IGB NEWS

Upcoming Events

Monthly Profiles

Happenings at IGB

Image Of The Month

Research News

Department Announcements

Volume 12 Number 7

UPCOMING EVENTS

IGB Faculty Spotlight Lecture
January 21, 2020, 12:00 p.m.
612 Carl R. Woese Institute for Genomic Biology

Katy Heath, PhD
University of Illinois; Department of Plant Biology; IGB Faculty, Infection Genomics for One Health

Fox Family Innovation and Entrepreneurship Lecture
January 28, 2020, 12:00 p.m.
612 Carl R. Woese Institute for Genomic Biology

Rosemarie Truman, PhD
Founder & CEO, Board Member of The Center for Advancing Innovation

IGB Faculty Spotlight Lecture
February 11, 2020, 12:00 p.m.
612 Carl R. Woese Institute for Genomic Biology

Alison Bell, PhD
University of Illinois; Department of Evolution, Ecology and Behavior School of Integrative Biology; IGB Faculty, Gene Networks in Neural & Developmental Plasticity

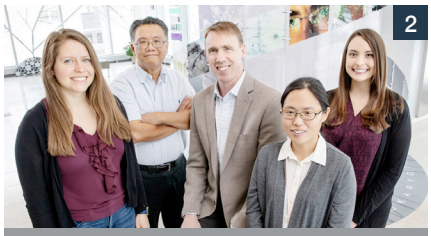
IGB Seminar - Special Science of Team Science Seminar
February 18, 2020, 12:00 p.m.
612 Carl R. Woese Institute for Genomic Biology

Jonathan Kramer, PhD
National Socio-Environmental Synthesis Center (SESYNC)

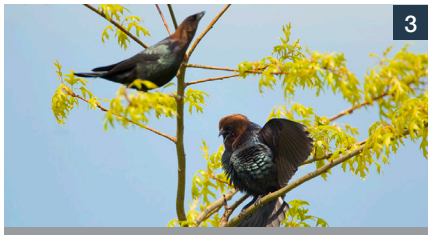
IGB Pioneers Seminar
February 25, 2020, 12:00 p.m.
612 Carl R. Woese Institute for Genomic Biology

Joseph Costello, PhD
University of California, San Francisco; Professor, School of Medicine

