CELL SOCIOLOGY AND THE PROBLEM OF AUTOMATION IN THE
DEVELOPMENT OF PLURICELLULAR ANIMALS

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(Received 8-VI-1979)

ABSTRACT

The principles of automation (automatism and programming) in the unfolding of spatio-temporal patterns during animal development are deduced from experimental data reconsidered from the point of view of cell sociology. The developmental programme in the egg is not part of the genetic information but a part of the cytoplasmic information. Throughout development cells store extra-cellular information released by their neighbours in the form of cytoplasmic information. Successive determinations cannot be considered as successive reprogrammings of cells: each one consists of a selection of one specific programme from the total information previously stored. This programme specifies cell interactions in the determined population as a whole; it is very imprecise and is progressively completed during the course of further differentiation by information released by neighbouring cell populations. Complicated patterns may emerge from only two homogeneous populations involved in distinct differentiation pathways and confronting each other. Consequently the 'egg developmental programme' provides gene effectors and specific physico-chemical conditions necessary for the starting of at least two distinct differentiation pathways. Experimental data suggest that there are two components in this programme. One is a molecular machinery which starts at fertilization in the whole cytoplasm. It yields two programmes of differentiation, typically first an endodermal and then an ectodermal one. The other component of the egg developmental programme, which does not require specific information, allows the interception of the first (endodermal) programme. The application of informatics to developmental automation is discussed in the latter part of the paper.

INTRODUCTION

The progressive unfolding of spatio-temporal patterns during development is the visible manifestation of cell differentiation (i.e. the progressive specialization and diversification of cell types), differential growth, and cell displacements (morphochoresis). In a previous paper (Chandebois, 1976a), I showed that these processes all result from the possibility of cells to exchange, store and interpret information. Development is a kind of social phenomenon, which can be compared to the evolution of a civilization. Nevertheless, there is a fundamental difference between a civilization and the development of an animal: the former is an achievement which stands alone in human history,

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while the latter is exactly reproduced from generation to generation in every species. Obviously the unfolding of spatio-temporal patterns is an entirely automatic process, even in those animals where a choice between two or more definitive adult forms depends on environmental conditions.

The autonomy of the transformations undergone by growing organisms and their extraordinary precision suggested to German embryologists the word 'Entwicklungsmechanik'. However, at present the complexity of the processes thus automatically unfolding themselves compels us to put the problem of development in terms of cybernetics. Although this recent idea has imposed itself upon everybody, embryologists only introduced in their routine vocabulary a few terms devoid of explanatory value (for instance the word 'programming', which is used in various contexts). For this reason so far only predictive theories of developmental automatism, which are more or less completely divorced from experimental data, have been developed by theoretical biologists.

Today the problem of automatism in development appears as the most fascinating one in biology, and many people — particularly non-specialists and students — aim at understanding this problem rather than at obtaining more precise information about molecular features, which hold the interest of most researchers. Recently, while reconsidering the mechanisms of pattern formations in the context of Cell Sociology, I arrived at certain conclusions which have prompted me to take up the important problem of developmental automatism in pluricellular animals. In this essay I shall attempt to lay down its general principles and to consider the possible mechanisms of its programming — in other words the three-centuries-old problem of egg determination.

1. MODELS OF DEVELOPMENTAL AUTOMATISM IN THE ORGANISM AS A WHOLE

The developing pluricellular organism as a whole has been compared to a running clockwork which is wound up during maturation of the oocyte and released by sperm entrance. However, this comparison is misleading because it might suggest that the fate of every cell line is a steady state, and that the fate of the whole organism tends towards a certain inertia. This idea has been implicitly expressed by Waddington (1940) when he compared the progression of differentiation to a ball rolling down the 'epigenetic landscape'. Today we know that when adult cells are deprived of their normal environment their individuality is changed to some extent. They often undergo complete morphological dedifferentiation and may exhibit potencies which seemed lost1.

1. For many authors, the fact that dedifferentiated cells may re-acquire potencies lost during development has not been proved. Nevertheless, asexual reproduction in ascidians provides an unambiguous demonstration. The germ layers are determined at an early