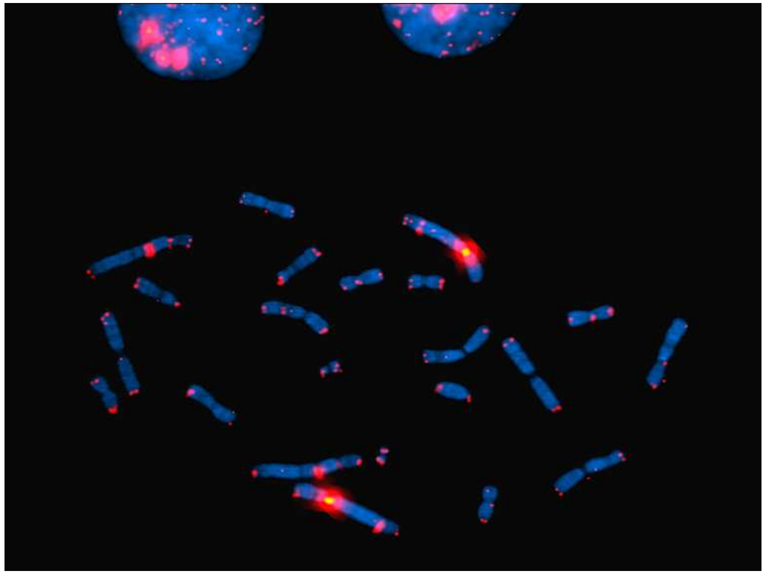
Research at the inner-individual level: 5° relationships physiology - immunocompetency – behavior



