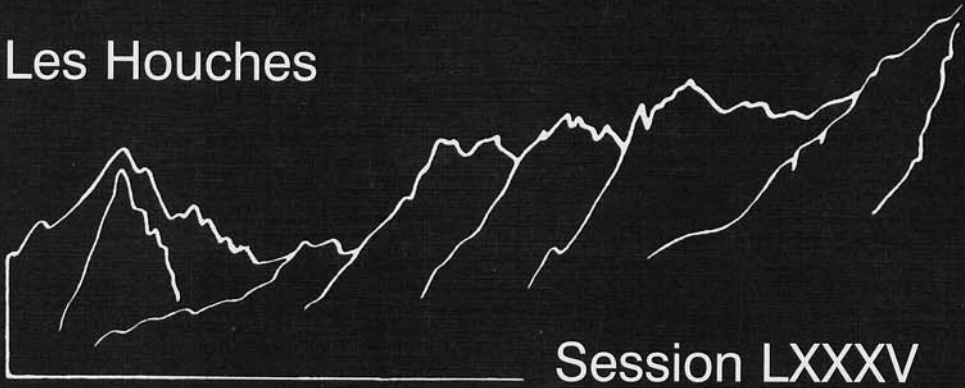




Les Houches



Session LXXXV

complex systems

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Course 14

**EPIGENETIC LANDSCAPE AND CATASTROPHE
THEORY: COMMENTARY ON A CORRESPONDENCE**

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The paper “Une théorie dynamique de la morphogenèse” by René Thom, appeared in *Towards a theoretical Biology I* (1968), published by Conrad Hal Waddington, can be considered as the *princeps* paper of the catastrophe theory. In this paper Thom declares that embryology and, in particular, Waddington’s notions of epigenetic landscape and chreod have been one of his sources in conceiving catastrophe theory. Moreover, Thom tries to show that embryology, in particular the problem of cellular differentiation as it was posed by Max Delbrück in 1949, can be a field of application of Thom’s catastrophe theory, *i.e.* a mathematical theory of morphogenesis, based on the study of the property of structural stability by topology and differential analysis.

In the collection of René Thom’s works *Modèles mathématiques de la Morphogenèse*, published in 1980, the French version of this paper is augmented by a correspondence between Conrad Hal Waddington and René Thom (five letters, from the 25th of January till the 23th of February 1967) about two Waddington’s criticisms to the first version of Thom’s paper.

The first criticism concerns the paternity of the notion of cellular differentiation. In Thom’s paper Waddington argues:¹

- “the biochemical interpretation (due to Delbrück and Szilard) of cellular differentiation”.

The second one concerns the use of alternative steady states instead of time extended chreods. On this point Waddington argues:

- “every cellular specialization being – following the idea of Delbrück and Szilard – characterized by a stable regime of metabolism, *i.e.* an attractor A of the local biochemical dynamics”.

And he suggests instead, as far as the first point concerns:

- “I had stated the main point as early as 1939”.

And as far as the second point concerns:

- “I got it right, and spoke of alternatives between time-extended chreods (though I did not yet call them that), whereas Delbrück and Szilard had the simpler and basically inadequate idea in the context of development of alternative between steady states”. Hence Thom proposes the following modifications of his text:

¹All the quotations of the correspondence are from Thom (1980), 23–33.

– “The idea of interpreting cellular differentiation in terms of a “stable regime of the metabolism” *i.e.* of an attractor of the biochemical kinetics, is often attributed to Delbrück and Szilard. In fact it was stated – under its local form, which is the only correct one – in C.H. Waddington, *Introduction to Modern Genetics*, 1939.”

– “every cellular specialization being – following the idea of Delbrück and Szilard – characterized by a stable regime of local metabolism”.

However, concerning the second and most conceptually important point, Waddington would prefer:

- “by a stable but evolving regime of local metabolism”.

Thom hence suggests:

- “an attractor of the biochemical kinetics tangent to the point under consideration”.

Despite the fact that from the rest of the correspondence one can argue that even this last expression is not completely satisfactory for Waddington, it will be the one retained by Thom for the definitive version of his paper.

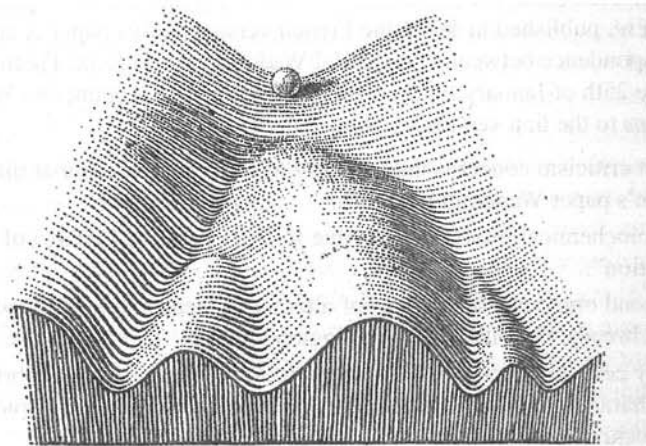


FIGURE 4

Part of an Epigenetic Landscape. The path followed by the ball, as it rolls down towards the spectator, corresponds to the developmental history of a particular part of the egg. There is first an alternative, towards the right or the left. Along the former path, a second alternative is offered; along the path to the left, the main channel continues leftwards, but there is an alternative path which, however, can only be reached over a threshold.

Waddington (1957), 29.

One can ask the question: which is the reason of the misunderstanding between the two scientists?

A first interpretation of this lack of agreement between the two scientists can be based on the taking into account of their cultural differences. To use the expression introduced by Evelyn Fox Keller in *Making Sense of Life*, they do not share the same “epistemological culture” and they do not have the same explanatory needs.

René Thom himself introduces this correspondence as an example of the difficulties in communication between a mathematician and a biologist because of the differences in their exigencies of mathematical rigour. However, following some Waddington’s remarks on the peculiarity of the variable “time” in biology, I suggest another interpretation of their disagreement, based on the Waddington’s unsatisfied need of representing, thanks to the metaphor of epigenetic landscape, different time scales in the process of the organism development.

The full commentary on this correspondence has been published in:

Franceschelli S. (2006). “Morphogenèse, stabilité structurelle et paysage épigénétique”. In A. Lesne & P. Bourguine (eds.), *Morphogenèse. L’origine des formes*. Belin, 298–308.

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