On the Cover: Self-incompatibility (SI) is an important genetically controlled mechanism to prevent inbreeding in higher plants. SI involves highly specific interactions during pollination, resulting in the rejection of incompatible (self) pollen. The article by Wilkins et al. (pp. 766–779) describes the pivotal role of SI-induced acidification in mediating programmed cell death (PCD) in the SI response. After an incompatible interaction between the female stigmatic S-determinant, field poppy (Papaver rhoeas) stigma S, and the pollen S-determinant, field poppy pollen S, a signaling cascade is initiated which results in rapid, dramatic acidification of the pollen tube cytosol (green/blue, pH 5.5). Significant acidification occurs within 10 min of SI induction and continues for approximately 60 min. This acidification is essential for the formation of punctate actin foci and PCD in incompatible pollen. The cover shows pseudocolored confocal microscopy images of field poppy pollen tubes labeled with the pH-dependent ratiometric dye, 2,7-bis-(2-carboxyethyl)-5-(and-6)-carboxyfluorescein acetoxymethyl ester. Healthy unchallenged pollen tubes (top two images) have a neutral cytosolic pH (red/orange/yellow; pH 7.15); after SI challenge, the pollen tube cytosol becomes increasingly more acidic as time progresses (yellow/green/pale blue; middle images), reaching pH 5.5 after 60 min (pale blue/dark blue; bottom image). Cover image credits: Katie A. Wilkins (School of Biosciences, University of Birmingham, UK).

ON THE INSIDE

Peter V. Minorsky

BREAKTHROUGH TECHNOLOGIES

[OPEN] Imaging of Lipids in Microalgae with Coherent Anti-Stokes Raman Scattering Microscopy. Lillie Cavonius, Helen Fink, Juris Kiskis, Eva Albers, Ingrid Undeland, and Annika Enejder

Lipids are accumulated as giant droplets alongside coalescing emerging droplets under excessive lipid storage, in contrast to the multiple micron-sized droplets formed at normal conditions.


Portability of root architecture data with the Root System Markup Language paves the way for central root phenotype repositories.


Genetically encoded sensors enable dynamic monitoring of phosphate concentrations in cells and cell compartments of live plants.


Transcription factors in seedling cotyledons are quantified using novel silicon photonic crystal protein arrays and their levels are correlated with transcript abundances.

Continued on next page
A heteromeric membrane-bound prenyltransferase complex from hop catalyzes three sequential aromatic prenylations in the bitter acid pathway. Haoxun Li, Zhaonan Ban, Hao Qin, Liya Ma, Andrew J. King, and Guodong Wang

A membrane-bound prenyltransferase complex is responsible for all prenylations in the bitter acid pathway of hop glandular trichomes.

Reexamination of chlorophyllase function implies its involvement in defense against chewing herbivores. Xueyun Hu, Satoru Makita, Silvia Schellert, Shinsuke Sano, Masanori Ochiai, Tohru Tsuchiya, Shigeaki F. Hasegawa, Stefan Hörtstensteiner, Ayumi Tanaka, and Ryouchi Tanaka

A jasmonate-inducible chlorophyllase catabolizes chlorophyll upon tissue disruption to generate compounds that are toxic to insect herbivores.

Phosphoenolpyruvate carboxylase in Arabidopsis leaves plays a crucial role in carbon and nitrogen metabolism. Jianghua Shi, Keke Yi, Yu Liu, Li Xie, Zhongjing Zhou, Yue Chen, Zhanghua Hu, Tao Zheng, Renhu Liu, Yunlong Chen, and Jingqin Chen

Phosphoenolpyruvate carboxylase in Arabidopsis leaves balances carbon and nitrogen metabolism.

ECERIFERUM2-LIKE proteins have unique biochemical and physiological functions in very-long-chain fatty acid elongation. Tegan M. Haslam, Richard Haslam, Didier Thoraval, Stéphanie Pascal, Camille Delude, Frédéric Domergue, Aurora Mañas Fernández, Frédéric Beaudoin, Johnathan A. Napier, Ljerka Kunst, and Jérôme Joubes

An Arabidopsis protein that lacks enzymatic activity in long-chain fatty-acid condensation nonetheless affects chain length specificity of very-long-chain fatty acid elongation, which is important for cuticle and pollen coat function.