FEATURED NEWS



App discovers dozens of potential new antibiotics

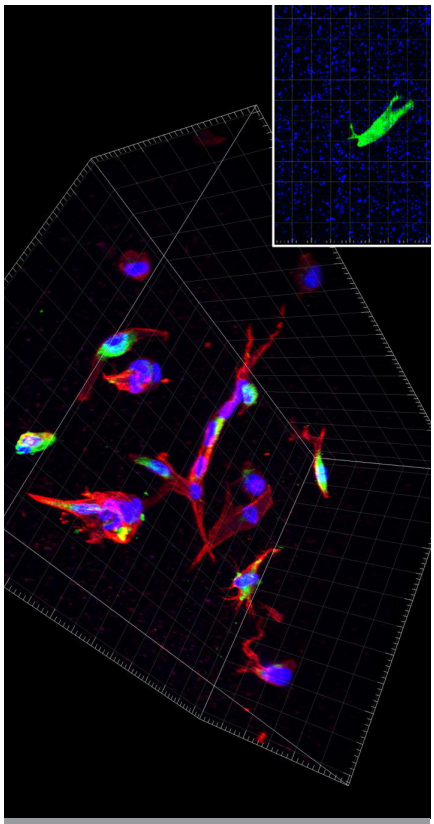


Signature cowbird call unlocks song learning

Monthly Profile: Andrew Smith

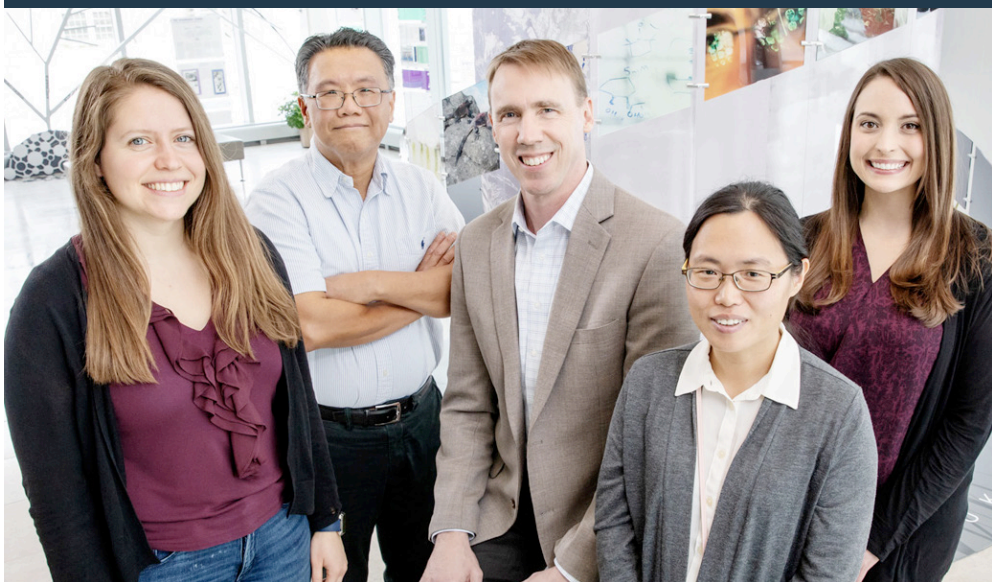
On the Grid: Happenings at IGB

IMAGE OF THE MONTH



This month features primary human hepatic stellate cells cultured in synthetic polyethylene glycol gels with RGD for 5 days. Red is the phalloidin actin stain, green the antibody collagen stain and blue the DAPI nucleus stain. Inset shows calcein-stained hepatic stellate cell (green) encapsulated in a synthetic polyethylene glycol gel embedded with fluorescent beads (blue). A healthy cell's cytoskeleton is depolymerized using Cytochalasin D. Change in bead position is captured and analyzed to calculate the three-dimensional traction force of the cell. Zeiss LSM 880 with Imaris Software, Hyeon Ryoo, Gregory Underhill Lab.

FEATURE



Dozens of potential new antibiotics discovered
with free online app

A new web tool speeds the discovery of drugs to kill Gram-negative bacteria, which are responsible for the vast majority of antibiotic-resistant infections and deaths. The tool also offers insights into discrete chemical changes that can convert drugs that kill other bacteria into drugs to fight Gram-negative infections. The team proved the system works by modifying a Gram-positive drug and testing it against three different Gram-negative bacterial culprits in mouse sepsis. The drug was successful against each.

Researchers report their findings in the journal Nature Microbiology.

"It's really hard to find new antibiotics for Gram-negative pathogens, because these bacteria have an extra membrane, an outer membrane, that's very good at keeping antibiotics out," said University of Illinois chemistry professor Paul Hergenrother (ACPP leader/MMG), who led the research.

The challenge is so profound that no new classes of drugs to fight Gram-negative bacteria have been approved by the Food and Drug Administration in 50 years, Hergenrother said.

"A few years ago, we discovered the molecular features that allowed an antibiotic compound to surpass this barrier," he said. "Now, we've developed a tool to help others do this as well."

The new app, called eNTRyway, can quickly evaluate potential drug compounds to determine if they have the molecular characteristics that will enable them to cross the membrane and accumulate inside Gram-negative bacteria.

Developed by graduate student Bryon Drown, the app also can point to ways of modifying existing drugs – for example, those known to work against Gram-positive bacteria – to convert them into potent killers of Gram-negative pathogens.

As a demonstration of this latter capability, postdoctoral researcher and study co-lead author Erica Parker used the tool to identify a drug already in use against Gram-positive infections that – with a basic chemical modification – could potentially be converted to fight Gram-negative bacteria. By adding a positively charged chemical group known as an amine to the drug, Parker created a compound that, further tests revealed, accumulated in Gram-negative bacteria and was effective against several types of Gram-negative infections in mice.