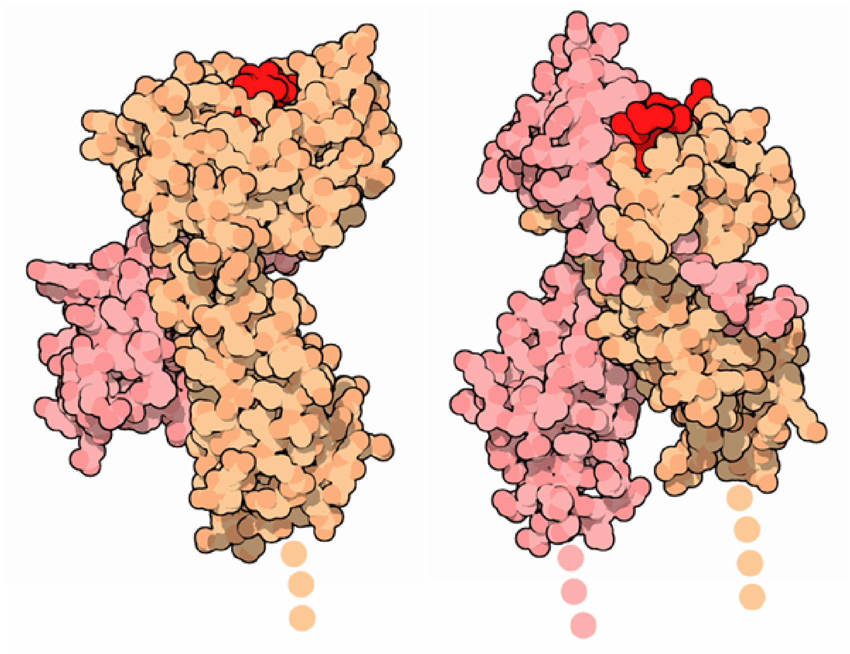




Research at the sub-cellular level: 6° cytogenetics and genetics

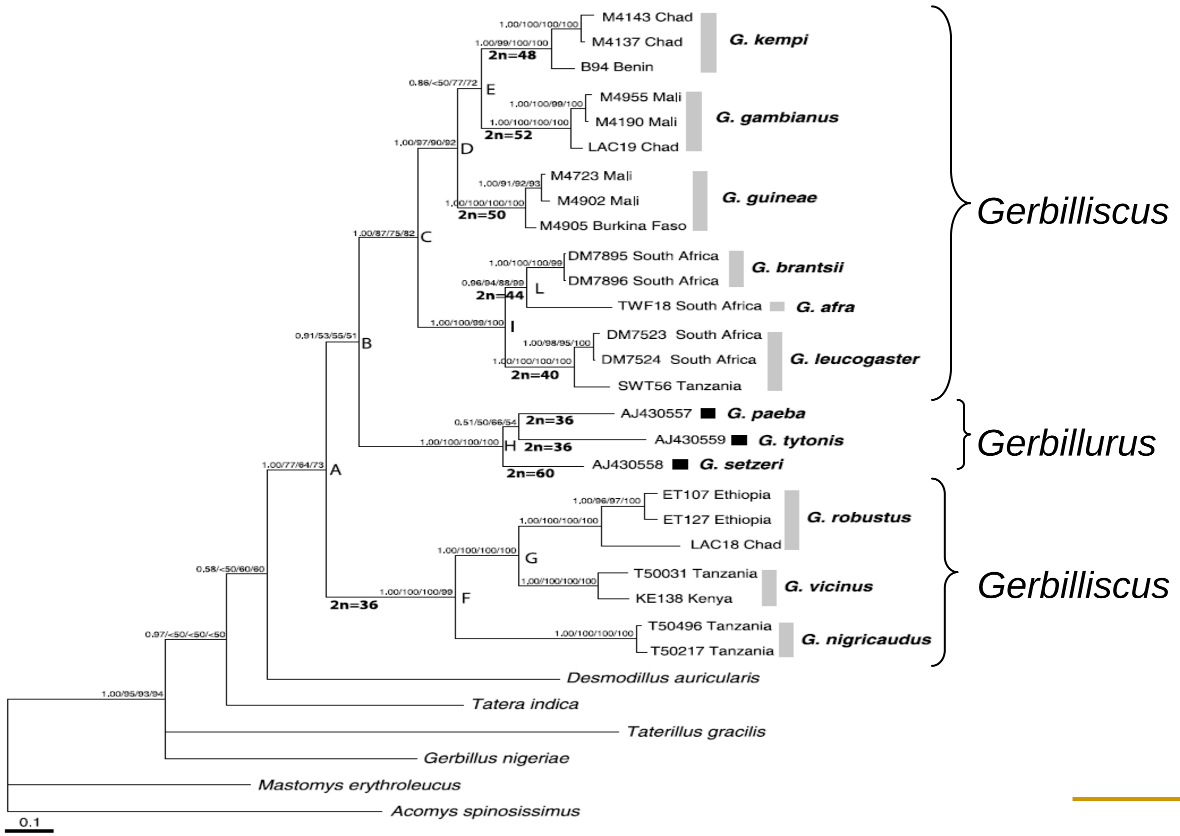


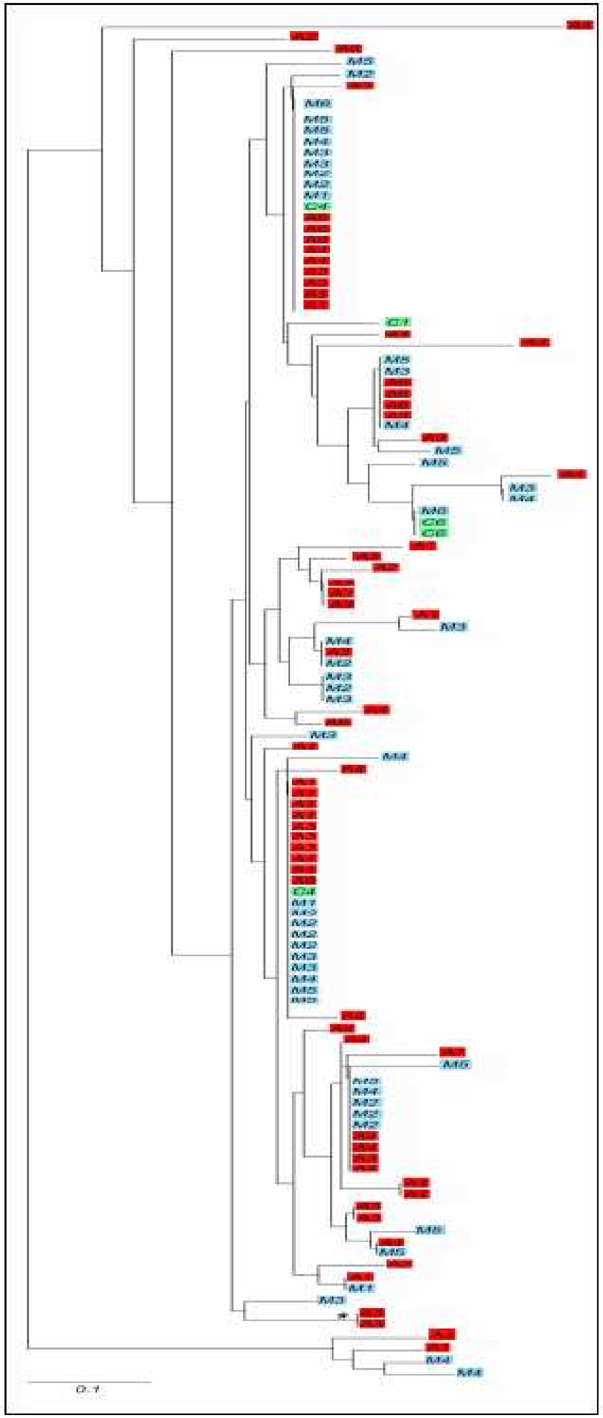
Chromosome hybridation



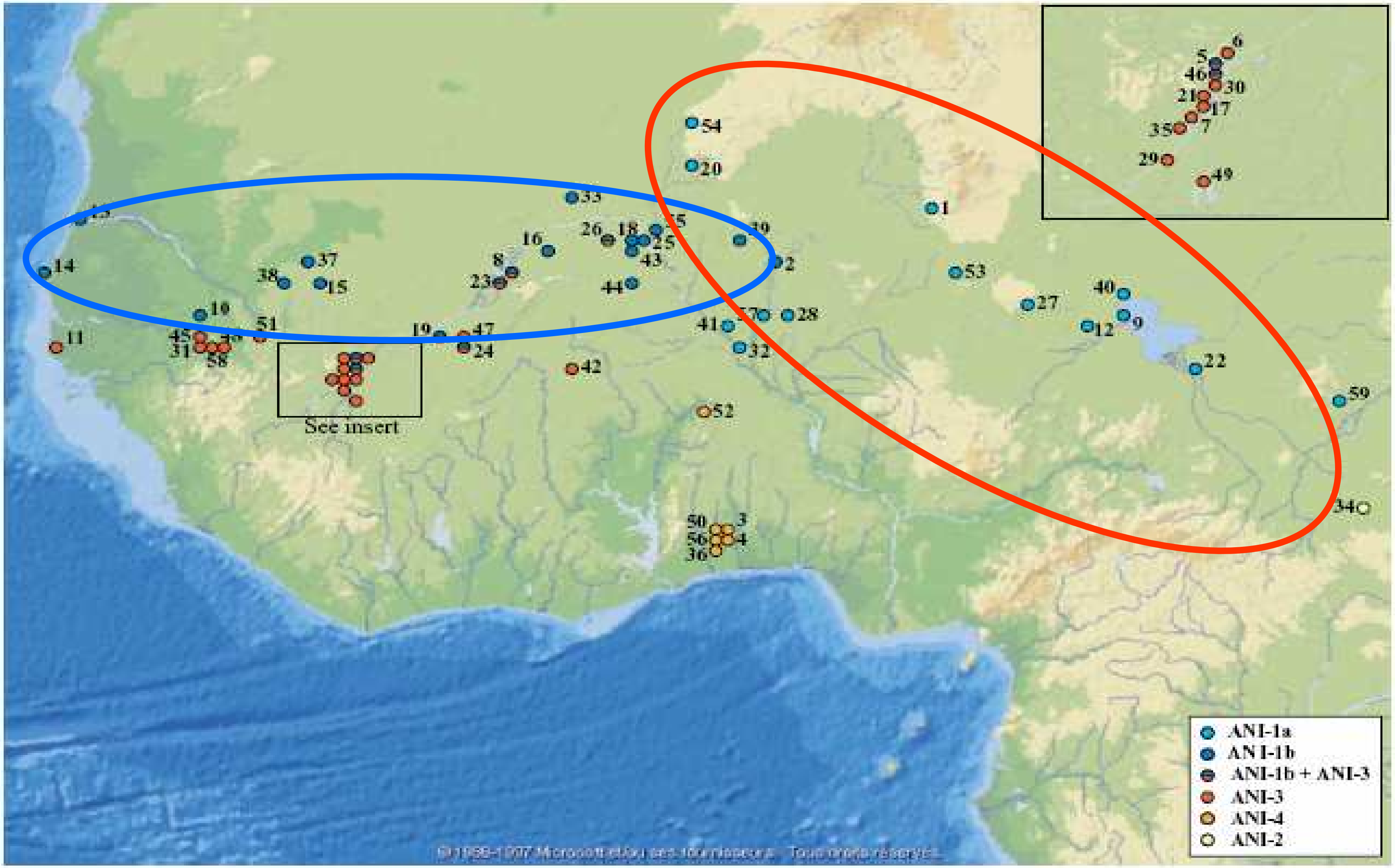
MHC – gene complex

Research at the sub-cellular level: 7° phylogeny & co-evolution host-parasites





Research at the clade level: 8° co-evolution/co-adaptation



Volobouev et al., 2001

Summary set of research scales

- Clade
- Population
- Community
- Inter-individual
- Individual
- Inner-individual
- Sub-cellular

<u>Question</u>:
on what formal
basis establishing
a core
framework ?

