

An Interdisciplinary Approach to Morphogenesis

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

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A simple definition ?

Morphogenesis (*Oxford dictionary*)

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

→ *A well-defined notion ?*

... *Or a scrambled-eggs basket ?*

Research Question

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

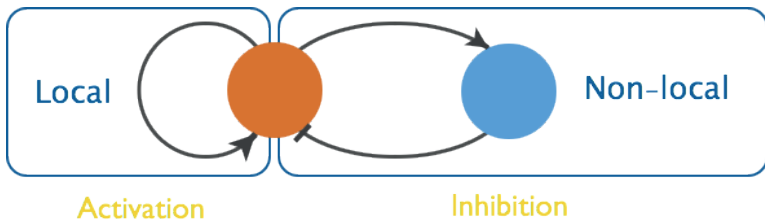
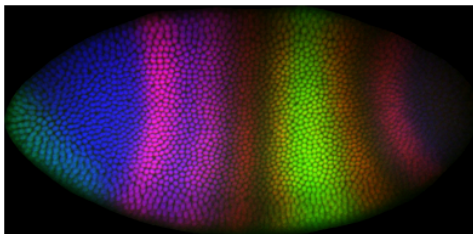
→ *To what extent the notion is indeed transdisciplinary, i.e. are there common definitions across disciplines ? What are the concepts shared or the divergence ?*

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

- Started significantly with embryology around 1930 [Abercrombie, 1977]
- Turing's 1952 paper [Turing, 1952], linked to the development of Cybernetics
- 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?

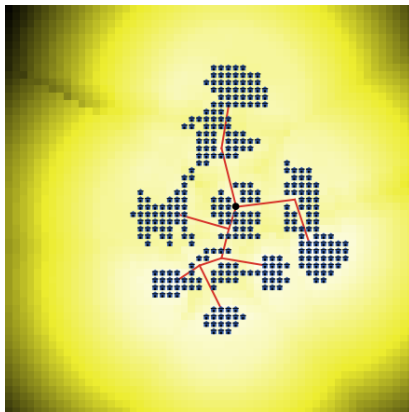


Example: Tissues change shape during animal development

Example : urban geography

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

- local interactions captured by density feedback
- global position captured by network centrality feedback and accessibility to amenities



Example : psychology

→ Metaphor to conceptualize social change and of the subject within it and processes like the relation to evolution of human cultural behavior and learning.

→ Morphogenetic phenomena related to the structure of the neural nets and hardware of the brain ; in Clinical psychology and psychopathology 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 [Lord, 1981]

- **Social Sciences** : Archeology [Renfrew, 1978]

- **Epistemology** : [Gilbert, 2003]

- **Artificial Intelligence** : From self-assembly to Morphogenetic Engineering [Doursat et al., 2013]. Synthetic Biology ?

- **Geomorphology** : dunes formation [Douady and Hersen, 2011]

- **Physics** : Arbotrons playing Tetris ?

- 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]
- **Life and Death** : autopoiesis, cognition

Framework Proposition

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Perspectives

- Systematize the framework : iterative construction ; systematic comparison / update of concepts
- Application to a concrete case to implement effective interdisciplinary transfer
- Algorithmic Literature Review and Text-mining

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).



Douady, S. and Hersen, P. (2011).

Dunes, the collective behaviour of wind and sand, or: Are dunes living beings?

In *Morphogenesis*, pages 107–118. Springer.

References II



Doursat, R., Sayama, H., and Michel, O. (2013).

A review of morphogenetic engineering.

[Natural Computing](#), 12(4):517–535.



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.



Lord, E. M. (1981).

Cleistogamy: a tool for the study of floral morphogenesis, function and evolution.

[The Botanical Review](#), 47(4):421–449.

References III



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.



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.

References IV



Thom, R. (1974).

Stabilité structurelle et morphogénèse.

Poetics, 3(2):7–19.



Turing, A. M. (1952).

The chemical basis of morphogenesis.

Philosophical Transactions of the Royal Society of London B:
Biological Sciences, 237(641):37–72.