A University of Illinois team developed a web app that can identify drug compounds that will accumulate in Gram-negative bacteria, overcoming a major hurdle in the development of new drugs to kill these dangerous pathogens. The team includes, from left, graduate student Emily Geddes, pathobiology professor Gee Lau, chemistry professor Paul Hergenrother, postdoctoral researcher Hyang Yeon Lee, and postdoctoral researcher Erica Parker.

The process of identifying the compound and modifying it took only a few weeks, Hergenrother said.

"Keep in mind that before this, over 100 derivatives of this same compound had been made. We found them in patents and papers," he said. "And none of these other derivatives had notable Gram-negative activity."

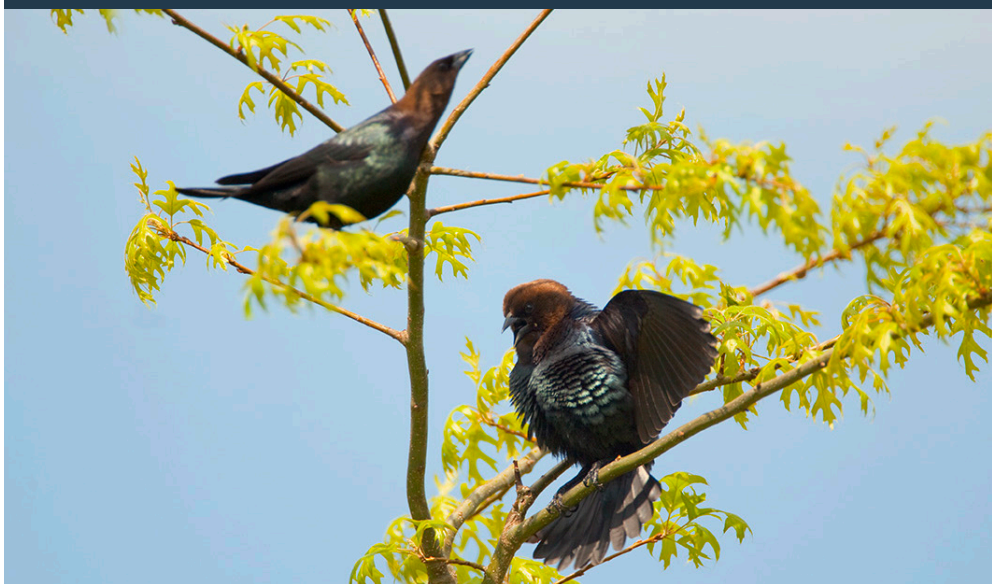
Hergenrother and his colleagues have so far identified more than 60 antibiotics that are effective only against Gram-positive bacteria but can be converted into drugs to fight Gram-negative infections. These compounds kill bacteria in a variety of different ways. The newly created drug, known as Debio-1452-NH3, interferes with fatty acid synthesis in bacterial – but not mammalian – cells.

Hergenrother said the new tool will speed the process of drug discovery to fight the burgeoning problem of antibiotic-resistant infections.

"We can use this tool to rapidly identify compounds that accumulate in Gram-negative bacteria," he said.

The National Institutes of Health supported this research. ■

Written by Diana Yates. Photo by L. Brian Stauffer.



Signature call in cowbirds is the password that unlocks song learning

They say it takes a village to raise a child. But if you are a cowbird, left by your parents to be hatched and raised in the nest of unwitting foster parents, how do you know who your village is? If the signature behaviors of your bird identity are not instinctive, how do you know who to learn them from?

Cowbirds, like cuckoos and a few others, stealthily lay their eggs in the nests of other birds and leave their young to be raised by parents of another species. Mark Hauber (GNDP), Harley Jones Van Cleave Professor of Host-Parasite Interactions in the Department of Evolution, Ecology and Behavior at the University of Illinois in Urbana-Champaign, has studied these brood parasitic birds throughout his career. In a report available online this week in Current Biology, he and his coauthors shared the culmination of a decades-long effort to work out how cowbirds learn the courtship song that enables males to attract mates, and females to recognize them.

"I did my PhD on this question . . . how [cowbirds] recognize their own species when they have never seen their own species, which is of course what brood parasites do in general," said Hauber, who is also a member of the Carl R. Woese Institute for Genomic Biology at Illinois, said. "We wanted to finalize the research and ask the question, but does the password actually change the way you learn?"

