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Marcelo Epstein



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# Mathematical characterization and identification of remodeling, growth, aging and morphogenesis

Marcelo Epstein\*

## Abstract

A clear demarcation between various processes of material evolution is established and the implications of the symmetry type on our ability to distinguish between them are investigated. The general features of the various types of material evolution are emphasized by establishing a spatio-temporal analogy between material uniformity and processes of material evolution.

**Keywords:** Material evolution, symmetry groups, normalizer, natural states, Mandel stress, functionally graded materials

## 1 Introduction

In biological contexts, the terms remodeling, growth, aging and morphogenesis are used somewhat loosely to describe various processes of *material evolution* observed in Nature. Given the amazing variety of observable phenomena in the wondrous flora and fauna that populate our planet, it would be impossible to encapsulate all of them within such narrow limits as a formal definition can afford. Nevertheless, when it comes to the definition of the scope of a particular mathematical model, a precise terminology and, more importantly, a precise delimitation of the intended horizon encompassed by the model, is a necessity. In the classical review paper by Taber [11], we find

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\*Department of Mechanical and Manufacturing Engineering, University of Calgary, Canada.

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