

**On the Cover:** Plants are known to defend themselves from the onslaught of herbivore attack with an arsenal of defense compounds by recognizing chemical cues from insect oral secretions, oviposition materials and frass. Accumulation of herbivore frass in enclosed feeding sites such as the maize whorl constitutes one of the most copious cues of herbivory. Although, several insect-derived elicitors from oral secretions are known to induce herbivore-defenses in plants, frass-related chemical cues that alter plant defenses are generally unknown. In this issue, Ray et al. identified two maize chitinases, Pr4 and Endochitinase A, from fall armyworm frass that suppress herbivore-induced defenses in plants. These plant chitinases are induced in the host tissue in response to insect feeding, however, they do not affect the insect's performance. Subsequently, the insect deposits these chitinases on the host with their frass, which in turn suppresses herbivore-induced defenses and increases herbivore performance. This co-option of host defenses ultimately benefits the insect and differs from the induction of herbivore defenses by insect oral secretions in many host-herbivore systems. Cover Image Credit: Nick Sloff, Multimedia Specialist, Department of Entomology, The Pennsylvania State University, University Park, PA.

## ON THE INSIDE

Peter V. Minorsky

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## BREAKTHROUGH TECHNOLOGIES

<sup>[OPEN]</sup>Comparative Transcriptomic Approaches Exploring Contamination Stress Tolerance in *Salix* sp. Reveal the Importance for a Metaorganismal de Novo Assembly Approach for Nonmodel Plants. Nicholas J. B. Brereton, Emmanuel Gonzalez, Julie Marleau, Werther Guidi Nissim, Michel Labrecque, Simon Joly, and Frederic E. Pitre

*Shared metatranscriptomic responses to petroleum hydrocarbon contamination in ten cultivars of field-grown willow expose native and foreign organism gene expression of effective phytoremediation.*

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Novel Approach for High-Throughput Metabolic Screening of Whole Plants by Stable Isotopes. Lisa Maria Dersch, Veronique Beckers, Detlev Rasch, Guido Melzer, Christoph Bolten, Katina Kiep, Horst Becker, Oliver Ernst Bläsing, Regine Fuchs, Thomas Ehrhardt, and Christoph Wittmann

*Stable isotopic labeling combined with combustion isotope ratio mass spectrometry elucidates metabolic properties of whole plants under strictly controlled physiological conditions.*

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<sup>[OPEN]</sup>Transcriptomic Signature of the SHATTERPROOF2 Expression Domain Reveals the Meristematic Nature of Arabidopsis Gynoecial Medial Domain. Gonzalo H. Villarino, Qiwen Hu, Silvia Manrique, Miguel Flores-Vergara, Bhupinder Sehra, Linda Robles, Javier Brumos, Anna N. Stepanova, Lucia Colombo, Eva Sundberg, Steffen Heber, and Robert G. Franks

*Transcriptional profiles of spatially and temporally restricted cell populations from the Arabidopsis gynoecium reveals the meristematic nature of the gynoecial medial domain.*

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## RESEARCH REPORTS

<sup>[OPEN]</sup>The Histone Deacetylase Complex 1 Protein of Arabidopsis Has the Capacity to Interact with Multiple Proteins Including Histone 3-Binding Proteins and Histone 1 Variants. Giorgio Perrella, Craig Carr, Maria A. Asensi-Fabado, Naomi A. Donald, Katalin Páldi, Matthew A. Hannah, and Anna Amtmann

*A conserved ancestral domain of the intrinsically disordered protein Histone Deacetylase Complex 1 (HDC1) binds H3-binding proteins and H1 variants.*

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Gatekeeper Tyrosine Phosphorylation of SYMRK Is Essential for Synchronizing the Epidermal and Cortical Responses in Root Nodule Symbiosis. *Sudip Saha, Anindita Paul, Laura Herring, Ayan Dutta, Avisek Bhattacharya, Sandip Samaddar, Michael B. Goshe, and Maitrayee DasGupta*

