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Editorial

Advances in Biosensor Technologies for Infection Diagnostics

Guest Editorial for the Accounts of Chemical Research special issue "Advances in Biosensor Technologies for Infection Diagnostics".

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Infectious diseases continue to threaten human society. The ongoing COVID-19 pandemic is a keen reminder: more than 4.6 million lives have been lost within two years of its outbreak, and the global economic damage is mounting to $7 trillion. Emerging antimicrobial resistance and rising hospital infections also portend a looming challenge that may wear down global health care systems. In the US alone, the yearly cost to the health care system has been estimated at $34 billion dollars, accompanied by more than 8 million additional days of hospital stay.

Controlling infectious diseases starts with identifying causative pathogens. In 1881, Dr. Koch revolutionized how we perceive disease by introducing an agar plate to grow bacteria on the device invented by Petri (i.e., the Petri dish). Combined with his innovative microscopy, the method allowed him to link pathogens as the source of infections (Koch's postulates), and laboratory culture of infectious agents has become the "gold standard" in clinical microbiology. The development of polymerase chain reaction (PCR) in the 1980s was a significant breakthrough, expanding the list of detectable pathogens including noncultivatable or slow-growing ones. However, performing culture or PCR assays requires supporting infrastructure, such as capital equipment and highly trained personnel, which limits diagnostic tests to centralized medical laboratories. To better cope with fast-evolving infection, we now need the next technical leap to rapid, affordable, yet highly accurate diagnostic tests at the point of care (POC). Such tests would eliminate diagnostic delays from sample transport and enable the timely initiation of the most effective treatment.

Addressing these challenges, the research community has been creating a new generation of POC biosensors, inspired by recent advances in chemistry, material sciences, and device engineering. Chemistry is at the foundation of these new sensors. It plays a key role in understanding the molecular mechanisms of infection and host responses, which in turn facilitates discovering surrogate biomarkers of infection and designing molecular probes. Over the past years, for example, a library of nucleic-acid targets has been identified along with the development of distinct approaches for their detection. Materials sciences provide building blocks for nearly every aspect of biosensing. Nanomaterials have been adopted to amplify analytical signals, speed up reactions, or simplify the assay steps. New surface coatings also have been applied to minimize biofouling, leading to improved specificity. Device engineering essentially produces a tangible system tying up all necessary parts. A significant achievement in this area was miniaturization: bulky components in old systems became smaller and integrated into compact smart gadgets. Mobile biosensors, ideal for POC operations, have been implemented without compromising and often enhancing the assay sensitivity and the speed. Device miniaturization has also enabled new types of tests, such as mimicking and monitoring infections in a controlled in vitro environment. These multidisciplinary advances promise a new combating strategy against infection: molecular sensors distributed across the globe enabling early detection and prompt patient triaging.

This special issue of *Accounts of Chemical Research* highlights these exciting new signs of progress toward infection diagnostics. We specifically focus on breakthroughs in biosensors that transcend conventional lab-oriented tests. The topics cover the overall workflow in diagnostics: (i) preanalytical devices to process different sample matrices, including blood, saliva, urine, and stool; (ii) new molecular probes designed for highly specific target recognition as well as signal amplification; and (iii) various POC systems developed for assay automation or uses in low-resource settings. We also discuss broader subjects related to infection: (i) rapidly testing antimicrobial resistance through droplet microfluidics; (ii) recapitulating pathophysiological features of human infectious diseases in organs-on-a-chip; (iii) monitoring host immune responses to complement pathogen detection; (iv) leveraging other surveillance sources, such as livestock and wastewater, to spot disease spread faster than traditional epidemiology does. In this special issue, research groups driving these innovations critically review the capability of their platforms and share insights for future improvements. We hope that this compendium would catalyze and strengthen our collaborative endeavor to fight against infectious diseases and prepare for future outbreaks.

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