The MYB182 protein down-regulates proanthocyanidin and anthocyanin biosynthesis in poplar by repressing both structural and regulatory flavonoid genes. Kazuko Yoshiida, Dawei Ma, and C. Peter Constabel

A poplar repressor protein negatively regulates flavonoid and proanthocyanidin pathway genes by interacting with other transcription factors.

COBRA-LIKE2, a member of the glycosylphosphatidylinositol-anchored COBRA-LIKE family, plays a role in cellulose deposition in Arabidopsis seed coat mucilage secretory cells. Daniela Ben-Tov, Yael Abraham, Shira Stav, Kevin Thompson, Ann Loraine, Rieka Elbaum Amancio de Souza, Markus Paudy, Joseph J. Kieber, and Smadar Harpaz-Saad

A previously uncharacterized protein plays a role in cellulose deposition during the course of seed coat epidermal cell differentiation.

HIGHLY METHYL ESTERIFIED SEEDS is a pectin methyl esterase involved in embryo development. Gabriel Levesque-Tremblay, Kerstin Müller, Shawn D. Mansfield, and George W. Haughn

An Arabidopsis gene is required for normal levels of pectin methyl esterase activity and embryo cell expansion during the accumulation of storage reserves.

Interaction of the potato mop-top virus movement protein with importin-α facilitates nucleolar passage and virus systemic movement.

SUMOylation by a Stress-Specific Small Ubiquitin-Like Modifier E2 Conjugase Is Essential for Survival of Chlamydomonas reinhardtii under Stress Conditions. Amy R. Knobbe, Kempton M. Horken, Thomas M. Plucinak, Eniko Balassa, Heriberto Cerutti, and Donald P. Weeks

The green algae Chlamydomonas reinhardtii possesses at least two SUMO conjugates, one involved in housekeeping and the other in response to stress.

Self-Incompatibility-Induced Programmed Cell Death in Field Poppy Pollen Involves Dramatic Acidification of the Incompatible Pollen Tube Cytosol. Katie A. Wilkins, Maurice Bosch, Tamanna Haque, Nianjun Teng, Natalie S. Poulter, and Vernonica E. Franklin-Tong

Self-incompatibility triggers rapid cytosolic acidification that is necessary and sufficient for programmed cell death and pivotal in reorganizing F-actin and associated proteins within punctate foci.


A microtubule-associated kinesin moves processively along cortical microtubules and contributes to the production of both primary and secondary walls by mediating membrane trafficking.

ECOPHYSIOLOGY AND SUSTAINABILITY

Does Low Stomatal Conductance or Photosynthetic Capacity Enhance Growth at Elevated CO₂ in Arabidopsis? Hsien Ming Easlon, Eli Carlisle, John K. McKay, and Arnold J. Bloom

Low stomatal conductance and photosynthetic capacity increases Arabidopsis CO₂ growth enhancement under N-limited but not N-sufficient conditions.


Arabidopsis accessions show different phenotypes in response to mild drought, yet a robust transcriptome response is conserved between the accessions.

GROWTH REGULATING FACTOR5 Stimulates Arabidopsis Chloroplast Division, Photosynthesis, and Leaf Longevity. Liesbeth Vercruysen, Vanesa B. Tognetti, Nathalie Gonzalez, Judith Van Dingenen, Liesbeth De Milde, Agnieszka Bielach, Riet De Ruycke, Frank Van Breusegem, and Dirk Inzé

A transcription factor increases plant productivity by delaying leaf senescence and stimulating leaf cell division, chloroplast division, photosynthesis, and tolerance to nitrogen deprivation.
The mechanism for a stomatal response to vapor pressure deficit evolved from a passive regulation in basal vascular plants to mediation by ABA in the earliest angiosperms.

A KNOTTED1-LIKE HOMEOBOX protein regulates abscission through modulating auxin concentration and transport.

A network of transcription factors regulates arbuscular mycorrhizal symbiosis in Lotus.

Nine major plant hormone signaling pathways originated at different times, with horizontal gene transfer possibly contributing to their origin and evolution.

Ancient gene duplication may have led to the diversification of a key acyltransferase of plant triacylglycerol synthesis in the core eudicots.

