# Preface

This book presents new ideas and theories that account for oscillatory contraction in muscle and the various modes of flagellar and ciliary movements. Despite the great variety of dynamical behaviours, attempts have been made to model some of the specific modes, though not to account for the overall properties. I have tried to develop theoretical models and to interpret nearly all of the dynamical behaviours in terms of these models. This book is intended for students and specialists in biology, physics, chemistry and mathematics, as cellular motility is a subject of interdisciplinary interest.

The book consists of an Introduction, Part I and Part II. Nearly all the chapters are self-contained, so that the reader can start with any of them. Although there are a lot of mathematical equations in this book, the reader need not follow each step, but rather should try to understand the overall conepts behind them. For this purpose, I include more than 200 illustrations.

Chapter 1 gives basic examples of temporal and spatial orders. The problems of these orders are not just restricted to biology, but apply also to mechanics and chemistry.

Part I deals with the mechanical properties of vertebrate skeletal muscle and insect flight muscle. I am concerned with the oscillatory properties of these muscles, as the molecular mechanism for oscillation has been one of the most intriguing subjects for experimentalists and theoreticians.

Chapter 2 describes the experimental observations. Oscillatory contractions have been observed, not only in heart muscle, but in skeletal and insect flight muscle as well. Thus a common molecular mechanism for oscillation might exist in various types of muscle. Starting from the organic structure of muscle, experimental results are outlined.

Chapter 3 discusses some of the mathematical models for muscle contraction. Instead of giving a detailed explanation of each model, its essential features are summarized. After the quick review of these models, I propose a simplified model that accounts for oscillatory contraction. The analogy between the muscle system and the nerve system is discussed, based on this simplified model behaviour.

Part II sketches the self-organization of flagellar and ciliary bending patterns. Like other nonlinear distributed systems, the flagellar system, which is viewed as a one-dimensional array of functional units, gives rise to regular and irregular dynamical behaviours.

Chapter 4 starts with the definition of flagella and cilia, and then describes their internal structure. Functional as well as structural hierarchy is discussed.

Chapter 5 discusses fluid-dynamical principles of flagellar and ciliary motion. Then, the fundamental equation which governs the behaviour of a thin filament through a viscous medium is derived. With these theoretical backgrounds, important mathematical models are discussed, with emphasis on their significance and their status.

Chapter 6 discusses the molecular mechanism underlying bend initiation and propagation. Using computer simulations, the one-demensional array of excitable units not only shows symmetric beating patterns typical of flagella, but also demonstrates asymmetric beating patterns typical of cilia. Although these simulation results are restricted to the zero external viscosity and small-amplitude oscillations, the two different types of behaviours are demonstrated by using a similar mechanism.

Chapter 7 develops simplified models for flagellar motility, to examine whether the excitable mechanism that was studied in Chapter 6 generates bend propagation of small amplitudes. In the limit of zero external viscosity, simulation results show self-organization of symmetric bends as occurred in the previous chapter. At non-zero external viscosity, the model shows regular base-to-tip and irregular tip-to-base propagating waves, depending on the structural asymmetry along the axoneme.

Chapter 8 develops simplified models for ciliary dynamics at non-zero external viscosity. Besides regular repetitive beating with alternate effective and recovery strokes of small amplitudes, these models exhibit a resting phase called quiescence, and mechano-sensitivity.

Chapter 9 extends the simplified models proposed in Chapter 7, in order to demonstrate large-amplitude oscillations and bend propagation. Recent experimental observations are briefly summarized, and are used to develop new models.

Chapter 10 discusses the various types of dynamical behaviours at the molecular level. Using a simple model of dynein–tubulin interaction, I predict many interesting phenomena.

Like other nonlinear phenomena in biology, such as pattern formation in developmental biology, recognition in neurobiology and immunology, and enzyme reaction in biochemistry, cellular motility has exhibited attractive and interesting phenomena. However, the subject of cellular motility has not drawn interdisciplinary attention, probably because the mathematical models that have been developed are too complicated to deal with, and also because the details of molecular structure and function have not been completely understood.

It is impossible to refer to all of the experimental and theoretical studies. Instead, I prefer to emphasize interesting results from a point of view of nonlinear science, and to develop simple models in order to make qualitative interpretations and predictions rather than quantitative data fittings. Of course, there are many ways to develop theoretical models. My standpoint is 'simple is best'.

I hope that this book stimulates greater interest in cellular motility.

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