An Interdisciplinary Approach to Morphogenesis

C. Antelope, L. Hubatsch, J. Raimbault, J.M. Serna

July 7th 2016

A simple definition ?

Morphogenesis (*Oxford dictionary*)

1. *Biology* : The origin and development of morphological characteristics
2. *Geology* : The formation of landforms or other structures.

$\rightarrow$ *A well-defined notion ?*
... Or a scrambled-eggs basket ?

Research Question

[Bourgine and Lesne, 2010] : interdisciplinary workshop on morphogenesis

$\rightarrow$*To what extent the notion is indeed transdisciplinary, i.e. are there common definitions across disciplines ? What are the concepts shared or the divergence ?*

Method : Broad interdisciplinary review on its use or the use of related concepts ; extraction of fundamental concepts ; construction of a meta-framework

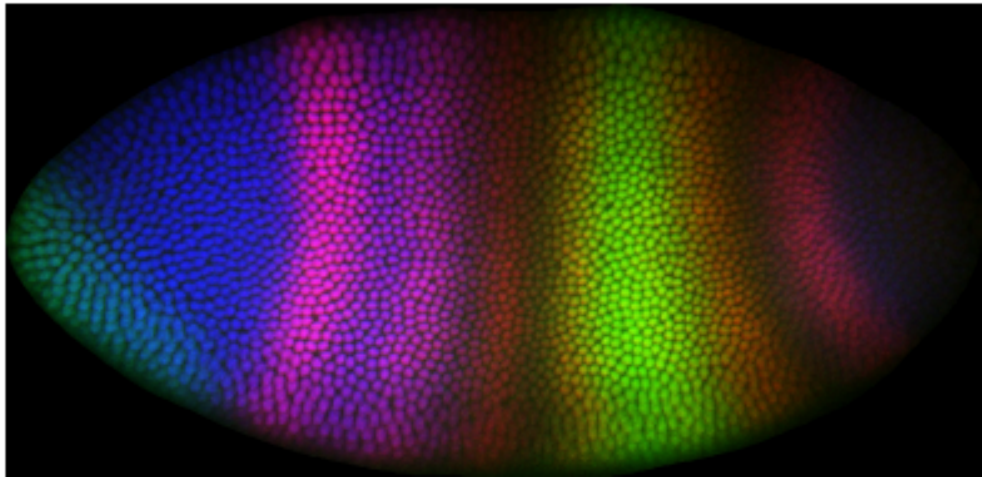
History of the notion

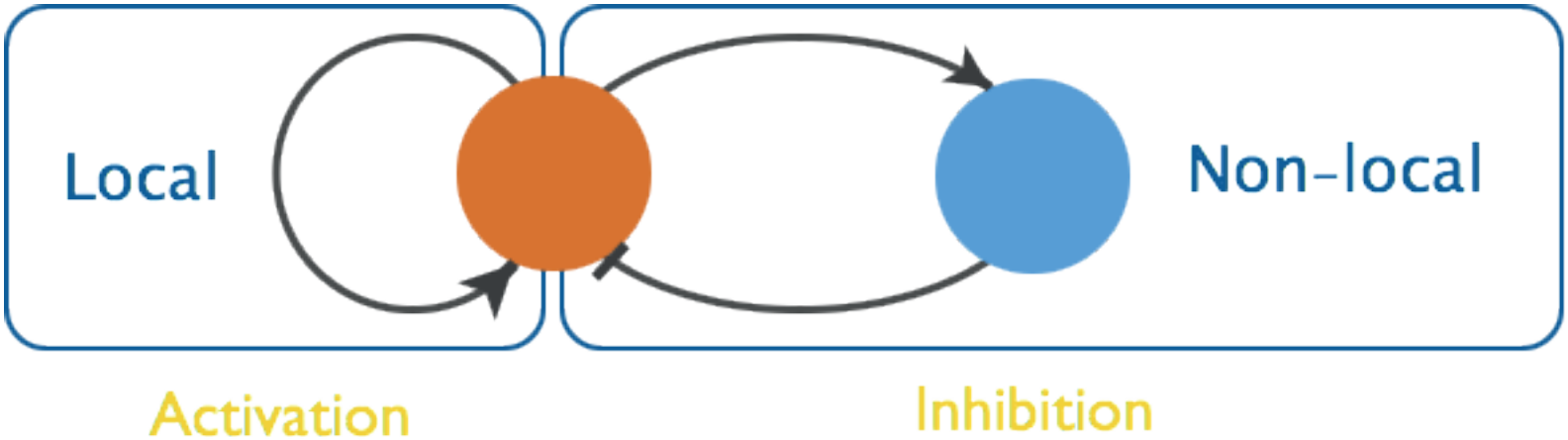
$\rightarrow$ Started significantly with embryology around 1930 [Abercrombie, 1977]

$\rightarrow$ Turing's 1952 paper [Turing, 1952], linked to the development of Cybernetics

$\rightarrow$ first use in 1871, large peak in usage between 1907-1909, increase until 1990, decrease until today. *Scientific fashion ?*

Example: Patterns arise during animal development?



