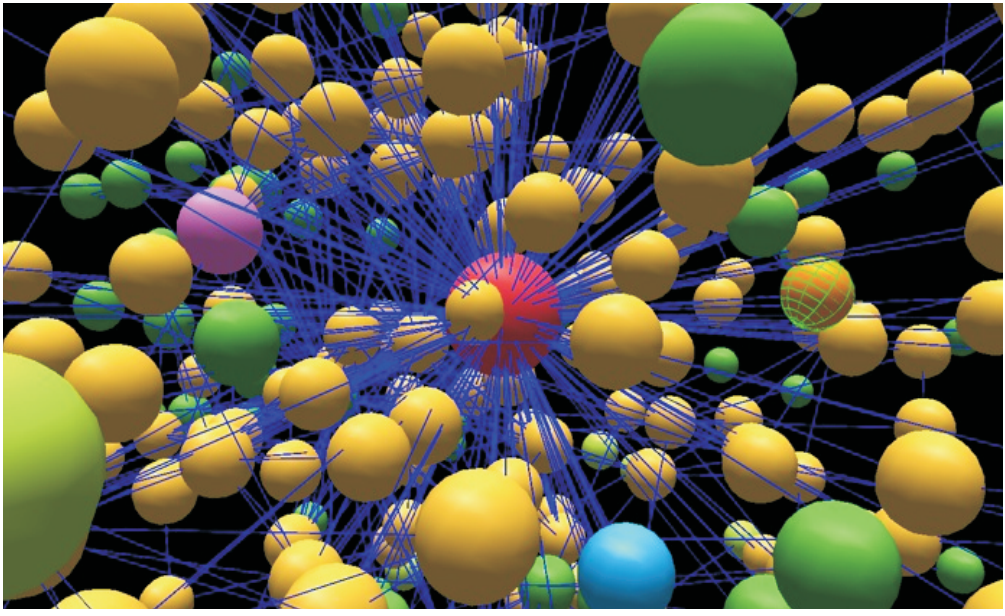
Physical Approach to Biology

Tetsuya Watanabe



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Preface

I wrote this book not only for biologists but also physicists and chemists who are interested in biology where a computational modeling is applied. I hope this book becomes a bridge between physics and biology.

In the Boltzmann model, the distribution law is derived from the number of states given by counting the number of ways for placing certain number of indistinguishable particles in the possible number of different energy cells. It is also important to know how the given total amount of energy is distributed among the certain number of independent individuals. Energy was assumed countable. His idea was thought to be peculiar at his time, but was well understood and accepted later in the time of quantum mechanics. Boltzmann also gave a statistical basis to the fact that pure different independent particles tend to be mixed spontaneously and occupy more space individually whereby increasing its randomness. Entropy is maximized at equilibrium in the isolated system. Chemical process proceeds toward the state of lowered Gibbs free energy usually accompanied by increasing randomness. Atoms bond together because the resultant bonding is more stable than the separate atoms. If electrons in outermost shell of atoms interact, they will form bonding only when their molecular orbitals become in lower energy state, and you will have more chance to find electrons in the close vicinity between each nucleus of the atoms. Negatively charged electron cloud between the nuclei will shield the positive nuclei of atoms and hold atoms together to form a molecule that is the neutral collection of atoms held by covalent bonds. If the resultant orbital is in the higher energy state, the bonding will never occur. If atoms are activated, they never stay at higher state. Instead, they will release the activated energy to the surrounding and become more stable. The quantum theory is applied to chemistry to explain chemical bonding, and reactions. Partial ionic character of covalent bond and hydrogen bond is extremely important for determining the shape of large

molecules in aqueous solution. The recent molecular biology and biophysics is based on the physical chemistry. On one hand experimental approach to molecular biology has demonstrated that functions of living cells are regulated by charged or polar signaling small molecules called ligands. Some ligands can change the conformation of the ion channels in the cell membrane when they bind specifically to the receptors on the surface of the pore columnar protein, and open the channels for ions such as Na^+, K^+, Ca^{2+}, and Cl^- to be able to pass through the membrane. Some ligands can relay signals down to the cell interior and operate via second messengers such as cyclic AMP when they bind selectively to the G protein-coupled receptors. On the other hand physical approach to biology explains the selective permeability of membrane which causes osmosis and the membrane potential. Axon of nerve can generate action potentials when the membrane potential is raised above the threshold since it has special voltage gated channels, and conducts its action potential in the way that action potentials are renewed at each point along the axon. In the nucleus of the living cell there are chromosomes made of DNA. The x-ray diffraction images of DNA led to the model of the DNA double helix. DNA is a double-stranded polymer of four kinds of nucleotides, and the genetic code on DNA is carried out by messenger RNA which provides the basic instructions for production of proteins in the cytoplasm. Messenger RNA gives a clue of protein structure in the living cell. Because enzymes are proteins, their activity as a catalyst might be changed if the code marked on DNA is changed by mutation that could cause diseases.

Discovery of structure and semiconservative replication of DNA, and the mechanism of protein synthesis in the living cell have contributed the development of biotechnology and medicine. This book will also give the recent history of science.

It is my pleasure to thank many people who helped me publish this book. First I would like to say thank Dr. Akio Yoshida for checking and offering helpful

suggestions though he has been too busy for other projects. He and I have been very close friends on studying physics and mathematics since both were high school students. Though we went to different universities, he often visited me for studying physics and swimming during summer time because I lived near the beach. I became interested in physics under his influence. Dr. Haruo Ito is my brilliant teacher who gave me an opportunity to do research in the effects of Ach and Epinephrine on phosphorylase activities on rat heart when I was a student. He introduced me to Dr. Domingo Aviado at medical school, University of Pennsylvania, where I did research in pharmacology. Dr. Osamu Nishimura was a graduate student of economics at Penn. We became friends because we both love statistical mathematics. He helped me check the chapter one. Thank Dr. Yosuke Shirakura for correcting mathematical calculation of the chapter one and chapter three.

Tetsuya Watanabe

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