The Future of Nanotechnology

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The Future of Nanotechnology: Cross-disciplined Progress to Improve Health and Medicine

Guest Editorial for the Accounts of Chemical Research special issue on "Nanomedicine and Beyond".

The future of nanomedicine is exciting! Nanomedicine involves the engineering of materials at the nanometer-scale for investigating fundamental biological problems and diagnosing and treating disease. We have witnessed significant investment by universities and companies in building the foundation for research activities in the field of nanomedicine in the last 20 years. This has led to the training of a workforce that understands the concepts of nanomedicine and works to move the field from "concept" to "reality". This workforce has built interdisciplinary teams including engineers, chemists, biologists, physicists, and clinicians to clinically translate nanotechnology to improve the lives of patients such that nanomedicine is now poised to revolutionize health care worldwide.

Nanomedicine research can be categorized as *in vitro* or *in vivo*. The *in vitro* applications of nanotechnology are much simpler to clinically translate in comparison to *in vivo* ones. *In vitro*, nanotechnology is used in sensors to diagnose disease and study biological processes via isolated tissues, cells, or molecules from biological samples or fluids. The requirements for approval by health agencies are less arduous than those for *in vivo* applications. For example, in point-of-care diagnostic devices, a nanotechnology-based system needs to demonstrate improved clinical sensitivity or specificity over current tests or provide a new function that is not available with current methods. Additionally, the use of nanotechnology for basic research is already emerging. Nanoparticles such as quantum dots and gold nanoparticles are used for studying receptor−ligand interactions, cellular processing, or signal transduction. The major scientific barriers to the translation of nanoparticles for *in vitro* applications is low. In many cases, it requires a company to focus on commercializing many of the nanotechnologies that have been developed. The company is the link to end users for academic research. The *in vitro* use of nanotechnology for medical applications should be accelerating in the next 20 years.

In contrast, *in vivo* medical applications of nanotechnology are more challenging. The human body and the *in vivo* environment are extremely complex. The administered nanoparticles will interact with many different organs, cells, tissues, and biological fluids. These interactions could be permanent or transient, and *in vivo* kinetics of the nanoparticles could affect their biodistribution patterns. This, in effect, can influence their ability to target, diagnose, or treat diseased tissues or cause toxicity that leads to side effects. As nanoparticles are transported in the body, they interact with different biological compartments (i.e., organs, tissues, and cells). We can view these organs as bioreactors that can chemically alter the nanoparticle physicochemical properties as they transit through the body. These reactions can impact toxicity, elimination, or interactions with diseased tissue. Many researchers are starting to tease out these interactions systematically, in order to develop maps that guide the engineering of nanoparticles for use in the body. In contrast to the *in vitro* application, the complexities of these studies would suggest that translation could take much longer than the use of nanoparticles for *in vitro* applications. Yet, these studies are critical to control the *in vivo* transport and function of the nanoparticles. This will be important in rationally designing nanotechnology for use in the body.

In this special issue of *Accounts of Chemical Research*, we highlight a broad range of advances in the field of nanomedicine in the last 20 years. The issue is organized to encourage the community to think beyond academic proof-of-concept studies with a view to advancing these studies to real-life medical products that help patients. This special issue of *Accounts of Chemical Research* is organized into (a) research toward rationale design of new nanomaterials for biology and medicine, (b) nanoparticle interactions with biological systems (nano−bio interaction), (c) imaging and sensing, (d) therapeutic proof-of-concept applications, and (e) clinical analysis.

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Notes

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