The cowbird's password, as Hauber and other songbird researchers refer to it, is a sound called the chatter call that to the human ear might sound a little bit like a monkey's chattering or a fast-forwarded version of a rodent's squeaks. To a young cowbird, Hauber and others believe it is an avian shibboleth; a sound that reaches into their brain and whispers, hey friend! This is the cowbird song. It's your song too, so pay attention.

Hauber wanted to confirm that this hypothesized message yields tangible results—do cowbirds actually learn better after hearing the chatter call? To answer this question, Hauber worked with then-postdoctoral researcher Matthew Louder and lab manager Amber Louder, former IGB Fellows Sarah London and Christopher Balakrishnan, and East Carolina University graduate student Robert Driver.

The team of researchers hand-raised young male cowbirds, playing the juveniles pre-recorded calls: either a canary song paired with a cowbird chatter call, or the same canary song paired with a mourning dove coo.

"It could be that just coupling the canary song with any noise will trigger learning," Hauber said. "Using the canary songs and then coupling it to the dove coo made a really nice negative control;" in other words, if any call paired with a song could trigger learning, the cowbirds would not perform the canary song any better when it was paired with their own species' chatter.

Instead, Hauber and his colleagues found the opposite. Although the cowbirds never became fluent in the canary song—the team speculated that their differing anatomy or the lack of other social cues made it difficult for them to learn—it was immediately apparent that male birds who heard the chatter learned to produce a more canary-like song.

"I could listen to these songs, and I could tell that this was a chatter call tutor canary song because it was simpler; it had more structure, this sound always follows that sound," Hauber said. "I could hear it from my own ears that it was going to work . . . it's one of those exciting moments when you're doing the stats but your ear is already telling you something."

Hauber's ear for birdsong told him the truth. Compared with the songs of the coo-trained birds, the songs of the chatter-trained bird were significantly more structured and more similar to the genuine canary song.

Assessing whether female cowbirds who heard the different call combinations had different learning experiences was more difficult, in part because the young females were not sexually mature enough to express song and mate preferences. Instead, the researchers repeatedly serenaded the juvenile females with one canary's song paired with a chatter, and another canary's song paired with a dove coo. They then played each female one of the two canary songs and analyzed subsequent gene activity in regions of the brain involved in song recognition. They also analyzed gene activity in response to canary song in the brains of chatter- and coo-trained males.

"We knew about a set of genes in the zebra finches that had to do with familiarity recognition and so we looked for those," Hauber said; in addition, he said, the team performed more open-ended search for groups of genes with related functions that might be involved in each bird's response to hearing a particular song. "That yielded these neuroplasticity and neurofamiliarity types of genes for the male and the females, respectively."

In the brains of the males that had previously heard a canary song paired with a cowbird chatter, the canary song was noteworthy; the genes that responded when the male heard it again were related to altering and strengthening connections between brain cells, supporting continued learning of the song. In females, who use songs to recognize and distinguish mates, gene activity data suggested that the canary song previously paired with a chatter was more familiar, while that paired with the coo was more startlingly novel, as though no memory of hearing it before had been retained.

Hauber is excited to have rounded out a scientific answer to an intriguing question of cowbird natural history, but also to see how this knowledge could be leveraged to better understand the biology of many other species.

"To show that the chatter call impacts learning was never done and now we have done it," he said. "Cowbirds are great because it's this system where instinct and learning and constraints come together . . . we need to seek out the contexts in which these early guided learning mechanisms should be important."

Christopher Balakrishnan is now an Associate Professor of Biology at East Carolina University. Sarah London is an Associate Professor of Psychology at the University of Chicago. Matthew Louder is now a postdoctoral researcher at the University of Tokyo. This work was supported by the National Science Foundation. ■

Written by Claudia Lutz. Photo by M. Read.

MONTHLY PROFILE

Andrew Smith is an associate professor of bioengineering and a member of the Carl R. Woese Institute for Genomic Biology. He is the Associate Head of Undergraduate Programs in the Department of Bioengineering.