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## RESEARCH ARTICLES

### BIOCHEMISTRY AND METABOLISM

[OPEN] Activation of the Stt7/STN7 Kinase through Dynamic Interactions with the Cytochrome *b<sub>6</sub>f* Complex. *Alexey Shapiguzov, Xin Chai, Geoffrey Fucile, Paolo Longoni, Lixin Zhang, and Jean-David Rochaix*

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[OPEN] Asparagus IRX9, IRX10, and IRX14A Are Components of an Active Xylan Backbone Synthase Complex that Forms in the Golgi Apparatus. *Wei Zeng, Edwin R. Lampugnani, Kelsey L. Picard, Lili Song, Ai-Min Wu, Isabela M. Farion, Jia Zhao, Kris Ford, Monika S. Doblin, and Antony Bacic*

*Xylan biosynthesis in the Golgi apparatus is affected by IRX9, IRX10, and IRX14A in Asparagus.*

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[OPEN] Cellulose Deficiency Is Enhanced on Hyper Accumulation of Sucrose by a H<sup>+</sup>-Coupled Sucrose Symporter. *Trevor H. Yeats, Hagit Sorek, David E. Wemmer, and Chris R. Somerville*

*The cellulose deficiency of the *sho3svl1* mutant is enhanced by the uptake of exogenous sucrose, which results in carbon redirection from cellulose to starch biosynthesis.*

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[OPEN] Evidence for a Role for NAD(P)H Dehydrogenase in Concentration of CO<sub>2</sub> in the Bundle Sheath Cell of *Zea mays*. *Richard B. Peterson, Neil P. Schultes, Neil A. McHale, and Israel Zelitch*

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Glucosylation of 4-Hydroxy-2,5-Dimethyl-3(2H)-Furanone, the Key Strawberry Flavor Compound in Strawberry Fruit. *Chuankui Song, Xiaotong Hong, Shuai Zhao, Jingyi Liu, Katja Schulenburg, Fong-Chin Huang, Katrin Franz-Oberdorf, and Wilfried Schwab*

*UDP-glucose:4-hydroxy-2,5-dimethyl-3(2H)-furanone glucosyltransferases were identified in strawberry fruit, and the position and nature of the amino acid residues important for the catalytic properties of these proteins were determined.*

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[OPEN] Modularity of Conifer Diterpene Resin Acid Biosynthesis: P450 Enzymes of Different CYP720B Clades Use Alternative Substrates and Converge on the Same Products. *Katrin Geisler, Niels Berg Jensen, Macaire M.S. Yuen, Lina Madilao, and Jörg Bohlmann*

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Xylans Provide the Structural Driving Force for Mucilage Adhesion to the Arabidopsis Seed Coat. *Marie-Christine Ralet, Marie-Jeanne Crépeau, Jacqueline Vigouroux, Joseph Tran, Adeline Berger, Christine Sallé, Fabienne Granier, Lucy Botran, and Helen M. North*

*Arabidopsis seed mucilage contains a population of RG-I with xylan side branches that mediate the adsorption of mucilage to cellulose microfibrils in vitro.*

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[OPEN] *WRINKLED1* Rescues Feedback Inhibition of Fatty Acid Synthesis in Hydroxylase-Expressing Seeds. Neil D. Adhikari, Philip D. Bates, and John Browse

*Rescuing the feedback inhibition of fatty acid synthesis in castor hydroxylase-expressing Arabidopsis seeds increases ricinoleic acid accumulation.*

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## CELL BIOLOGY

[OPEN] Defects in Peroxisomal 6-Phosphogluconate Dehydrogenase Isoform PGD2 Prevent Gametophytic Interaction in *Arabidopsis thaliana*. Christian Hölscher, Marie-Christin Lutterbey, Hannes Lansing, Tanja Meyer, Kerstin Fischer, and Antje von Schaewen

*Oxidative pentose-phosphate pathway reactions are required for reproduction.*

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[OPEN] Development of Polyspermic Rice Zygotes. Erika Toda, Yukinosuke Ohnishi, and Takashi Okamoto

