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Editorial: Bioluminescence and fluorescence molecular imaging in chemical biology

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Editorial on the Research Topic
Bioluminescence and fluorescence molecular imaging in chemical biology

Molecular imaging has transformed our ability to explore biological processes within living systems with unparalleled specificity and functionality. Central to this advancement are bioluminescence (BL) and fluorescence (FL)-based imaging techniques, which have provided a principal toolbox across both fundamental and applied sciences. This Research Topic showcases studies that illustrate the advantages of these imaging technologies addressing various frontier research challenges, such as pathogen research and drug discovery. The development of innovative molecular probes, including genetically encoded fluorescent and bioluminescent reporter systems, has significantly broadened the horizons of molecular imaging and can allow even real-time observation and tracking of biological phenomena with exceptional specificity and optical functionality, in both *in vitro* and *in vivo* contexts.

The research contributions in this Research Topic underscore how BL and FL imaging techniques are driving innovation across academic disciplines, from virology to parasitology, and are providing new solutions to some of today's most pressing scientific challenges. One of the studies featured in this Research Topic, led by Huaman et al., addresses the challenge of studying highly pathogenic henipaviruses, such as Nipah and Hendra, which require BSL-4 containment (Huaman et al.). To circumvent this limitation, the authors developed a safer BSL-2 model using the non-pathogenic Cedar virus (rCedV-luc) in interferon receptor-deficient (IFNAR-KO) mice. Through longitudinal BL imaging, they were able to visualize viral replication in real-time, providing a detailed temporal profile of infection. This innovative model opens up new possibilities for studying henipavirus biology and testing potential therapeutics in a more accessible and less hazardous environment. Similarly, Quiroga et al. applied BL technology to tackle a critical bottleneck in drug discovery for Chagas' disease, caused by the parasite Trypanosoma cruzi (Quiroga et al.). By engineering a red-shifted luciferase reporter strain of the parasite, the team developed a highly sensitive and scalable bioassay to screen potential drugs against the parasite's amastigote stage. This robust platform offers a new avenue for high-throughput screening, which is essential for accelerating the discovery of treatments for this neglected tropical disease. Benitez et al. contributed another important advance by developing a bioluminescent model for studying African trypanosomiasis, commonly known as sleeping sickness (Benitez et al.). This model, based on a luciferase-expressing Trypanosoma brucei strain, allowed the researchers to track infection dynamics and parasite burden in a living host. The ability to monitor these parameters non-invasively is invaluable for evaluating the efficacy of new drug candidates and for deepening our understanding of host-pathogen interactions. Their work highlights the potential of bioluminescent models to streamline drug development for parasitic diseases that remain major public health threats. To understand how cytokines shape the microenvironment and drive paracrine signaling at single-cell resolution, Yamagishi et al. propose a methodology that examines both the microenvironment and cellular responses to it, providing insights into microenvironment dynamics at the single-cell level (Yamagishi et al.). The Research Topic also features a review by Kim et al., which takes a critical look at the emerging use of BL in bioassays and molecular imaging (Kim et al.).

While BL technology offers powerful advantages, the authors highlight the complexities and limitations that researchers must consider when choosing the right probes for their purposes. Their comprehensive analysis helps guide scientists in making informed decisions about which tools to employ, ensuring that the benefits of BL imaging are fully realized without falling prey to its potential pitfalls.

Collectively, the studies presented in this Research Topic stage the transformative power of BL and FL imaging in diverse research areas. From developing safer models for studying dangerous pathogens to creating innovative drug screening platforms, these techniques are unlocking new possibilities for scientific discovery and therapeutic development. As molecular imaging continues to evolve, its applications will undoubtedly expand even further, offering new insights into biological processes and paving the way for advances in medicine, pharmacology, environmental science, and beyond.

The promise of BL and FL molecular imaging lies not only in its ability to visualize complex biological phenomena but also in its capacity to drive meaningful progress in addressing real-world challenges. This Research Topic highlights how researchers are harnessing the strengths of these imaging technologies to accelerate drug discovery, improve disease modeling, and refine diagnostic tools. Moving forward, the continued innovation in probe design and imaging methodologies will further enhance the impact of molecular imaging, offering new solutions to some of the most intractable challenges in the broad realm of fundamental and applied science.

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