

Introducing: The 2010 JALA Ten

“Our honorees come from academia and industry, representing a bridge between the inception of innovation and real-life application.”

Addressing the most pressing needs in areas like medicine and energy represent some of the greatest challenges of our time and require multidisciplinary innovation that unites expertise from all over the world. This year, JALA introduces The JALA Ten, which highlights a spectrum of the top breakthroughs of the year in broad disciplines that include bioengineering, chemistry, materials science, energy, automation, lab-on-a-chip technology, and beyond. Our honorees come from academia and industry, representing a bridge between the inception of innovation and real-life application. We are pleased to present to our readers The 2010 JALA Ten and look forward to featuring top scientific discoveries for years to come.

TOWARD PERSONALIZED CANCER TREATMENT: MONITORING CHEMOTHERAPY EFFICACY VIA MICRO POSITRON EMISSION TOMOGRAPHY

Current methods of measuring patient response to chemotherapy are challenged biopsy samples that can result in sampling errors. Deoxycytidine kinase (DCK) activity serves as a readout for patient response to chemotherapy, and given its high degree of variability between patients, noninvasive approaches to measure its activity are highly sought after. In this work, in vivo DCK monitoring is achieved using micro-positron emission tomography,

representing a significant advance toward tailored and personalized patient treatment.

Affiliation

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Department of Molecular and Medical Pharmacology, David Geffen School of Medicine, University of California, Los Angeles, CA

Reference

Laing, R. E.; Walter, M. A.; Campbell, D. O.; Herschman, H. R.; Satyamurthy, N.; Phelps, M. E.; Czernin, J.; Witte, O. N.; Radu, C. G. Noninvasive prediction of tumor responses to gemcitabine using positron emission tomography. *Proc. Natl. Acad. Sci. U.S.A.* **2009**, *106*(8), 2847–2852. Epub 2009 Feb 5.

OPTICAL CLOAKING VIA METAMATERIAL TECHNOLOGY

This study develops an optical cloak, making significant contributions toward an actual cloaking material that will be applicable toward several fields. The metamaterial technology will impact a broad spectrum of fields, allowing for real-time nanoscale imagery that will transform the field of microscopy and Lab-on-a-Chip technologies, among many other capabilities. With regard to cloaking, of the many promising applications of metamaterials, among the biggest challenges in this domain are the development of materials that can operate in wavelengths that are more relevant toward visible wavelengths or the optical regime. Microwave-regime cloaking has previously been realized. This study achieves the first demonstration (experimental) of optical cloaking.

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JALA 2010;15(4):344–347.

1535-5535/\$36.00

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doi:10.1016/j.jala.2010.05.001

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Reference

Valentine, J.; Li, J.; Zentgraf, T.; Bartal, G.; Zhang, X. An optical cloak made of dielectrics. *Nat. Mater.* **2009**, *8*(7), 568–571.

A SELF-CONTAINED AND SELF-POWERED LAB-ON-A-CHIP

Using conventional microfabrication techniques, a self-contained microfluidic lab-on-a-chip device is developed and is capable of separating plasma from whole blood. Traditionally, the operation of these devices requires the integration of several components including power sources and pumps. However, this work is based on a push-button catalytic process that enables full self-containment and self-powering based on a catalytic oxygen generation process. In addition to plasma separation, this device is capable of multiplexed blood protein assaying, signifying an exciting advance in the automation, microfluidics, and lab-on-a-chip disciplines, among many others.

Affiliation

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Reference

Qin, L.; Vermesh, O.; Shi, Q.; Heath, J. R. Self-powered microfluidic chips for multiplexed protein assays from whole blood. *Lab Chip.* **2009**, *9*, 2016–2020.

POLYETHYLENE NANOFIBERS WITH REMARKABLE THERMAL CONDUCTIVITY

Polyethylene polymers are versatile and have previously been explored for a broad range of applications. With regard to their electrical characteristics, they have previously been noted for their insulating behavior. The discovery outlined by this study develops polyethylene nanofibers with millimeter-long dimensions possessing remarkable thermal conductivity values that exceed those possessed by half of the pure metals and open up significant opportunities for

their use as heat exchangers. Given the broad applicability and scalability of polyethylene, these nanofibers promise to impact areas from cell phone casings to computer chip packaging.

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Reference

Shen, S.; Henry, A.; Tong, J.; Zheng, R.; Chen, G. Polyethylene nanofibres with very high thermal conductivities. *Nat. Nanotechnol.* **2010**, *5*, 251–255.

MICROENGINEERED HYDROGELS FOR STEM CELL DIFFERENTIATION

Khademhosseini and colleagues fabricate an array of micro-wells from patterned hydrogels to control the size of stem cell aggregates, known as embryoid bodies (EBs), and to direct stem cells to differentiate into cardiomyocytes and endothelial cells. In large EBs, cardiogenesis is enhanced, whereas in small EBs, cells differentiate into endothelial cells. These differentiation patterns are shown to correspond to the expression of the signaling molecules, Wnt11 and Wnt5a. These results demonstrate that microengineered hydrogel micro-wells can be used to direct stem cell differentiation into therapeutically relevant cells or to help investigate the underlying biology of tissue formation.