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[OPEN] Differential Regulation of Clathrin and Its Adaptor Proteins during Membrane Recruitment for Endocytosis. Chao Wang, Tianwei Hu, Xu Yan, Tingting Meng, Yutong Wang, Qingmei Wang, Xiaoyue Zhang, Ying Gu, Clara Sánchez-Rodríguez, Astrid Gadeyne, Jinxing Lin, Staffan Persson, Daniël Van Damme, Chuanyou Li, Sebastian Y. Bednarek, and Jianwei Pan

*Auxin and salicylic acid differentially affect clathrin recruitment to regulate endocytosis.*

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[OPEN] OsDMC1 Is Not Required for Homologous Pairing in Rice Meiosis. Hongjun Wang, Qing Hu, Ding Tang, Xiaofei Liu, Guijie Du, Yi Shen, Yafei Li, and Zhukuan Cheng

*OsDMC1, a conserved recombinase, maintains the stability of the single-end invasion process but is not required for homologous pairing in rice, which is quite different from the DMC1 homologs identified so far in other organisms.*

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[OPEN] Anisotropic Cell Expansion Is Affected through the Bidirectional Mobility of Cellulose Synthase Complexes and Phosphorylation at Two Critical Residues on CESA3. Shaolin Chen, Honglei Jia, Heyu Zhao, Dan Liu, Yanmei Liu, Boyang Liu, Stefan Bauer, and Chris R. Somerville

*Phosphorylation of a subunit of cellulose synthase differentially alters the rate at which cellulose synthase moves in both directions along microtubules, thereby impacting growth and development.*

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[OPEN] Role of SKD1 Regulators LIP5 and IST1-LIKE1 in Endosomal Sorting and Plant Development. Rafael Andrade Bueno, Julio Paez-Valencia, Nathan D. Miller, Kaija Goodman, Christoph Spitzer, Edgar P. Spalding, and Marisa S. Otegui

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Relationships of Leaf Net Photosynthesis, Stomatal Conductance, and Mesophyll Conductance to Primary Metabolism: A Multispecies Meta-Analysis Approach. Jorge Gago, Danilo de Menezes Daloso, Carlos María Figueroa, Jaume Flexas, Alisdair Robert Fernie, and Zoran Nikoloski

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[<sup>OPEN</sup>]The Cytoplasmic Carbonic Anhydrases  $\beta$ CA2 and  $\beta$ CA4 Are Required for Optimal Plant Growth at Low CO<sub>2</sub>. Robert J. DiMario, Jennifer C. Quebedeaux, David J. Longstreth, Maheshi Dassanayake, Monica M. Hartman, and James V. Moroney

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[<sup>OPEN</sup>]A Formate Dehydrogenase Confers Tolerance to Aluminum and Low pH. He Qiang Lou, Yu Long Gong, Wei Fan, Jia Meng Xu, Yu Liu, Meng Jie Cao, Ming-Hu Wang, Jian Li Yang, and Shao Jian Zheng

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[<sup>OPEN</sup>]A Drought-Inducible Transcription Factor Delays Reproductive Timing in Rice. Chunyu Zhang, Jun Liu, Tao Zhao, Adam Gomez, Cong Li, Chunsheng Yu, Hongyu Li, Jianzhong Lin, Yuanzhu Yang, Bin Liu, and Chentao Lin

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[<sup>OPEN</sup>]Arabidopsis CALCINEURIN B-LIKE10 Functions Independently of the SOS Pathway during Reproductive Development in Saline Conditions. Shea M. Monihan, Courtney A. Magness, Ramin Yadegari, Steven E. Smith, and Karen S. Schumaker

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[OPEN]Critical Roles of Vacuolar Invertase in Floral Organ Development and Male and Female Fertilities Are Revealed through Characterization of GhVIN1-RNAi Cotton Plants. Lu Wang and Yong-Ling Ruan

*Genetic, developmental, and gene expression analyses of GhVIN1-RNAi cotton plants reveal critical roles of vacuolar invertase in floral organ development and male and female fertilities.*

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[OPEN]CURLY LEAF Regulates Gene Sets Coordinating Seed Size and Lipid Biosynthesis.