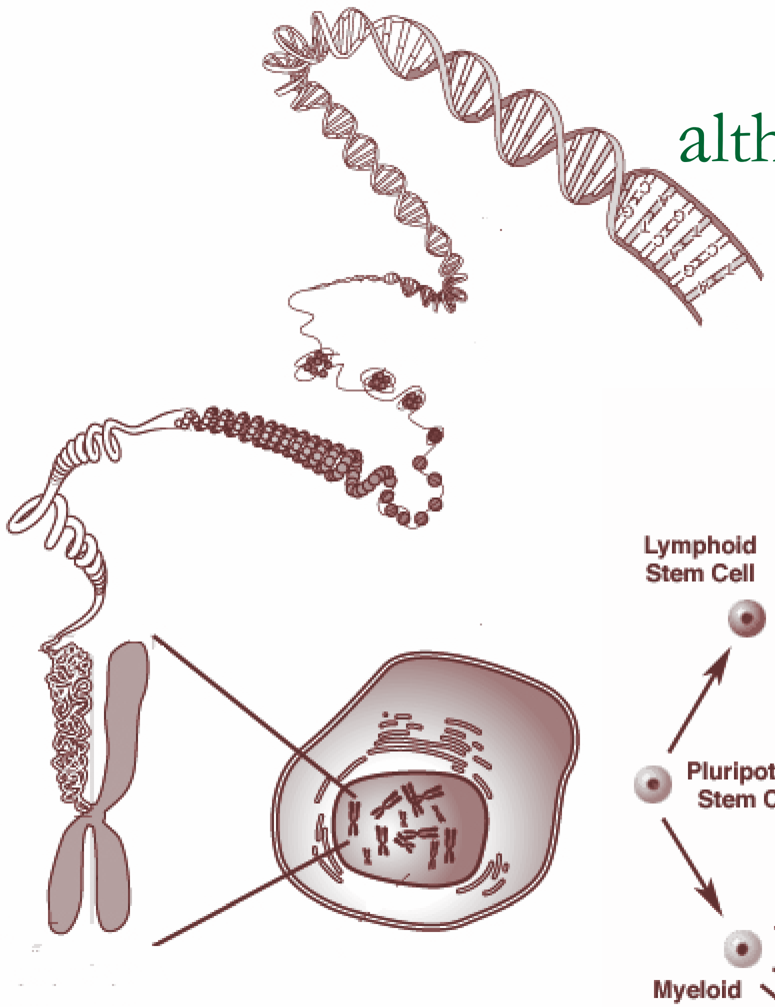
3. Challenges bound to the formalization,

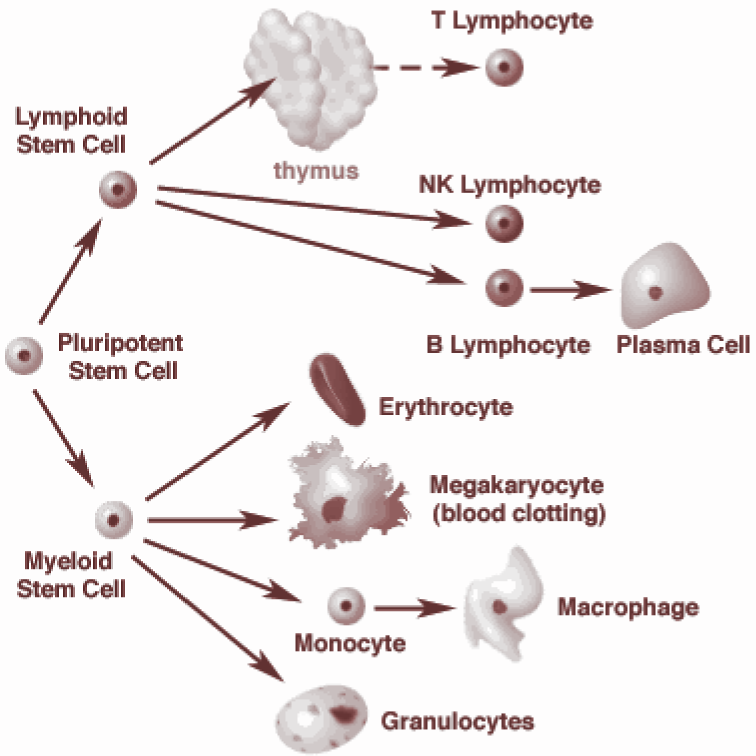
and lines of thought for the implementation

1. Problems regarding scales
2. Generic/compatible formalization

Problem regarding functional scales : one cannot formalize all levels

although the hierarchy appears to be a continuum





etc.

Compromising on functional scales

- Hierarchy theory → nearly decomposable system (Simon, 1962) or holons (Koestler, 1968)
- Pros:
  - Focus on discrete hierarchical level, favors a gradual accretion of the domain aspects
  - Based on the scientist interests : case studies
- Cons:
  - Do not permit to catch the continuous emergence, miss the interplay of feedback processes across several integration levels (Broëckling et al., 2006)

Problems regarding temporal scale …

(how to deal with a wide range of…)

The model simulates the environmental conditions over one year. One day is simulated each month, with the assumption that this day is representative of the whole month. The calculated growth during one day is then scaled to get monthly development. Other variables are scaled in a similar fashion. This procedure is followed to keep simulation time within reasonable limits. Each day is divided into 5-min intervals so that short-term behavior can also be studied.