Andrew Smith

Lighting up the molecular dark

When Andrew Smith (ONC-PM) began his research career as an undergraduate student, he was looking for a way to reconcile several seemingly disparate interests, including biomedicine, humanitarian research, and technological innovation. When he attended the annual conference of the Biomedical Engineering Society, serendipitously held that year in Atlanta where he was attending Georgia Tech, he found his intellectual niche.

"I thought it was the coolest stuff I'd ever seen," Smith said. "That really hooked me. I joined some research labs and I knew instantly: this is what I want to be doing."

As Smith progressed to a graduate degree in bioengineering and then to an NIH-funded fellowship at Emory University, he focused on twin research goals that his lab at Illinois continues to pursue: development of nanomaterials to aid in biosensing related to diagnostics and imaging and of those that enable targeted drug delivery.

"Most of what we do is based on developing new quantitative ways to analyze biology," Smith said. "That's why we make molecular probes, that's why we study things like individual cells in microscopy, and that's why we make also diagnostic agents for blood analysis, all of these are connected by quantitative analysis and imaging."

The Smith laboratory's work is helping to push quantitation in the molecular realm to a new level; in recent publications, they share new methodologies for counting individual molecules of growth factor, microRNAs, and other potential biomarkers. A key aspect of this work, focusing on interactions among substances and strategies for targeting specific structures, cell types, or tissues, is what connects it to the lab's second aim of drug delivery. Smith hopes that someday, these two aims might be united through the development of multimodal molecules that could act as both probes and a therapeutic delivery systems.

"We may have a material that we know targets one cell type, which for us is usually a macrophage, and then we're envisioning what could allow us to do that's beneficial," he said. The optimal function could either be medical or molecular imaging, "Or we could also eventually use it to alter that cell type when it's in a disease state . . . often there's only value in one side, it seems."

One stumbling-block for targeted drug delivery is the body's own immune system. Smith's lab has worked with this limitation by using it as a strength, and targeting macrophages, which are likely to encounter introduced substances as a part of the immune response those substances provoke.

> *"This whole field of targeted delivery and drug delivery systems, it's fundamentally limited by this," he said. "You're actually targeting the immune system by accident. So we're trying to just focus on that, something we know we can do."*

"This whole field of targeted delivery and drug delivery systems, it's fundamentally limited by this," he said. "You're actually targeting the immune system by accident. So we're trying to just focus on that, something we know we can do."

Alongside the healthy growth of his research program, Smith has found great satisfaction in honing his capabilities as a teacher and mentor for graduate students in his lab. He appreciates the way that the breadth of his own past research experiences have given him greater versatility even as his academic focus has sharpened, and he enjoys thinking about how to help position his own students for success.

"In the last two years, I've had my first grad students graduate, and that's been really a motivating factor," he said. "They have five years, potentially, to be here; what are they going to look like five years from now, what are they missing right now that we can focus on, and what credentials do they need to have to get to the next step of their careers?"

He also appreciates the supportive community he has found among Illinois faculty and research staff as he continues to advance his career.

"There are probably 10-15 campuses in America that have facilities that are somewhat equivalent where I could function and do high-level research, but of those this is the only place that I thought . . . it's just a very good community of people," Smith said. "You have great mentors; people care."

The mentorship and collaboration he found within the Micro and Nanotechnology Laboratory (MNTL), particularly from MNTL Director Brian Cunningham, as well as a crucial working relationship with IGB's Core Facilities microscopy team, led to Smith's membership in one of IGB's newer research themes, Omics Nanotechnology for Cancer Precision Medicine (ONC-PM). Even within the collaborative environment at Illinois, he has found participation in IGB's model of team science refreshingly novel.

"It's a very different way of thinking about research, and I like it," he said. "I think that as a young theme . . . we're still putting pieces together, so it's very exciting right now to see how it's all working." ■

Written by Claudia Lutz.
Photo by L. Brian Stauffer.

ON THE GRID
HAPPENINGS AT THE IGB

AWARDS

LISA AINSWORTH, ANDREW ALLEYNE, AND PAUL HERGENROTHER

Lisa Ainsworth, USDA Agricultural Research Service (GEGC), Andrew Alleyne, Professor of Mechanical Science and Engineering (BSD), and Paul Hergenrother, Professor of Chemistry (ACPP Theme Leader/MMG) were elected 2019 Fellows of the American Association for the Advancement of Science.

