J. Non-Equilib. Thermodyn.
Vol. 1 (1976), pp. 33–41

Dissipation in Embryogenesis

J. Hiernaux and A. Babloyantz
Faculté des Sciences Université Libre de Bruxelles, Belgique

Received 12 January 1976 Reg. Number 11
Key-Number 31 02 227

Abstract

The non-linear Thermodynamics of Irreversible Processes is used to evaluate dissipation during embryogenesis. Simple model systems for cell differentiation and pattern formation are presented. The dissipation in these systems is evaluated by computing the entropy production per unit mass. It is shown that for those models there is an increase in dissipation during the early stages of development.

I. Introduction

This paper is devoted to the study of some thermodynamic aspects of embryonic development. In particular, we show that one can account for the increase of dissipation during embryogenesis as reported in the literature [1].

It is widely accepted that Prigogine's minimum entropy production theorem [2], introduced in the context of development by Prigogine and Wiame [3], can already account for some of these phenomena, in particular, the decrease of specific dissipation rate during late developmental stages. The unability of minimum entropy production theorem to describe the increase in dissipation during the early stages of embryogenesis has often been interpreted as an inadequacy of irreversible thermodynamics to account for the biological phenomena. However, the theorem of minimum entropy production is only valid in the linear range of irreversible processes, and as such it cannot be applied to systems very far from thermodynamic equilibrium, which is the usual situation in most biological problems.

More explicitely, if P denotes the entropy production for a given system, then, near thermodynamic equilibrium, it can be shown that

$$\frac{dP}{dt} \leqslant 0 \ . \tag{1}$$

This inequality implies a minimum entropy production at the steady state. However, it breaks down for states far from thermodynamic equilibrium. Still, if the system is