# Chapter 6
# Nucleic Acids–Based Nanotechnology:
## Engineering Principals and Applications

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## ABSTRACT

*Nanobiotechnology is emerging as a valuable field that integrates research from science and technology to create novel nanodevices and nanostructures with various applications in modern nanotechnology. Applications of nanobiotechnology are employed in biomedical and pharmaceutical research, biosensoring, nanofluidics, self-assembly of nanostructures, nanopharmaceutics, molecular computing, and others. It has been proven that nucleic acids are a very suitable medium for self-assembly of diverse nanostructures and catalytic nanodevices for various applications. In this chapter, the authors discuss various applications of nucleic-based nanotechnology. The areas discussed here include building nanostructures using DNA oligonucleodite, self-assembly of integrated RNA-based nanodevices for molecular computing and diagnostics, antibacterial drug discovery, exogenous control of gene expression, and gene silencing.*

## INTRODUCTION

Nanotechnology aims to engineer a variety of functional systems at a scale of a few nanometers (Harris et al.). This novel technology presents, in its original meaning, a various methods for building systems from the bottom up at molecular and even atomic level. It is believed that the theoretical envision of nanotechnology was made by Richard Feynman, a Nobel Prize laureate in physics, in his famous lecture entitled "There is a plenty of room at the bottom" in 1959. In his lecture Feynman stated that the laws of physics do not speak against the possibility of creating things atom by atom. The implementation of the idea of molecular manufacturing brings new classes of problems and unfamiliar research areas that are at the core of the emerging field of nanotechnology.

Nowadays, nanotechnology is emerging as a crossing point among the natural and engineering sciences. It is an area of exciting discoveries that includes many different scientific and technological fields.

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In fact, many natural sciences, including chemistry and biology along with many types of chemical and biological engineering at a molecular and sub-molecular level are involved in nanobiotechnology.

Many scientists believe that function at the nanoscale is an essential element of nanotechnology. As nanotechnology developed, its definition is leading more to the design and engineering of functional systems at the molecular level rather than the design of nanostructures. Nanotechnology is a rapidly improving field that involves several major developments. In general, it includes a creation of passive and active nanostructures, made of many interacting components, and finally leading to integrated nanodevices (Penchovsky, 2012). The passive nanostructures are engineered to perform one particular task, whereas the active structures are designed to execute several different functions. Active nanostructures can be molecular sensors, actuators, drug delivery devices, and others (Penchovsky & Stoilova, 2013). For instance, molecular sensors can detect the presence or the absence of specific molecules and pass predefined molecular signals to other sensors. Such molecular sensors can be used as report systems for many different biosensoring applications including drug discovery through high-throughput screening arrays (Penchovsky, 2013). Moreover, molecular sensors can be engineered to work as Boolean logic gates. As a result, they can perform logical operations and solve computational problems. Molecular logic gates can be designed to work together by passing signals between them in various circuits *in vitro (Penchovsky & Breaker, 2005)* as well as *in vivo*.

In fact, nanobiotechnology is one of the fastest growing fields of nano research based on engineering nanosystems using various biomolecules. It refers to the intersection of nanotechnology and biology. This chapter discusses the main applications of designer nanostructures and nanodevices based on DNA (Seeman, 2004) and RNA (Famulok & Ackermann, 2010; Guo, 2010) molecules. In fact, one of the first nanostructures were made of nucleic acids using the expertise accumulated in recombinant DNA technology and molecular biology over the last three decades. Nucleic acids have been proven to be suitable nanoscale materials. They are relatively easy to synthesize, amplify, detect, and modify. They can be used both in vitro and in vivo. Therefore, nucleic acids engineering plays a very important role in modern nanobiotechnology. Nucleic acid-based nanotechnology involves the engineering of various nanostructures based on DNA or RNA molecules.

The progress achieved by the next generation sequencing (NGS) technologies (Mardis, 2008) in recent years led to the discovery of novel targets for drug development and diagnostics. The interplay among RNA engineering, RNA biology, NGS technologies, and medical genomics creates new possibilities for drug development and molecular diagnostics. In this review, I present current and future RNA-based approaches to medical genomics as the focus set on drug development (Penchovsky & Stoilova, 2013), molecular diagnostics (Penchovsky, 2012b) and forthcoming RNA-based therapeutic strategies (Penchovsky, 2012a; Penchovsky & Kostova, 2013).

As RNA-based biotechnology developed, its definition is leading more to the design of functional systems that can detect and react to molecular signals from the environment (Penchovsky, 2013). RNA technology is a rapidly improving field that involves several major discovers and technology developments. The discoveries include ribozymes and riboswitches (Brantl, 2004), microRNAs and RNAi (Hsu et al., 2006). The technology development in general, includes a creation of passive and active nanostructures, made of many interacting components or integrated nanodevices. The passive nanostructures are engineered to perform one particular task, whereas the active structures are designed to execute several different functions. Active nanostructures can be molecular sensors, actuators, drug delivery devices, and others. For instance, molecular sensors can detect the presence or the absence of specific molecules and pass predefined molecular signals to other sensors. Such molecular sensors can be used as report