STEPHEN BOPPART AND DAVID KRANZ

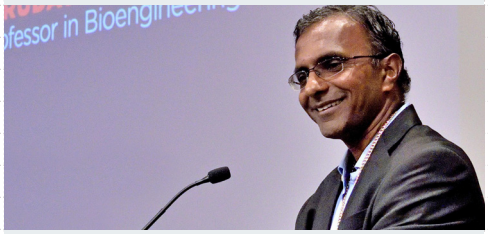
Stephen Boppart, Abel Bliss Professor of Engineering (RBTE) and David Kranz, Phillip A. Sharp Professor of Biochemistry (ACPP) were named Fellows of the National Academy of Inventors (NAI), which highlights academic inventors who have demonstrated a spirit of innovation in creating or facilitating outstanding inventions with an impact on quality of life, economic development and societal welfare.

JAMES O'DWYER

James O'Dwyer, Associate Professor of Plant Biology, was appointed a Center for Advanced Study (CAS) Associate, Class of 2020-2021, pending BOT approval.

MARTIN BURKE

Martin Burke, Professor of Chemistry (MMG), received the Mukaiyama Award from the Society of Synthetic Organic Chemistry, Japan, for pioneering the field of molecular prosthetics and the development of an automated Lego-like platform for democratizing small molecule synthesis.



JOSEPH IRUDAYARAJ

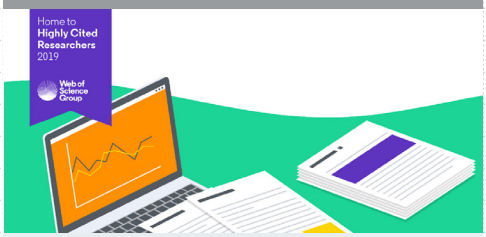
Joseph Irudayaraj, Founder Professor in Bioengineering (ONC-PM) was elected a 2019 Fellow of the Biomedical Engineering Society (BMES) for demonstrating exceptional achievement in the field of biomedical engineering.

MOOCS

IGB MOOCS

In partnership with Coursera, the IGB has seen great success with our MOOC "Genomics: Decoding the Universal Language of Life" with over 12,100 total learners to date. Our MOOC in partnership with the College of Law, "Genomics for Law," has seen over 1400 total learners. And "Emergence of Life," the MOOC led by Professor of Geology and Microbiology Bruce Fouke (BCXT) has amassed an amazing 362,000 total learners since launching in 2014!

RANKING



HIGHLY CITED RESEARCHERS

Three IGB members have been named to the 2019 Highly Cited Researchers list, a global listing of scientists who produced the past decade's most influential papers.

The IGB faculty include USDA Agricultural Research Service and crop sciences and plant biology adjunct professor Lisa Ainsworth (CABBI/GEGC, highly cited for cross-field impact), crop sciences and plant biology professor Stephen P. Long (BSD/CABBI/GEGC, cross-field), and plant biology professor Donald Ort (GEGC leader/BSD/CABBI, plant and animal science).

IGEM

UNIVERSITY OF ILLINOIS IGEM TEAM

Sophie Liu, Sachin Jajoo, Jenny Ward, Pauline Ostoja-Starzewski, and Ally Choi of the University of Illinois iGEM team chose as their project research into how glyphosate can be degraded into nontoxic components. They focused on glyphosate degradation in bodies of water, as there are few aquatic microorganisms that can naturally degrade it. This group of undergraduate students, guided by several researchers at CABBI and the IGB, based their project around the degradation pathway found in Pseudomonas pseudomallei 22, a bacterium naturally found in the soil.

DEPARTMENT ANNOUNCEMENTS

PURCHASING

CATERED EVENTS

A reminder that all catered events need a purchase order in advance of the event. The one exception is using University Catering. This link has full information, or reach out to IGB Purchasing for any assistance or questions, they are always happy to help. ■

CNRG

100GB NETWORK UPGRADE

On October 18, the IGB upgraded our connection to the campus research network to 100Gbps, an increase of 1000%. If you need to send or receive large amounts of research data to organizations outside of the University, please let us know. By leveraging this new connection, the amount of time needed to transfer files can be greatly reduced.