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*A histone methyltransferase negatively regulates a set of genes coordinating seed size and lipid biosynthesis pathways in developing Arabidopsis embryos.*

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[OPEN]Habitat-Associated Life History and Stress-Tolerance Variation in Arabidopsis arenosa.

Pierre Baduel, Brian Arnold, Cara M. Weisman, Ben Hunter, and Kirsten Bomblies

*Plants of the usually perennial autotetraploid Arabidopsis arenosa that colonized railways became vernalization insensitive, early and perpetually flowering, and constitutively heat and cold stress tolerant.*

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[OPEN]Programming of Plant Leaf Senescence with Temporal and Inter-Organellar Coordination of Transcriptome in Arabidopsis. Hye Ryun Woo, Hee Jung Koo, Jeongsik Kim, Hyobin Jeong, Jin Ok Yang, Il Hwan Lee, Ji Hyung Jun, Seung Hee Choi, Su Jin Park, Byeongsoo Kang, You Wang Kim, Bong-Kwan Phee, Jin Hee Kim, Chaehwa Seo, Charny Park, Sang Cheol Kim, Seongjin Park, Byungwook Lee, Sanghyuk Lee, Daehye Hwang, Hong Gil Nam, and Pyung Ok Lim

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[OPEN]TOPOISOMERASE1 $\alpha$  Acts through Two Distinct Mechanisms to Regulate Stele and Columella Stem Cell Maintenance. Yonghong Zhang, Lanlan Zheng, Jing Han Hong, Ximing Gong, Chun Zhou, José Manuel Pérez-Pérez, and Jian Xu

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*OsCCC1 functions as a K<sup>+</sup>, Na<sup>+</sup>, and Cl<sup>-</sup> cotransporter in rice to maintain osmotic potential for cell elongation through increasing internal solute concentrations.* 494

[<sup>OPEN</sup>] Connecting Source with Sink: The Role of Arabidopsis AAP8 in Phloem Loading of Amino Acids. *James P. Santiago and Mechthild Tegeder*

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Heat Induction of Cyclic Electron Flow around Photosystem I in the Symbiotic Dinoflagellate *Symbiodinium*. *Yusuke Aihara, Shunichi Takahashi, and Jun Minagawa*

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[<sup>OPEN</sup>] Light Modulates the Biosynthesis and Organization of Cyanobacterial Carbon Fixation Machinery through Photosynthetic Electron Flow. *Yaqi Sun, Selene Casella, Yi Fang, Fang Huang, Matthew Faulkner, Steve Barrett, and Lu-Ning Liu*

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[<sup>OPEN</sup>] Long-Distance Transport of Thiamine (Vitamin B<sub>1</sub>) Is Concomitant with That of Polyamines. *Jacopo Martinis, Elisabet Gas-Pascual, Nicolas Szydlowski, Michèle Crèvecoeur, Alexandra Gisler, Lukas Bürkle, and Teresa B. Fitzpatrick*

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[<sup>OPEN</sup>] MtSWEET11, a Nodule-Specific Sucrose Transporter of *Medicago truncatula*. *Igor S. Kryvoruchko, Senjuti Sinharoy, Ivone Torres-Jerez, Davide Sosso, Catalina I. Pislariu, Dian Guan, Jeremy Murray, Vagner A. Benedito, Wolf B. Frommer, and Michael K. Udvardi*

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[<sup>OPEN</sup>] Photosynthesis Activates Plasma Membrane H<sup>+</sup>-ATPase via Sugar Accumulation. *Masaki Okumura, Shin-ichiro Inoue, Keiko Kuwata, and Toshinori Kinoshita*

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## SIGNALING AND RESPONSE

[OPEN]Chloroplasts Are Central Players in Sugar-Induced Leaf Growth. *Judith Van Dingenen, Liesbeth De Milde, Mattias Vermeersch, Katrien Maleux, Riet De Rycke, Michiel De Bruyne, Véronique Storme, Nathalie Gonzalez, Stijn Dhondt, and Dirk Inzé*