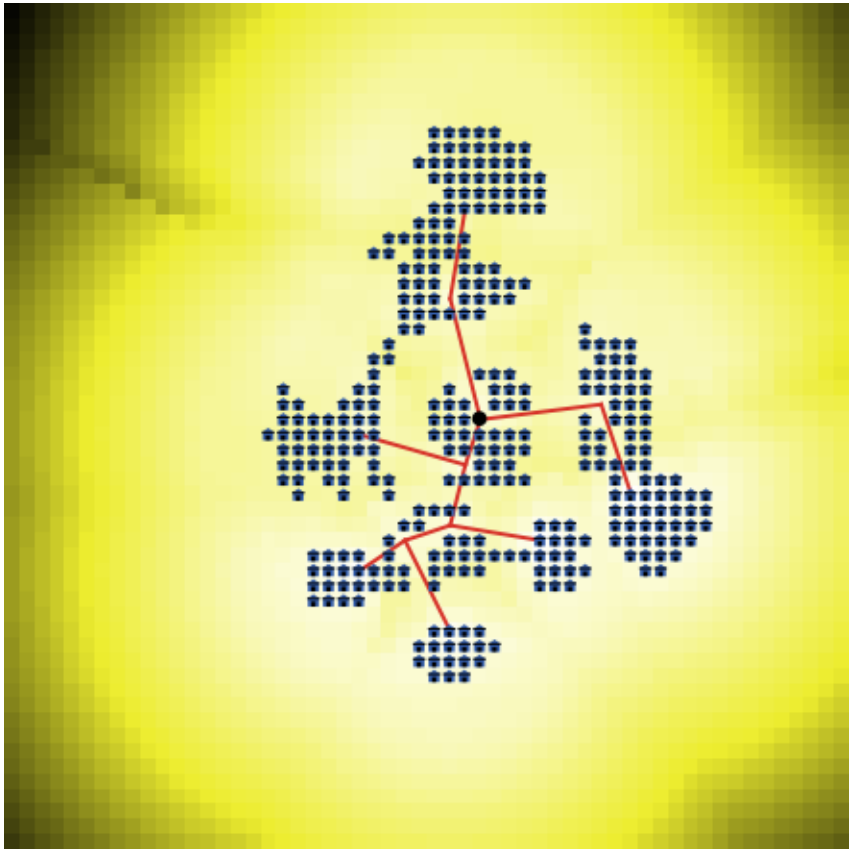


Example: Tissues change shape during animal development

Example : urban geography

Simple model of urban morphogenesis in [Raimbault et al., 2014]

$\rightarrow$ local interactions captured by density feedback
$\rightarrow$ global position captured by network centrality feedback and accessibility to amenities



Example : psychology

Even though Morphogenesis has been sparsely used as a useful metaphor to understand different processes in various psychological fields, it is nonetheless a very powerful metaphor to conceptualize social change and of the subject within it and processes like the relation to evolution of human cultural behavior and learning.
Neuroscience we have a plethora of morphogenetic phenomena related to the structure of the neural nets and hardware of the brain, and In Clinical psychology and psychopathology we have analogies to understand the emergence of psychical structures (Neurosis, Psychosis, etc) and the self-organization of relational forms (the self and the other), the formation of the symptom and of the transference-countertransference matrix. These structures form in early stages of development, but continue to repeat and influence behavior all throughout a subjects life.

Overview

- **Biology**
  - External phenotype morphogenesis (ant colony) [Minter et al., 2012]
  - Symbiosis of species [Chapman and Margulis, 1998]
  - Botany []
- **Social Sciences** : Archeology [Renfrew, 1978]
- **Epistemology** : [Gilbert, 2003]
- **Artificial Intelligence** : From self-assembly to Morphogenetic Engineering. Synthetic Biology ?
- **Geomorphology**
- etc. . .

Concepts

- **Morphogenesis and Self-Organisation** : when does a system exhibit an architecture ? Insights from Morphogenetic Engineering [Doursat et al., 2013]. Architecture : the relation between the form and the function ?
- **Scales, Units and Boundaries** From local interactions to global information flow (Holland's signal and boundaries [Holland, 2012]: morphogenesis as the development of Complex Adaptive Systems ?)
- **Symmetry and Bifurcations** : on quantitative becoming qualitative. René Thom's theory of catastrophes [Thom, 1974]

Framework Proposition

Perspectives

Systematize the framework : iterative construction
Algorithmic Literature Review and Text-mining

Conclusion

References I


Abercrombie, M. (1977).
Concepts in morphogenesis.
Proceedings of the Royal Society of London B: Biological Sciences, 199(1136):337–344.


Bourgine, P. and Lesne, A. (2010).
Morphogenesis: origins of patterns and shapes.
Springer Science & Business Media.


Chapman, M. J. and Margulis, L. (1998).
Morphogenesis by symbiogenesis.
International Microbiology, 1(4).


Doursat, R., Sayama, H., and Michel, O. (2013).
A review of morphogenetic engineering.
Natural Computing, 12(4):517–535.

References II


Gilbert, S. F. (2003).
The morphogenesis of evolutionary developmental biology.
International Journal of Developmental Biology, 47(7-8):467.


Holland, J. H. (2012).
Signals and boundaries: Building blocks for complex adaptive systems.
Mit Press.


Minter, N. J., Franks, N. R., and Brown, K. A. R. (2012).
Morphogenesis of an extended phenotype: four-dimensional ant nest architecture.
Journal of the Royal Society Interface, 9(68):586–595.

References III


Raimbault, J., Banos, A., and Doursat, R. (2014).
A hybrid network/grid model of urban morphogenesis and optimization.
In Proceedings of the 4th International Conference on Complex Systems and Applications (ICCSA 2014), pages 51–60.


Renfrew, C. (1978).
Trajectory discontinuity and morphogenesis: the implications of catastrophe theory for archaeology.
American Antiquity, pages 203–222.


Thom, R. (1974).
Stabilité structurelle et morphogénèse.
Poetics, 3(2):7–19.

References IV

Turing, A. M. (1952).
The chemical basis of morphogenesis.
Philosophical Transactions of the Royal Society of London B: Biological Sciences, 237(641):37–72.