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Characterization of Nanomaterials: Knowing How Nano-Bio Interactions Work

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Abstract

Despite their remarkable smallness, nanomaterials can be utilized to great effect. Over the past ten years, a lot has been learned about how nanomaterials affect biological interactions and effects. However, as-synthesized materials are typically used for nanomaterial characterization. We contend that nanomaterials ought to be studied and regulated as dynamic entities. As a result, biotransformation should be taken into account when characterizing nanomaterials. In nanosafety, however, in situ characterization of nanomaterials as they undergo dynamic changes in a living system (coronation, dissolution, degradation) remains a formidable obstacle. To address this issue, toxicologists and material scientists must collaborate.

Keywords: Nanomaterials • Nanosafety • Extracellular matrix

Introduction

Nanotechnology is not an exception to the tension that exists between humans and technology. On the one hand, brand-new technologies might have unanticipated negative effects that were not intended. Nanotechnology, on the other hand, has the potential to significantly enhance our lives. One illustration of this is the overwhelming success of the mRNA vaccines against COVID-19. Nanotechnology is the process of manipulating matter at the atomic or molecular level. However, just like the elephant in the well-known parable of the elephant and the blind men, nanotechnology can be interpreted in a variety of ways. The introduction of the scanning tunneling microscope (STM) and its cousin, the atomic force microscope (AFM), which made it possible to not only "see" matter at the nanoscale but also to manipulate it, opened the doors to nanotechnology from an engineering perspective. "Life is a nanoscale phenomenon" merits mention from a biological perspective. Although it is evident that nanotechnology may also benefit from a better understanding of the myriad nanoscale "machines" that reside in every cell in our body, Bruce Alberts predicted that "much of the great future in biology lies in gaining a detailed understanding of the inner workings of the cell's many marvelous protein machines [1].

Description

The responsible application of nanotechnology relies heavily on the safety evaluation of engineered nanomaterials. The standardization of methods for measuring the physicochemical properties of nanomaterials has made significant progress, enhancing the relevance and quality of nano(eco)toxicological studies. In a previous article published in this journal, we emphasized that the characterization of nanomaterials should also be useful. Some additional musings can be found here.

Nanomaterial interactions with biological systems are largely governed by physicochemical properties like size, shape, chemical composition, and surface chemistry. In addition, it is becoming increasingly apparent that nanomaterials can undergo a variety of transformations in a biological system (i.e., in the body or the natural environment). These transformations include agglomeration, which is perhaps the transformation that occurs the most frequently, and bio-corona formation, particularly the adsorption of proteins onto the surface of nanomaterials, which appears to be the topic that is receiving the most attention. As will be discussed further down, other transformations, such as the dissolution of metallic particles and degradation of carbon-based materials, must also be taken into account. The conclusion: Nanomaterials ought to be studied and regulated as dynamic entities. To address the biotransformation of nanomaterials in biological systems, a unified strategy that aligns material characterization and risk assessment is required. Indeed, there is a pressing need to investigate and describe the dynamic changes of a nanomaterial in a living system. As a result, appropriate analytical tools for evaluating these transformations must be developed or implemented, and risk assessment must take into account nanomaterials' dynamic nature.

The protein corona, also known as the surface-adsorbed layer of proteins that forms when nanomaterials enter a biological system, has been extensively studied over the past ten years with a wide range of analytical techniques. In point of fact, earlier research established that "blood plasma-derived coronas are sufficiently long-lived that they, rather than the nanomaterial surface, are likely to be what the cell sees." An eco-corona could also be formed by naturally occurring biomolecules binding to nanomaterials released into the environment. However, the current regulatory framework does not take into account this dynamic transformation of nanomaterials, despite the fact that corona formation appears to be nearly universal and has an impact on the fate and behavior of nanomaterials in the human body and the natural environment. Even though the protein corona has been the focus, it is clear that nanomaterials can also interact with lipids, nucleic acids, and metabolites (the intermediate or end products of cellular metabolism), even though the protein corona has been the focus. As a result, the term "bio-corona" is more appropriate. When nanomaterials are inhaled, it makes sense that they would interact with proteins and lipids as well [2-5].

Conclusion

A new study has shed light on this nano-bio interface. As a result, evidence for so-called nanomaterial "quarantining" (deposition) on the surface of lung epithelial cells with the formation of cauliflower-like structures made of nanomaterials (TiO^2 nanotubes) and lipids was presented using in

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vitro and in vivo model systems. Lung epithelial cells actively responded to the nanomaterials by producing more lipids, which were then used to immobilize the nanoparticles on the cell surface, according to the researchers. The authors were also able to demonstrate, through co-cultures of the murine alveolar macrophage cell line (MH-S) and the murine epithelial lung cell line (LA-4) that the “quarantined” nanomaterials on the surface of the lung epithelial cells caused macrophages to consume the nanomaterial-lipid complexes. They discovered that the nanomaterial-laden macrophages eventually perished and released bare nanomaterials, which were then taken up again by the epithelial cells in the nanomaterial-exposed co-cultures in a cycle of uptake, surface deposition, and release. The TiO^2 nanotubes were suspended in water with 2% v/v mouse serum prior to the in vivo exposures, whereas the two cell lines were cultured in medium supplemented with 10–15% fetal calf serum. In addition to the "self-inflicted" lipid corona, the nanomaterials undoubtedly acquired a protein corona prior to the in vitro and in vivo experiments. Nevertheless, study provides an illustration of the complexity of interactions between nanoorganisms and living things and suggests that the formation of bio-coronas may serve a cytoprotective function in the lungs.

Acknowledgement

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Conflict of Interest

None.

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