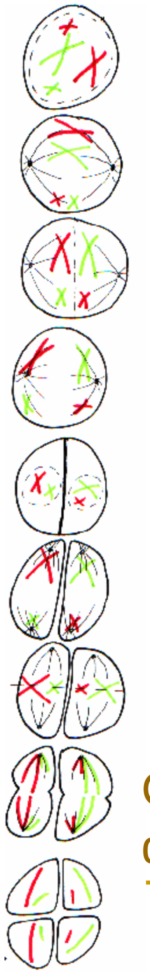
Strand E, Huse G, Giske J. (2002) Artificial evolution of life history and behavior. The American Naturalist 159:624-644

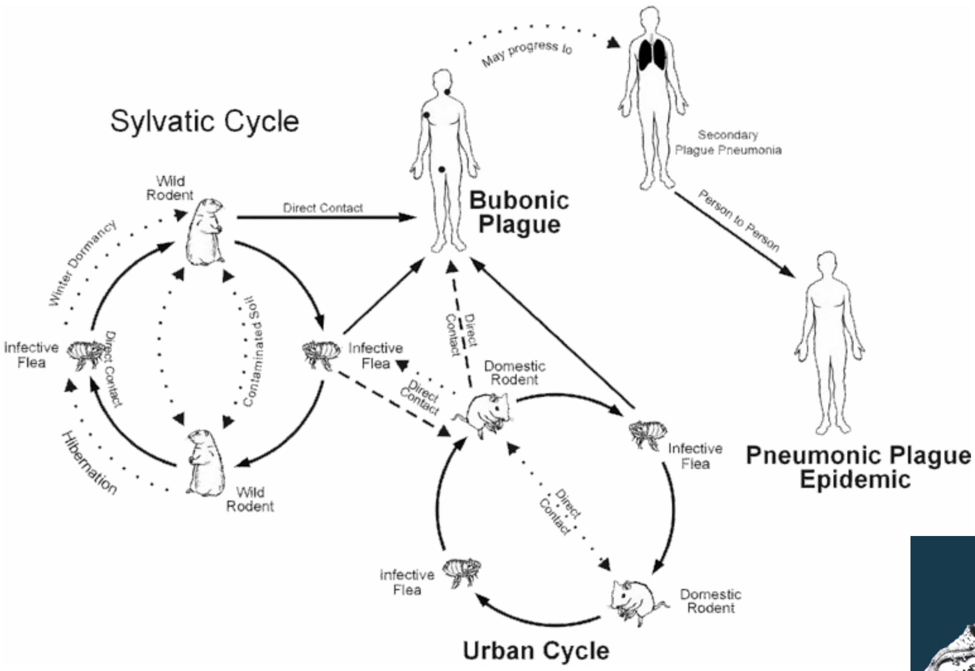
… and Spatial scale:

(hope) there also exist identical formal artifices to account for great ranges of spatial scales…

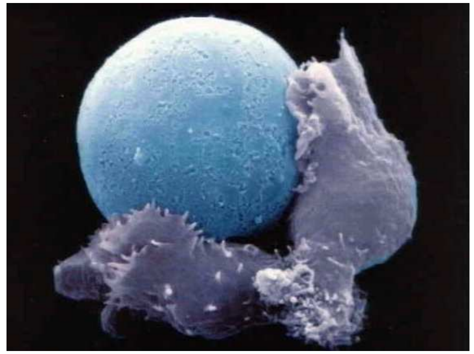
Problem regarding generic/compatible formalization

The framework should have to potentially formalize all significant processes: heterogeneous mechanisms