*Sucrose promotes early leaf growth by stimulating cell proliferation and repressing chloroplast transcription through the induction of GPT2 expression.*

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[OPEN]Heat stress yields a unique MADS box transcription factor in determining seed size and thermal sensitivity. *Chen Chen, Kevin Begcy, Kan Liu, Jing J. Folsom, Zhen Wang, Chi Zhang, and Harkamal Walia*

*Characterization of developing rice seeds under heat stress identifies OsMADS87 as a determinant of seed size sensitivity to increased temperature.*

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[OPEN]NO-Mediated  $[Ca^{2+}]_{cyt}$  Increases Depend on ADP-Ribosyl Cyclase Activity in Arabidopsis. *S.M. Abdul-Awal, Carlos T. Hotta, Matthew P. Davey, Antony N. Dodd, Alison G. Smith, and Alex A.R. Webb*

*ADP-ribosyl cyclase activity in Arabidopsis is up-regulated by nitric oxide to increase the cellular concentration of cyclic ADP ribose and free  $Ca^{2+}$ .*

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[OPEN]Phosphate Deficiency Induces the Jasmonate Pathway and Enhances Resistance to Insect Herbivory. *Ghazanfar Abbas Khan, Evangelia Vogiatzaki, Gaëtan Glauser, and Yves Poirier*

*Phosphate deficiency induces the jasmonic acid biosynthesis and signaling pathways and increases resistance to insect herbivory.*

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[OPEN]Potato NPH3/RPT2-Like Protein StNRL1, Targeted by a *Phytophthora infestans* RXLR Effector, Is a Susceptibility Factor. *Lina Yang, Hazel McLellan, Shaista Naqvi, Qin He, Petra C. Boevink, Miles Armstrong, Licida M. Giuliani, Wei Zhang, Zhendong Tian, Jiasui Zhan, Eleanor M. Gilroy, and Paul R.J. Birch*

*An effector from the potato late blight pathogen targets a host protein that negatively regulates immunity.*

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[OPEN]The Chloroplastic Protein THF1 Interacts with the Coiled-Coil Domain of the Disease Resistance Protein N' and Regulates Light-Dependent Cell Death. *Louis-Philippe Hamel, Ken-Taro Sekine, Thérèse Wallon, Yuji Sugiwaka, Kappei Kobayashi, and Peter Moffett*

*A chloroplastic protein inhibits defense-induced cell death and is destabilized by activation of a disease resistance protein.*

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The *Pseudomonas fluorescens* Siderophore Pyoverdine Weakens *Arabidopsis thaliana* Defense in Favor of Growth in Iron-Deficient Conditions. *Pauline Trapet, Laure Avoscan, Agnès Klinguer, Stéphanie Pateyron, Sylvie Citerne, Christian Chervin, Sylvie Mazurier, Philippe Lemanceau, David Wendehenne, and Angélique Besson-Bard*

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[OPEN] Turnabout Is Fair Play: Herbivory-Induced Plant Chitinases Excreted in Fall Armyworm Frass Suppress Herbivore Defenses in Maize. *Swayamjit Ray, Patrick C.M.S. Alves, Imtiaz Ahmad, Iffa Gaffoor, Flor E. Acevedo, Michelle Peiffer, Shan Jin, Yang Han, Samina Shakeel, Gary W. Felton, and Dawn S. Luthe*

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[OPEN] Zinc-Finger Transcription Factor ZAT6 Positively Regulates Cadmium Tolerance through the Glutathione-Dependent Pathway in Arabidopsis. *Jian Chen, Libo Yang, Xingxing Yan, Yunlei Liu, Ren Wang, Tingting Fan, Yongbing Ren, Xiaofeng Tang, Fangming Xiao, Yongsheng Liu, and Shuqing Cao*

*The transcription factor ZAT6 coordinately activates phytochelatin synthesis-related gene expression and directly targets GSH1 to positively regulate Cd accumulation and tolerance in Arabidopsis.*

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