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Reference

Hwang, Y. S.; Chung, B. G.; Ortmann, D.; Hattori, N.; Moeller, H. C.; Khademhosseini, A. Microwell-mediated control of embryoid body size regulates embryonic stem cell fate via differential expression of WNT5a and WNT11. *Proc. Natl. Acad. Sci. U.S.A.* **2009**, *106*, 16978–16983; Epub September 23, 2009, doi:10.1073/pnas.0905550106.

NANODIAMONDS SHINE AS TARGETED LABELING AGENTS

Nanodiamonds are being increasingly explored as biocompatible fluorescent labels for cell labeling as they do not photoblink and can be produced in large quantities for biological applications. Nanodiamonds are carbon-based particles that can range from the single-digit nanometer range to ~100 nanometers per particle. This work develops folate-functionalized nanodiamonds via polyethylene glycol cross-linking for enhanced uptake by HeLa cells. By providing real-time monitoring of internalization of this exciting material, important insight into receptor-mediated nanodiamond uptake is provided.

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Reference

Zhang, B.; Li, Y.; Fang, C. Y.; Chang, C. C.; Chen, C. S.; Chen, Y. Y.; Chang, H. C. Receptor-mediated cellular uptake of folate-conjugated fluorescent nanodiamonds: a combined ensemble and single-particle study. *Small*. **2009**, *5*(23), 2716–2721.

DYNAMIC FLUIDIC ARRAYS: HIGH-THROUGHPUT BIO-ANALYSIS

Fluidigm's dynamic arrays and integrated fluidic circuit technology have generated significant advances toward rapid and highly accurate genotyping. Because of their ability to handle extremely small sample volumes, in the picoliter range, as many as 1000 genes in a single cell have been studied. Fluidigm's technologies can yield significant findings at rapid time-scales. A recent study used the dynamic array technology for high-throughput single nucleotide polymorphism (SNP)

genotyping, demonstrating its relevance toward several areas of medicine. SNP analysis is a prevalent readout for patient susceptibility to serious physiological disorders including cancer, heart disease, and complications associated with diabetes, among many others.

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Reference

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ELECTROPHORETIC MANIPULATION OF POLYMERS FOR ENHANCED SEPARATIONS

Molecular manipulation and separation techniques form the building blocks for much of fundamental science; yet many separation challenges still remain. Synchronous Coefficient of Drag Alteration (SCODA), a novel molecular separation and concentration technique, is developed and aimed at addressing such challenges. SCODA takes advantage of physical properties associated with the nonlinear response of long charged polymers to electrophoretic fields, which defines a novel parameter for separating DNA from other molecules. This technique is applied to a wide range of samples, including DNA extraction from the Athabasca tar sands.

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Reference

Pel, J., et al., Nonlinear electrophoretic response yields a new parameter for separation of biomolecules. *Proc. Natl. Acad. Sci. U.S.A.* **2009**, *106*(35), 14796–14801.

ELECTRONIC NANOGAP SENSOR ARRAYS FOR BIOSENSING APPLICATIONS

Direct electronic signal transductions in nanodevices can significantly simplify the detection of biomolecules. In this work, a novel nanogap device and the corresponding detection scheme for ultrasensitive detections of nucleic acids is reported. Such nanogap-based detection scheme is demonstrated for the detection of two-model target DNAs: a 1446 bp full-length human protein kinase B-2 and a synthetic 200-bp oligonucleotide. A linear relationship between the conductance change and DNA concentration is obtained from 1.0 fM to 1.0 pM. The conductance significantly changes from 10^{-12} S for the control to a saturation value around 10^{-3} S.

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Reference

Roy, S.; Chen, X. J.; Li, M. H.; Peng, Y. F.; Anariba, F.; Gao, Z. Q. Mass-produced nanogap sensor arrays for ultrasensitive detection of DNA. *J. Am. Chem. Soc.* **2009**, *131*, 12211–12217.

ADAM: AUTONOMOUS LABORATORY ROBOTICS

A natural extension of the trend to ever-greater computer involvement in science is the concept of a Robot Scientist. This is a physically implemented laboratory automation system that exploits techniques from the field of artificial intelligence to execute cycles of scientific investigation. The Robot

Scientist “Adam” autonomously generates functional genomic hypotheses about the yeast *Saccharomyces cerevisiae* and experimentally tests them using laboratory automation. Adam’s conclusions are confirmed through manual experiments. Adam is the first physically implemented laboratory automation system demonstrated to be capable of the autonomous discovery of novel scientific knowledge.

Affiliation

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THANK YOU

The Journal of the Association for Laboratory Automation offers sincere thanks to the many scientific thought leaders who shared their achievements for consideration in this special feature and to the members of the JALA Editorial Board and other distinguished ALA volunteers who served on The JALA Ten review panel.