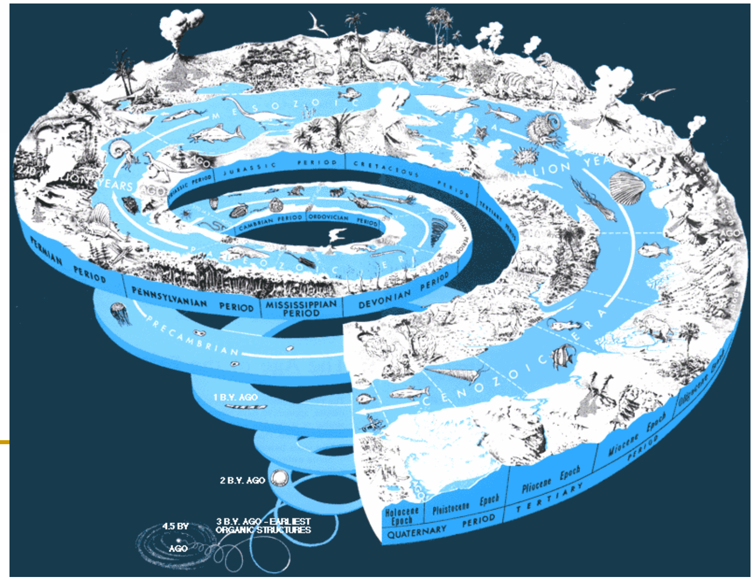


Epidemic diagnosis



Immune reaction

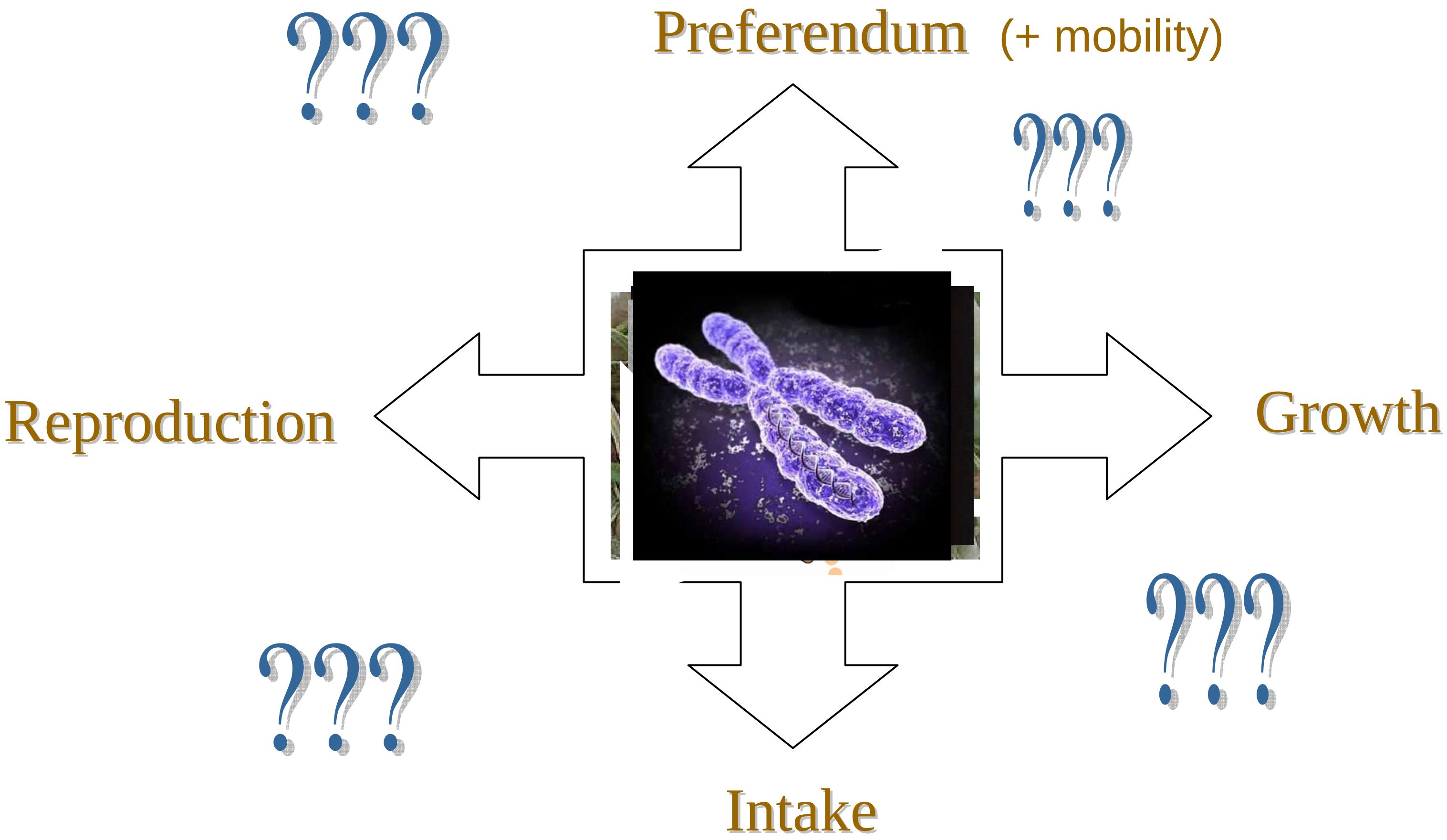
Cell division



→ search for common primitives

Species evolution

A.- Search for common primitives inspired from life science: species survival example



Nb: DeAngelis & Mooij, 2005: dispersal, reproduction, survival

B. Search for common primitives inspired from experts knowledge

→ Elicitation of the scientists expertise to determine the questions' range

Modeling protocol :

1. **Documentation**
2. **Interaction (consultation)**
3. **Elicitation**
4. **Reification**
5. **Articulation (types consolidation)**
6. **Formalization**

Interviews of the theme scientists

Given a limited quantity of resources there are …

Each item may be a source for formalization (⇔ data sets)

biological, physiological traits.

We indeed would like to establish the relationship between a gene expression and the organism response. In fact it is not reachable in the field, we cannot assess the relationship.

