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Bionanomaterials for Skin Regeneration

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Introduction

> The impact of nanotechnology on health, wealth and the standard of living for people will be at least the equivalent of the combined influences of microelectronics, medical imaging, computer-aided engineering, and man-made polymers…
>
> Richard Smalley, Nobel laureate 1996

If asked to define nanotechnology, almost everybody bold enough to do it would say that it is the study of materials with sizes of 1–100 nm. Since its murky origin in the 1950s physics, it made big strides ahead finding applications in fields like materials science, engineering, medicine, pharmaceutics, cosmetics, and many others. It started by capitalizing on the unique properties of materials with nanometer sizes, many of which are different from those of the bulk material with the same chemistry. The high surface to volume ratios, increasing exponentially with decreasing size, make for similar increases in reactivities, for some novel properties, and even, sometimes, for shape-dependent behavior.

This field, the epitome of interdisciplinarity, emerged where many disciplines came together blurring frontiers and establishing an incredibly fast-growing new discipline based on materials having very small dimensions. And growing it blurred the well-defined numbers in the definition, imparting flexibility and refusing to fit into predetermined molds and scenarios. It did so also because it is the best field to explore life, since life itself happens at the nanolevel, somewhere between how big atoms are and, at the other limit, the size of a bacterium. Working at the interface between nanotechnology and biology makes a lot of sense, and some bionanomaterials have been known for a long time (pigments, viruses). Numerous other nanomaterials have been discovered or synthesized more recently and, due to their amazing properties, were claimed, tested, and many times adopted by different fields. The advantages they offer, such as enhanced stability of unstable species (antioxidants, volatile compounds) by encapsulation, increased bioavailability, targeted approach which reduced doses of medication, and the possibility to tailor them to different applications, made nanomaterials look attractive to specialists in many domains. For the pharmaceutical industry, the appeal is tremendous as it is for the cosmetic

industry and for regenerative medicine. But the cosmetic industry, less hindered by regulation, has been more dynamic in adopting them, while the pharmaceutical and the medical field are lagging behind due to the arduous and lengthy process which is required for FDA approval. The increasing client base which is represented by an aging population makes potential applications of nanomaterials even more numerous and more desirable. There are growing demands for antiaging skin care products, for medications for skin conditions (especially degenerative ones) and for chronic wounds, and for materials able to regenerate tissues.

This book focuses on nanomaterials from the organic world, synthetic ones, materials from biological sources, or hybrids thereof. Nanoparticles made from inorganic materials (titanium oxide, carbon nanotubes, etc.) which received a lot of attention in the scientific literature, some of which found well-established commercial applications (such as sunscreens), are not included herein. After discussing the special properties of materials at the nanosize and their interactions with other entities and with their environment, this book visits briefly the structure of skin and its function as a barrier. Short descriptions of its layers and of their roles are given, as is a discussion of the skin aging process, with special attention to photoaging. Wounds (chronic and acute), burns, the great toll they take on healthcare costs, and the importance of skin regeneration are discussed in another chapter. Modalities to deliver different compounds to the skin (topical, transdermal) are introduced qualitatively, with short discussions of quantitative aspects, and comparisons are made. A chapter is dedicated to nanoparticles and to different types of nanocarriers (nanoemulsions, micelles, dendrimers, gels, etc.), sources, preparative processes, comparative discussion of properties, and applications. A special chapter is focused on nanomaterials as a solution to enhance bioavailability of active principles to the skin.

A number of chapters are dedicated to the study of different classes of bionanomaterials based on their natural sources. Due to their characteristics (natural, biodegradable, and able to encapsulate both hydrophilic and lipophilic species), lipid (and solid lipid) nanoparticles are discussed in a separate chapter together with their applications for the skin and the enhancements they afford. Antioxidants are valuable agents for health in general and for the skin in particular (care and treatment), but their reduced stability limits their actual benefits. Encapsulation in nanocarriers is a viable solution for this, and it is discussed, together with examples, in a separate chapter. Chitosan, an inexpensive polymer from natural sources, found many applications during the last 20 years. Due to its antimicrobial and antimycotic properties, and to the facility of preparing nanochitosan, it offers a huge potential for medical and cosmetic applications, some of which are already in use, and a chapter of the book discusses them. Also natural, available from many sources, inexpensive, and with special mechanical properties, nanocellulose found many applications, alone or in hybrid materials, and it is discussed in a separate chapter. Bionanomaterials from plant sources have received great attention from scientists due to their healing properties, antioxidant effects, and biodegradability. Their poor chemical stability and limited bioavailability have been addressed by encapsulation in nanocarriers, and a chapter is dedicated to this discussion. Regenerative medicine is a topic of

high interest in general and of particular importance for dermatology. This makes the chapter focused on nanofibers, nanoscaffolds, and skin regeneration an important one for the scope of the book. A separate chapter discusses bionanomaterials based on peptides and proteins and briefly mentions the importance of those based on small interfering RNA (siRNA) species in the treatment of skin conditions.

The history of nanomaterials is not long enough for their long-term effect to be known and for their toxicity to be assessed over time. After the hype and enthusiasm of the beginnings when everything nano was adopted and praised, hazards started to be reported, and the public opinion shifted to the other extreme. A later chapter discusses what is known versus what is not yet clear about the toxicity of nanomaterials and evaluates benefits against risks as known so far. Finally, the last chapter of the book discusses some of the ethical, regulatory, and social issues linked to using nanomaterials in skin regeneration.

Discussion and growth in the field of nanomaterials need specialists in many domains. Not all the disciplines are preoccupied to provide adequate training in this field which makes dialogue difficult or even lacking sometimes. This small book hopes to be a modest start of the discussion for newcomers and for some experts interested in collaborating at a place where their disciplines come together.

“Science is the only possible adventure of our times…”
One of our fathers—sometime during the second half of the twentieth century
“…, and technology….”
The authors—sometime at the beginning of the twenty-first century

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Mihaela D. Leonida dedicates her part of this book to the memory of her parents who taught her that science cannot be hijacked by history and that a scientist has to make a mark not only in his/her field but in culture as well. She is very grateful to them and to Jim for his infinite patience, unwavering support, and willingness to participate in any cultural endeavor.

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