



BOOK REVIEW

Mechanics of the Cell, Second Edition, by David Boal, Cambridge University Press, 2012, xiv +608 pp, ISBN: 978-0521-11376-2 Hardback, ISBN: 978-0521-13069-1 Paperback.

The book is a revised edition of the textbook originally published 10 years ago. It is about one half longer and with four new chapters being added that expand the treatment of dynamical processes such as cell growth and cell division. This new Edition is also significantly enhanced by homework problems posed at the end of each chapter. The book intends to be a complete exposition of the mechanical behavior of the cell, which is complex system made of soft interacting components prone to biophysical and mechanical functionalities. The textbook starts from the treatment of the building blocks of the cells (the filaments viewed as rods and ropes), which themselves organize into 2D and 3D networks, up to the whole cell conceived as a dynamical organization subjected to processes like deformation, protrusion, growth and division. The physical and mechanical aspects are presented in a balanced manner and each chapter generally starts with experimental views of the phenomena under consideration. The mechanical and mathematical background is kept at a reasonable level, so that the reader not very experienced with the language and concepts of mechanics can easily follow. Four appendices expose in a synthetic manner the molecular constitution of animal cells and tissues and the necessary background of statistical mechanics and elasticity theory. A short summary of each chapter is first introduced, so that the reader can grasp in a few lines the objective of the developments to follow. Similarly, a summary of the material exposed and principal results concludes each chapter. Problems are classified into “Applications”, which are intended as direct illustrations of the presented formula and results, and “formal developments and extension”, requiring a deeper understanding of the mathematical developments underlying those results.

The book first introduces the architecture of the cell. The analogy with the design of structural elements at the human macroscopic scale is fruitful, since it highlights the common features of natural (biological) and artificial (man-made) structures, a parallel that will help the reader understanding the mechanical description and the functions of cell components. Chapter 2 deals with a statistical treatment of the fluctuations of the filaments of the cell (more details about statistical mechanics

are provided in Appendix C), which obey entropic elasticity. In the same spirit, since cells are moving in a surrounding fluid, motion in viscous fluids is described, thereby introducing the notion of viscous drag. Part I of the book deals with the behavior of rods and ropes as models of the filaments, which are the structural elements of the cell. The entropic elasticity of those filaments is described as the result of a competition between bending energy and entropy, and the notions of persistence length, Young and bending modulus, up to buckling that pertain to the mechanical behavior of those simple filaments undergoing (simple) bending are presented. The behavior of complex filaments - in the sense they are composite filaments made of the assembly of proteins - endowed with torsion, twist and writhe, is exposed in Chapter 4, which starts with a descriptive overview of single and multiple helices encountered in macromolecules and cellular filaments up to 10 nanometers. The two dimensional elasticity of 2D networks is treated in Chapter 5, with a classification of uniform networks in terms of their discrete symmetries (according to connectivity), focusing on the four-fold and six-fold connectivity networks found in the most important biological cells. The stress-strain behavior of those networks submitted to stress is derived, and their effective moduli are determined from a simple homogenization of the discrete network structure to a continuum when identifying the energy in both representations. Temperature effects leading to non uniform networks are taken into account according to statistical mechanics concepts within a mean field approximation. Those developments are extended to 3D networks in Chapter 5, which additionally presents the notion of network percolation and failure, and a few elements of the rheology of cytoskeletal components. The second part of the book deals with the behavior of biomembranes, considered as two dimensional sheets, adopting the framework of continuum mechanics for the description of their elasticity and rupture. The thermally induced undulations are treated in Chapters 8 and 9. The intermembrane forces and the effect of cell adhesion to a substrate on cell shape are exposed in the same Chapter 9. Part III of the book deals with the whole cell. Chapter 10 treats the equilibrium of shapes of cells and vesicles without consideration of the cytoskeleton; especially, stability diagrams of such shapes are presented. The dynamics of cells is the object of the two last chapters, and the molecular mechanisms responsible for the cell motion and polymerization are described. Chapter 12 describes the structural changes a cell undergoes during its division cycle, up to DNA transcription and replication. The last chapter approaches the mechanisms underlying switching and signal transmission at various scales that reflect the cooperative behavior of cells.

In conclusion, the book provides a very clear and comprehensive presentation of the cell mechanics, aimed for both the graduate student level and the non specialist interested in various aspects of cell mechanics. Although the main goal is

clearly to use concepts from elasticity and statistical mechanics to derive the mechanical properties and response of the cell starting from the behavior of its basic constituents, biological and experimental aspects are always present, so that the exposed material is in fact presented from a multiphysical and multidisciplinary viewpoint.

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