Chapter 10
Bionanotechnology

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ABSTRACT

Bionanotechnology is multidisciplinary knowledge gained at the intersection of biology and nanotechnology. Certainly, biology operates in the nanoscale regime, using natural processes that occur in the nanoscale, by convention, under 100 nm in dimension. Therefore, bionanotechnology relates to those subtopics in the biological life sciences that exploit the analytical and experimental tools of nanotechnology. This chapter makes no pretense of acting as a comprehensive treatise, but rather selects a mix of timely topics that span over a wide set of tools and applications. It is addressed to practitioners, researchers, faculty, and university/college students within the field of bioengineering/biomedical engineering; it is also addressed to other closely-related governmental, non-governmental, and industrial entities.

10.1. CHAPTER OBJECTIVES

Bionanotechnology has the opportunity to exert a dominant impact on nanotechnology products that are to be developed in the coming decades. This is in no small part due to the compelling advances in nanomedicine. This chapter presents a comprehensive review that would form the basis of a monograph on bionanotechnology. A judicious choice has been made in this chapter to identify areas of bionanotechnology that span a wide range of technological tools and form a basis for the evolving art. Following the historical background, the focus is on biosensors, drug delivery and nanomedicine, biotechnology templates for electronic device architecture, and biosynthesis of nanoparticles.

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10.2. INTRODUCTION

Innovations at the intersection of engineering, biotechnology, medicine, physical sciences and information technology are spurring new directions in research, education, commercialization and technology transfer. It is at this intersection where nanotechnology operates. Anticipating a robust market, there is enormous excitement and expectation surrounding this multidisciplinary phenomenon. In fact, the future of nanotechnology is likely to continue along this path, as significant technologic advances across multiple scientific disciplines will continue to be proposed, validated, patented and commercialized.

One of the greatest impacts of nanotechnology is taking place in the context of biology, biotechnology and medicine. This arena of nanotechnology is generally referred to as bionanotechnology, with an evolving emphasis on nanomedicine.

Commercial bionanotechnology, although at a nascent stage of development, is already a reality. However, most agree that its full potential is years or decades away. Obviously, development is progressing more rapidly in certain sectors; the most active areas of product development are drug delivery, nanoelectronics, nanocoatings, and *in vivo* imaging.

10.3. DEFINITION OF BIONANOTECHNOLOGY

10.3.1. What is Nanotechnology and Nanomedicine?

Although the term "*nanotechnology*" is very much in vogue, defining it is not simple. A nanometer (Greek, *nanos*, dwarf) is one billionth of a meter, or 1/75,000th the size of a human hair. An atom is about one third of a nanometer in width. Nanotechnology is not a well-defined field, but encompasses many technical and scientific fields such as medicine, chemistry, physics, engineering, biology, etc. One can view it as an umbrella term used to define the products, processes and properties at the nano/micro scale.

One of the major problems regulators and lawyers face regarding nanotechnology is the confusion and disagreement about its definition (Bawa 2007a-b; Bawa, 2011). There are numerous definitions of nanotechnology. One often used – yet sometimes troublesome – definition of nanotechnology was proposed by the US National Nanotechnology Initiative (NNI) – a federal R&D program established by the U.S. government to coordinate the efforts of government agencies involved in nanotechnology. It simply limits nanotechnology to "*... about 1 to 100 nanometers ...*" (NNI, 2011). Various government agencies, including the Food and Drug Administration (FDA) and the Patent and Trademark Office (PTO) continue to use this vague definition based on a sub-100 nm size. Although the FDA is part of the NNI and had participated in the development of this narrow definition, it has yet to officially adopt the NNI's definition for its own regulatory purposes, or establish a "*formal*" definition.

The NNI nanotechnology definition presents numerous difficulties. For example, although the sub-100 nm size range may be important to a nanophotonic company (e.g., a quantum dot's size dictates the color of light emitted therefrom), this size limitation is not critical to a drug company from a formulation, delivery or efficacy perspective because the desired property (e.g., improved bioavailability, reduced toxicity, lower dose, enhanced solubility, etc.) may be achieved in a size range greater than 100 nm. Moreover, this NNI definition excludes numerous devices and materials of micrometer dimensions (or of dimensions less than 1 nanometer), a scale that is included within the definition of nanotechnology by many nanoscientists. Therefore, experts have cautioned against an overly rigid definition, such as this, based on a sub-100 nm size, emphasizing instead the continuum of scale from the "*nano*" to "*micro*".

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