A methyl-CpG-binding domain protein participates in active DNA demethylation and appears to act as an anti-silencing agent in Arabidopsis.

A negative regulator of strawberry fruit development and ripening is a homolog of a well-characterized protein kinase.

A transcription factor represses abscisic acid biosynthesis and fruit ripening.
MEMBRANES, TRANSPORT, AND BIOENERGETICS

Crystal Structure and Functional Characterization of Photosystem II-Associated Carbonic Anhydrase CAH3 in Chlamydomonas reinhardtii. Reyes Benlloch, Dmitriy Shevela, Tobias Hainzl, Christin Grundström, Tatyana Shutova, Johannes Messinger, Göran Samuelsson, and A. Elisabeth Sauer-Eriksson

Lumenal carbonic anhydrase is required for efficient turnover of the water-oxidizing complex of PSII.

Phloem as Capacitor: Radial Transfer of Water into Xylem of Tree Stems Occurs via Symplastic Transport in Ray Parenchyma. Sebastian Pfautsch, Justine Renard, Mark G. Tjoelker, and Anya Salih

Visual evidence for the radial transfer of water from phloem into xylem supports theoretical predictions that phloem acts as a water storage capacitor in tree stems.

Characterization of Chloroplast Protein Import without Tic56, a Component of the 1-Megadalton Translocon at the Inner Envelope Membrane of Chloroplasts. Daniel Köhler, Cyril Montandon, Gerd Hause, Petra Majovsky, Felix Kessler, Sacha Baginsky, and Birgit Agne

Plastids import a significant number of proteins in the absence of the chloroplast inner envelope membrane translocon subunit.

SENSITIVE TO PROTON RHIZOTOXICITY1, CALMODULIN BINDING TRANSCRIPTION ACTIVATOR2, and Other Transcription Factors Are Involved in ALUMINUM-ACTIVATED MALATE TRANSPORTER1 Expression. Mutsutomo Tokizawa, Yuriko Kobayashi, Tatsunori Saito, Masatomo Kobayashi, Satoshi Iuchi, Mika Nomoto, Yasuomi Tada, Yoshiharu Y. Yamamoto, and Hiroyuki Koyama

A set of unexpected transcription factors affects complex regulatory control of AtALMT1 expression in response to Al stress.

SIGNaling AND RESPONSE

Membrane-Localized Extra-Large G Proteins and Gβγ of the Heterotrimeric G Proteins Form Functional Complexes Engaged in Plant Immunity in Arabidopsis. Natsumi Maruta, Yuri Trusov, Eric Brenya, Urví Parekh, and José Ramón Botella

Arabidopsis immunity against multiple pathogens depends on unconventional G protein complexes.

ARACINs, Brassicaceae-Specific Peptides Exhibiting Antifungal Activities against Necrotrophic Pathogens in Arabidopsis. Jenny Neukermans, Annelies Inzé, Janick Mathys, Barbara De Coninck, Brigitte van de Cotte, Bruno P.A. Cammue, and Frank Van Breusegem

Two new antimicrobial peptides exhibit antifungal activities against necrotrophic pathogens.

Small Heat Shock Proteins Can Release Light Dependence of Tobacco Seed during Germination. Hyun Jo Koo, Soo Min Park, Keun Pill Kim, Mi Chung Suh, Mi Ok Lee, Seong-Kon Lee, Xia Xinli, and Choo Bong Hong

Ectopically expressed and heat shock-induced proteins trigger light-independent seed germination in tobacco.

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Two Distinct Families of Protein Kinases Are Required for Plant Growth under High External Mg$^{2+}$ Concentrations in Arabidopsis. Junro Mogami, Yasunari Fujita, Tukiya Yoshida, Yoshifumi Tsukiori, Hirofumi Nakagami, Yuko Nomura, Toru Fujitawa, Sho Nishida, Shuichi Yanagisawa, Tetsuya Ishida, Fuminori Takahashi, Kyoko Morimoto, Satoshi Kidokoro, Junya Mizoi, Kazu Shinozaki, and Kazuko Yamaguchi-Shinozaki

Two sets of ABA-activated protein kinases and their interacting partners are required for plant growth under high external Mg$^{2+}$ concentrations in Arabidopsis. 1039

