Chapter 7
DNA Computing: Future of Renewable Smart Computation Systems

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ABSTRACT

The modern era of classical silicon-based computing is at the edge of a number of technological challenges which include huge energy consumption, requirement of massive memory space, and generation of e-waste. The proposed alternative to this pitfall is nanocomputing, which was first exemplified in the form of DNA computing. Recently, DNA computing is gaining acceptance in the field of eco-friendly, unconventional, nature-inspired computation. The future of computing depends on making it renewable, as this can cause a drastic improvement in energy consumption. Thus, to save the natural resources and to stop the growing toxicity of the planet, reversibility is being imposed on DNA computing so that it can replace the traditional form of computation. This chapter reflects the foundation of DNA computing and renewability of this multidisciplinary domain that can be produced optimally and run from available natural resources.

1. INTRODUCTION

The history of modern silicon-based computer technology has evolved through a long sequence of changes and is heading towards faster analysis and calculation. Literally classical computing is facing several technological challenges, like, consumption of large amount of energy, requirement of huge memory space and generation of vast e-waste. The massive growth in industrial activities is gradually leading us towards the global climate change which is of real concern. To overcome these drawbacks several modes of unconventional, nature-inspired computing have been proposed where a handful of atoms are being used to perform computation. Here comes the term nano-computing. The concept of nano-computing was proposed by Richard P. Feynman.

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On 9th December 1959, Feynman delivered lecture on "There's Plenty of Room at the Bottom" at the annual meeting of the American Physical Society at Caltech (Feynman, 1960). In this seminal talk, Feynman accentuated to control and manipulate things on nano-scale to solve computing problems. He stated that nano particles like quantum molecules, DNA molecules are capable to perform computation.

Natural biochemical nano computers exist in all living organisms which store, process and retrieve all information in form of chemical structures and interactions. But these nano-computers of nature are basically uncontrollable by humans. The concept of developing a biochemical nano computer was established by Leonard Adleman of University of Southern California in 1994 (Adleman, 1994). He first exemplified DNA computing by solving the seven-point Hamiltonian Path Problem, a NP complete problem, using DNA strands. This piece of work first explored the idea that computing is possible by directly controlling molecules in nano-scale level.

Besides performing computations (Adleman, 1994; Winfree et al., 1998; Benenson et al., 2001; Chang et al., 2003; Green et al., 2006; Akerkar and Sajja, 2009), various algorithms have been developed to resolve reasoning and classification problems (Yeung and Tsang, 1997; Ray and Mondal, 2011a; Ray and Mondal, 2011b; Ray and Mondal, 2016) using DNA strands. Computation using DNA sequences requires some operations to handle the DNA strands *viz.* synthesis, merging, melting and annealing, amplification, separation, extraction, cutting, ligation, substituting, marking, destroying, detection and reading. By manipulating synthetic DNA strands the mathematical and logical aspects of computation have been replaced by unique DNA chemistry.

Different innovative and novel research works are being performed globally to develop renewable smart computation systems, where the intelligent eco-friendly molecular arrangement can be reused leading to less energy consumption. Recently DNA computing is gaining acceptance in the field of eco-friendly unconventional computation. The reversible DNA computing models (Garg et al., 2018; Eshra et al., 2019) recycles complex structures constructed by single-stranded (ssDNA), partially double-stranded and complete double-stranded (dsDNA) DNA sequences forming DNA gate structures and hairpin complexes.

Section 2 of this chapter review the sphere of DNA computing which includes definition, advantages, innovative DNA models to perform computation. The renewable or reversible aspect of DNA computation is highlighted in section 3 where the restorable models are demonstrated to perform computation and construct DNA logic gates. Section 4 contains the conclusion of the chapter with future scope of research.

2. DNA COMPUTING

Before delving deeper into the DNA computing, a recapitulation of basic concepts around DNA is a mandate. The next subsection illustrates some of those basic premises of DNA in molecular biology.

DNA in Molecular Biology

Deoxyribonucleic Acid or DNA can be defined as genetic material that carries instructions throughout the generations of all the cellular organisms and most of the viruses. This genetic blueprint determines all the characteristic of each organism. Generally, DNA molecules are arranged in the chromosomes placed in the cell nucleus (Watson and Crick, 1953). The molecular structure of DNA was revealed by James D. Watson and Francis Crick in 1953.