2.2.3 Eco-physiology

- Stress plays a role on immune-competency, the ability to resist to an infection.
- Notion of physiological trade-offs: the more you reproduce the less you have got energy to fight against parasites.
- Given a limited quantity of resource, there are physiological compromises between reproduction, search for resource, ability to resist to infestation. This last is associated with survival, they are balanced with reproduction. The more you reproduce, the less you can survive longer (since reproduction has a cost).

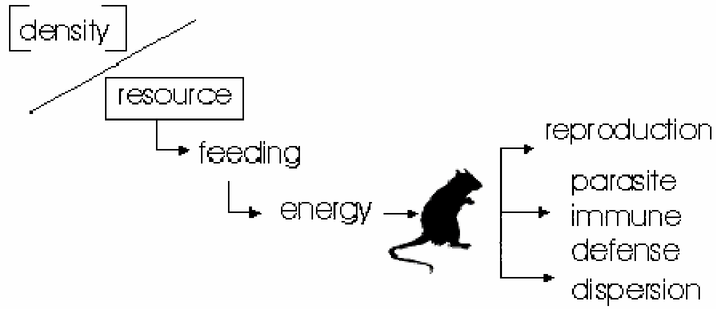


Figure 1: eco-physiology and trade-offs approach: density is the mean used to estimate resource, the source of energy, levels. Energy is shared by the organism between three main functions.

2.2.4 Two kind of host-parasites dynamics

1. In a stressing environment, organism will have a tendency to invest into reproduction, less into immune defence which will give the opportunity to opportunist parasites to infest the host.
2. In a heavy parasitism pressure context, parasites will be at the origin of the event cascade and one can imagine a prevailing selection of the individuals which have a good response to the parasite.

Measuring reproduction is nevertheless not accessible *in situ* (nesting occurs in burrows), derived parameters are thus used such as **density which influences the amount of resource available**[3] (the more density the less resource available by individual).

The energetic cost bound to immune defense consists in maintaining the organ of immunity and developing an immune response (elaborating molecules, physiology). There can be also time spend to remove fleas, etc.

2.2.5 Combining disciplines

Phylogeny is at a different scale compared to eco-physiology, whereas with phylogeography there is a kind of continuum since there intervene the same forces that population genetics but expressed at a larger scale.

[3] NB: H_0

Reification of the scientist discourse and stepwise elaboration of the knowledge types

Significant Item identified by the scientist

*meta*type deduced

1.2 DISCIPLINE

1.2.Eco-physiology
1.2.eco-immunology
1.2.Population_genetics
1.2.Parasitology
1.2.*PHYLOGENY*

1.3 COUNTRY / LOCALIZATION

1.3.Jura
1.3.Transect_Drôme

1.4 SPATIAL SCALE / SPACE DESCRIBER

1.5 TEMPORAL SCALE / TIME DESCRIBER

1.5.The_shortest_time_scale_is_the_one_of_the_individual
1.5.Seasonal
1.5.Inter-annual_cycle
1.5.Species_history
1.5.Micro-evolutive_scale
1.5.Some_generations
1.5.Macro-evolutive_scale
1.5.*TIME*
1.5.*TEMPORAL*

1.6 OTHER SCALES (*eg*, FUNCTIONAL)

1.6.Intra-individual
1.6.Population
1.6.Species
1.6.*MICRO-EVOLUTIONARY*
1.6.*LOCAL*

1.7 BIOLOGICAL ENTITIES / TAXONOMIC GROUP

1.7.*ALLELE*
1.7.Arenavirus
1.7.Arvicolidae
1.7.Cestoda
1.7.adult

Resulting shared typology among the experts

1	field
2	discipline
3	country / localization
4	spatial scale / space describer
5	temporal scale
6	other scales (e.g., functional)
7	taxonomic group
8	method
9	tool
10	measure or indicator
11	concept / field component
12	phenomenon
13	process and phenomenon
14	property/ability
15	action or activity

Result : A scope of subjects distinct from the raw description of concrete items

C.- Search for common primitives inspired from complex systems science

1. The complex system's approach is mostly focused on the emergent high level patterns and phenomenon
   - Self-organization, adaptation,
   - Sensitivity to initial conditions, non linearity, far-from-equilibrium, phase transition, criticality
   - Emergent properties,
2. Restricted to a small (in fact parsimonious) set of necessary characteristics and underlying mechanisms
   - Items, diversity of items,
   - Items' interaction, feedback
   - Environment (open systems), internal and external factors,

note: maybe not enough to establish a true link between sub-systems

D.- Search for common primitives inspired from computer science: example from Breckling *et al.*, 2006