TYPE-ONE PROTEIN PHOSPHATASE4 Regulates Pavement Cell Interdigitation by Modulating PIN-FORMED1 Polarity and Trafficking in Arabidopsis. Xiaola Guo, Qianqian Qin, Jia Yan, Yali Niu, Bingyao Huang, Liping Guan, Yuan Li, Dongtao Ren, Jia Li, and Suilwen Hou

Interaction with a protein phosphatase and dephosphorylation affects the polar localization and endocytic trafficking of an auxin-related membrane protein and its impact on cell pattern formation. 1058

The Arabidopsis Transcription Factor BRASSINOSTEROID INSENSITIVE1-ETHYL METHANESULFONATE-SUPPRESSOR1 Is a Direct Substrate of MITOGEN-ACTIVATED PROTEIN KINASE6 and Regulates Immunity. Sining Kang, Fan Yang, Lin Li, Huamin Chen, She Chen, and Jie Zhang

MAP kinase-mediated phosphorylation of a transcription factor regulates plant immunity. 1076


Three transcription factors form a sequential transcriptional regulatory cascade which is involved in rice response to the infection of Magnaporthe oryzae. 1087

Induced Jasmonate Signaling Leads to Contrasting Effects on Root Damage and Herbivore Performance. Jing Lu, Christelle Aurélie Maud Robert, Michael Riemann, Marco Cosme, Laurent Mène-Saffrané, Josep Massana, Michael Joseph Stout, Yonggen Lou, Jonathan Gershenzon, and Matthias Erb

Jasmonates reduce root damage by belowground herbivores, but enhanced jasmonate biosynthesis improves herbivore growth. 1100

[OPEN] Perturbation of Maize Phenylpropanoid Metabolism by an AvrE Family Type III Effector from Pantoea stewartii. Jo Ann E. Asselin, Jinshan Lin, Alvaro L. Perez-Quintero, Irene Gentzel, Doris Majercak, Stephen O. Opiyo, Wanying Zhao, Seung-Mann Paek, Min Gab Kim, David L. Coplin, Joshua J. Blakeslee, and David Mackey

The virulence activity of an effector protein belonging to the widely conserved AvrE family is linked to its ability to cause system-wide reprogramming of phenylpropanoid metabolism in susceptible maize seedlings. 1117

Bean Metal-Responsive Element-Binding Transcription Factor Confers Cadmium Resistance in Tobacco. Na Sun, Meng Liu, Wentao Zhang, Wanning Yang, Xiujuan Bei, Hui Ma, Fan Qiao, and Xiaoting Qi

A bean transcription factor binds to a metal-responsive element and confers Cd tolerance in tobacco by activation of tryptophan biosynthesis. 1136

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Inhibition of Auxin Signaling in \textit{Frankia} Species-Infected Cells in \textit{Casuarina glauca} Nodules Leads to Increased Nodulation. \textit{Antony Champion, Mikael Lucas, Alexandre Tromas, Virginie Vaissayre, Amandine Crabo, Issa Diédhiou, Hermann Prodjinoto, Daniel Moukouanga, Elodie Pirolles, Maimouna Cissoko, Jocelyne Bonneau, Hassen Gherbi, Claudine Franche, Valérie Hocher, Sergio Svistoonoff, and Laurent Laplaze}

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\textbf{SYSTEMS AND SYNTHETIC BIOLOGY}


The temporal dynamics of \textit{Zymoseptoria tritici} reproduction on \textit{Triticum aestivum} involves a biphasic manipulation of plant defense responses. 1158

Revealing Shared and Distinct Gene Network Organization in \textit{Arabidopsis} Immune Responses by Integrative Analysis. \textit{Xiaobao Dong, Zhenhong Jiang, You-Liang Peng, and Ziding Zhang}

Multiscale network analysis shows a robust gene network architecture in effector-triggered immunity of \textit{Arabidopsis}. 1186

\textbf{CORRECTIONS}

A Secreted Protein with Plant-Specific Cysteine-Rich Motif Functions as a Mannose-Binding Lectin That Exhibits Antifungal Activity. \textit{Miyakawa T., Hatano K., Miyauchi Y., Suwa Y., Sawano Y., and Tanokura M.}

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