ACCOUNTS
of chemical research

GUEST EDITORIAL

Chemistry of Molecular Imaging

Molecular imaging can been defined as "... the characterization and measurement of biological processes in living animals, model systems and humans at the cellular and molecular level using remote imaging detectors." Its history can be traced back to the early years of nuclear medicine, which employs radioactive isotopes for diagnosis and treatment. The chemistry to render these isotopes biologically compatible provided the foundation for the development of many of the molecular imaging agents used in experimental and clinical settings today.

The advent of new imaging tools such as confocal and two-photon microscopy, micro-magnetic resonance (MR), -positron emission tomography (PET), and -single photon emission computed tomography (SPECT), and ultrasound have provided scientists and clinicians with the ability to acquire in vivo images of the anatomy and physiology of cells and whole animals alike. Each of these different imaging modalities has its own specific strengths and weaknesses due to varying spatial and temporal resolution limits, but advances in technology have recently made possible the combination of two modalities (e.g., PET−CT), which takes advantage of the exquisite sensitivity of PET contrast probes and the high spatial resolution of CT images. More is expected by merging MRI and PET, as well as MRI and optical imaging modalities. As a result, molecular imaging is poised at the forefront of the quest to answer fundamental experimental and clinical questions that have remained unanswered.

As a research tool, for example, molecular imaging using optical microscopy has revolutionized the way living cells and intact tissues were investigated. This precision made possible the monitoring of developing embryos at submicrometer resolution. Specifically, the examination of subcellular events, biochemical processes, and tissue morphogenesis were made possible by this modality. Once recognized as the product of gene expression, the classification and differentiation of cells and tissues though all stages of development became increasingly important. It was necessary to track these developments with greater precision and acuity than previously attempted. Thus, various imaging techniques were developed to track the patterns, both temporal and spatial, of individual gene expression.

In clinical settings, the treatment of human disease at its earliest stages requires sensitive, quantitative, and nondestructive diagnostic monitoring methods. Each of the aforementioned modalities plays an increasingly important role in this regard. The development of sophisticated reporter probes for cell tracking, mapping gene expression, and monitoring therapeutic paradigms is rapidly changing the way these techniques are applied. In the past decade, significant advances have been actualized as a result of discoveries related to contrast media in all modalities, and in the future, development of efficient targeting procedures is expected to prompt the design of new "theranostic" agents, which combine imaging and therapy in a single probe. The availability of such "theranostic" agents could greatly advance the development of personalized treatments. Already, from some of the Accounts presented in this issue, one may envisage how properly designed nanosized systems may play a key role in pursuing the task of an "in vivo" visualization of drug targeting and drug release phases.

The number and sophistication of imaging probes has markedly increased in the past decade. The Accounts assembled in this issue focus on these advances and speculate what new generations of imaging probes will be capable of. The goal is to describe the most cutting-edge advances in experimental and clinical imaging probes while also exploring the most anticipated advances in contrast agent technology.

"Seeing is believing" is the driving force of molecular imaging, and chemistry is playing a central role in the development of this interdisciplinary field. Outstanding achievements in many chemical disciplines will continue to provide the tools for designing the "smart" probes needed to interrogate specific biological processes in both animals and humans. In this fashion, chemistry is providing a fundamental contribution to translating promising approaches into reliable scientific applications that will make molecular imaging an every day reality for early diagnoses and for monitoring the therapeutic outcome of major diseases.

It is our desire that this issue will inspire the readership of Accounts to contemplate the development of new imaging probes and their application in all modalities. The potential impact of experimental and clinical imaging is clear: the molecular probes that will realize this potential are yet to be discovered.

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AR900166C

Published on the Web 06/15/2009 **www.pubs.acs.org/acr**
10.1021/ar900166c CCC: $71.50