SECURITY TRAINING CLASS

CNRG would like to offer a big thank you to everyone who participated in this Fall's security training classes. For anyone who missed this class and would like to view a recording, it can be found here. ■

OPERATIONS & FACILITIES

SHIPPING AND RECEIVING POLICY PERSONAL PACKAGES

Shipping & receiving of personal packages to the Carl R. Woese Institute for Genomic Biology is prohibited, only items associated with University projects or research may be shipped or received. Please contact Jesse Southern, Director of IGB Operations and Facilities, with any questions. ■

IGB BUILDING HOLIDAY SCHEDULE AND INFORMATION

December 24 to January 1

IGB building access and services will be reduced. All exterior doors will be locked. Card access doors are only accessible with a valid IGB prox card. Please visit this link for full information. Full services will resume on Thursday, January 2. ■

RECENT PUBLICATIONS

Please include your connection to the IGB in your author byline when submitting publications, as it will greatly help track potential newsworthy items and increase the possibility of coverage.

Tran, H., Kanzaki, S., Triest, L., Hormaza, I., Kuk, N. J., Ming, R., ... Van Damme, P. (2019). Analysis of genetic diversity of lychee (*Litchi chinensis Sonn.*) and wild forest relatives in the Sapindaceae from Vietnam using microsatellites. *Genetic Resources and Crop Evolution*, 66(8), 1653-1669. https://doi.org/10.1007/s10722-019-00837-y

Winter, J., Luu, A., Gapinske, M., Manandhar, S., Shirguppe, S., Woods, W. S., ... Perez-Pinera, P. (2019). Author Correction: Targeted exon skipping with AAV-mediated split adenine base editors (*Cell Discovery*, (2019), 5, 1, (41), 10.1038/s41421-019-0109-7). Cell Discovery, 5(1), [56]. https://doi.org/10.1038/s41421-019-0125-7

Zhou, P., Fatima, M., Ma, X., Liu, J., & Ming, R. (2019). Auxin regulation involved in gynoecium morphogenesis of papaya flowers. *Horticulture Research*, 6(1), [119]. https://doi.org/10.1038/s41438-019-0205-8

Ragunathan, P. T., & Vanderpool, C. K. (2019). Cryptic-Prophage-Encoded Small Protein DicB Protects *Escherichia coli* from Phage Infection by Inhibiting Inner Membrane Receptor Proteins. *Journal of bacteriology*, 201(23). https://doi.org/10.1128/JB.00475-19

Fischer-Hwang, I., Ochoa, I., Weissman, T., & Hernaez, M. (2019). Denoising of Aligned Genomic Data. *Scientific reports*, 9(1), [15067]. https://doi.org/10.1038/s41598-019-51418-z

Kandel, M. E., Hu, C., Naseri Kouzehgarani, G., Min, E., Sullivan, K. M., Kong, H., ... Popescu, G. (2019). Epi-illumination gradient light interference microscopy for imaging opaque structures. *Nature communications*, 10(1), [4691]. https://doi.org/10.1038/s41467-019-12634-3

Lee, J., Schwieter, K. E., Watkins, A. M., Kim, D. S., Yu, H., Schwarz, K. J., ... Jewett, M. C. (2019). Expanding the limits of the second genetic code with ribozymes. *Nature communications*, 10(1), [5097]. https://doi.org/10.1038/s41467-019-12916-w

RECENT PUBLICATIONS

Wang, M., Zhang, J., Xu, H., & Golding, I. (2019). Measuring transcription at a single gene copy reveals hidden drivers of bacterial individuality. *Nature Microbiology*, 4(12), 2118-2127. https://doi.org/10.1038/s41564-019-0553-z

Thomey, M. L., Slattery, R. A., Köhler, I. H., Bernacchi, C. J., & Ort, D. R. (2019). Yield response of field-grown soybean exposed to heat waves under current and elevated [CO2]. *Global change biology*, 25(12), 4352-4368. https://doi.org/10.1111/gcb.14796