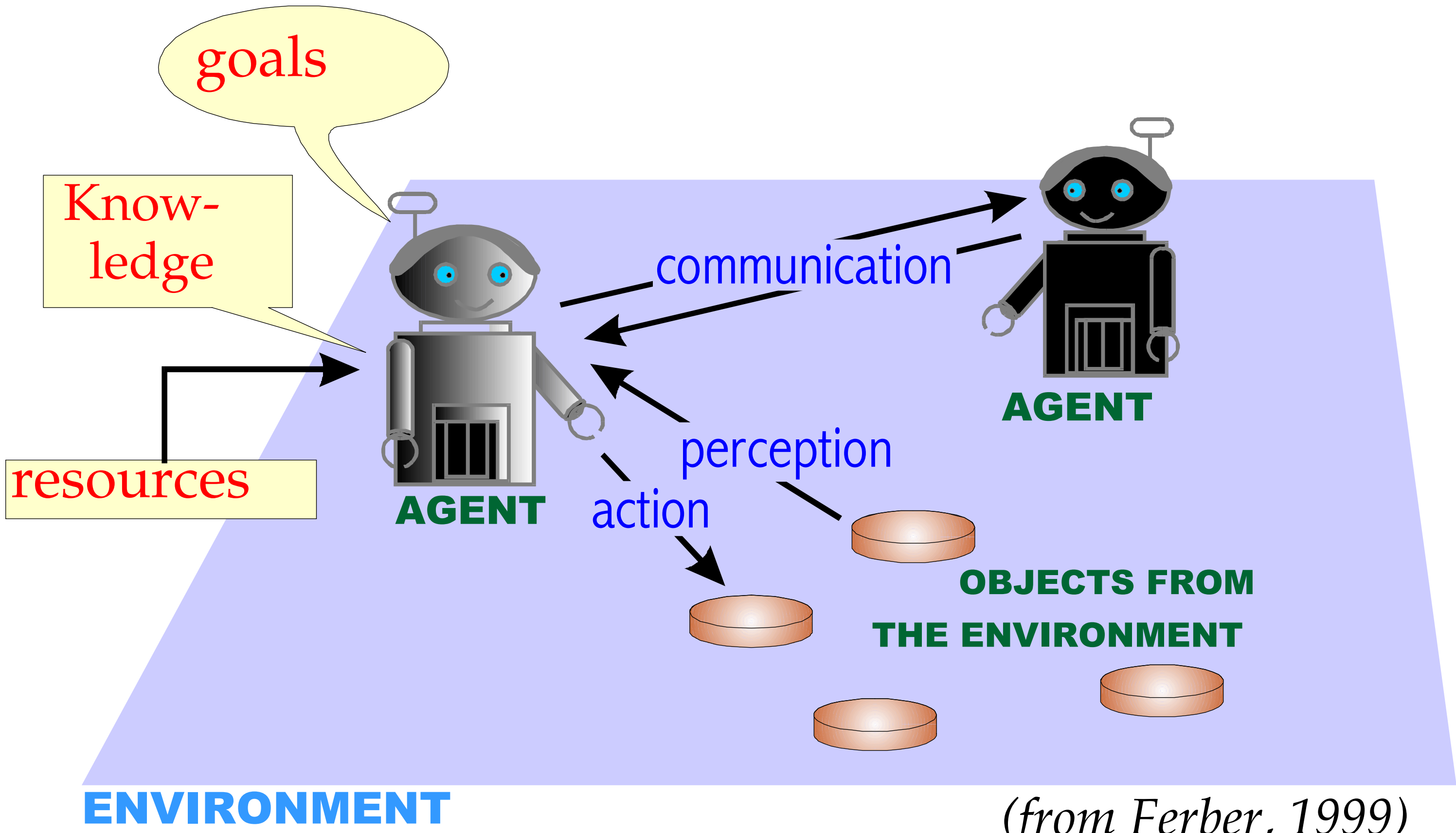
Computer agent →

```
Class Organism
    Declarations:
        Variables characterising individual state
            (e.g. location, biomass, age, alive)

        Activity Procedures („methods“) to update states
            (e.g. Movement, Growth, Reproduction)

    Life Loop:
        While alive do ...
            Apply (call) Activity Procedures
                (choose appropriate activity)
                (update variables)
            Hold [Delta t ]
                (i.e. detach this organism temporarily
                 to update others)
        End life loop
End organism
```

Fig. 1 – Basic object structure for the simulation of an individual.

note: risk of obtaining a patchwork of heterogeneous procedures for the natural aspects

D.- Search for common primitives inspired from computer science: the Multi-agent formalism



(from Ferber, 1999)

NB : generic formalism implicit within the IBM/ABM modeling scheme

Conclusion

- Choosing a generic formalization inspired from *(i)* life, *(ii)* scientific knowledge, *(iii)* complex system approach or *(iv)* computer science ?
- Each carries potentials and drawbacks
- The answer may be a hybrid or combination taking the best of the four worlds.
- But the question remains…