Dinh, H. V., Suthers, P. F., Chan, S. H. J., Shen, Y., Xiao, T., Deewan, A., ... Maranas, C. D. (2019). A comprehensive genome-scale model for *Rhodosporidium toruloides* IFO0880 accounting for functional genomics and phenotypic data. *Metabolic Engineering Communications*, 9, [e00101]. https://doi.org/10.1016/j.mec.2019.e00101

Andrade, F. C. D., Kramer, K. Z., Greenlee, A., Williams, A. N., & Mendenhall, R. (2019). Impact of the Chicago Earned Income Tax Periodic Payment intervention on food security. *Preventive Medicine Reports*, 16, [100993]. https://doi.org/10.1016/j.pmedr.2019.100993

Liu, W., & Irudayaraj, J. (2019). Understanding the dynamics and structure of epigenetic states with single-molecule fluorescence microscopy. *Current Opinion in Biomedical Engineering*, 12, 18-24. https://doi.org/10.1016/j.cobme.2019.08.010

Chowdhary, G., Gazzola, M., Krishnan, G., Soman, C., & Lovell, S. (2019). Soft Robotics as an Enabling Technology for Agroforestry Practice and Research. *Sustainability*, 11(23), [6751]. https://doi.org/10.3390/su11236751

Wang, X., Song, Z., Tan, Z., Zhu, L., Xue, T., Lv, S., ... Cheng, J. (2019). Facile Synthesis of Helical Multiblock Copolypeptides: Minimal Side Reactions with Accelerated Polymerization of N-Carboxyanhydrides. *ACS Macro Letters*, 8(11), 1517-1521. https://doi.org/10.1021/acsmacrolett.9b00784

Lin, Y., Yang, Z., Lake, R. J., Zheng, C., & Lu, Y. (2019). Enzyme-Mediated Endogenous and Bioorthogonal Control of a DNAzyme Fluorescent Sensor for Imaging Metal Ions in Living Cells. *Angewandte Chemie - International Edition*, 58(47), 17061-17067. https://doi.org/10.1002/anie.201910343

Parker, E. N., Drown, B. S., Geddes, E. J., Lee, H. Y., Ismail, N., Lau, G. W., & Hergenrother, P. J. (2019). Implementation of permeation rules leads to a FabI inhibitor with activity against Gram-negative pathogens. *Nature Microbiology*. https://doi.org/10.1038/s41564-019-0604-5

Singharoy, A., Maffeo, C., Delgado-Magnero, K. H., Swainsbury, D. J. K., Sener, M., Kleinekathöfer, U., ... Schulten, K. (2019). Atoms to Phenotypes: Molecular Design Principles of Cellular Energy Metabolism. *Cell*, 179(5), 1098-1111.e23. https://doi.org/10.1016/j.cell.2019.10.021

HamediRad, M., Chao, R., Weisberg, S., Lian, J., Sinha, S., & Zhao, H. (2019). Towards a fully automated algorithm driven platform for biosystems design. *Nature communications*, 10(1), [5150]. https://doi.org/10.1038/s41467-019-13189-z

Heldenbrand, J. R., Baheti, S., Bockol, M. A., Drucker, T. M., Hart, S. N., Hudson, M. E., ... Mainzer, L. S. (2019). Recommendations for performance optimizations when using GATK3.8 and GATK4. *BMC bioinformatics*, 20(1), [557]. https://doi.org/10.1186/s12859-019-3169-7

Schmidt, J. E., Kent, A. D., Brisson, V. L., & Gaudin, A. C. M. (2019). Agricultural management and plant selection interactively affect rhizosphere microbial community structure and nitrogen cycling. *Microbiome*, 7(1), [146]. https://doi.org/10.1186/s40168-019-0756-9

Bailey-Serres, J., Parker, J. E., Ainsworth, E. A., Oldroyd, G. E. D., & Schroeder, J. I. (2019). Genetic strategies for improving crop yields. *Nature*, 575(7781), 109-118. https://doi.org/10.1038/s41586-019-1679-0

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