

**On the Cover:** While spatially radiating and diverging across ecological niches, plant lineages have evolved mechanisms to cope with different environments. These adaptive mechanisms may include changes in biochemical or developmental pathways following environmental gradients, e.g. changes in the timing of flowering to allow optimal seed setting outside local cold or dry seasons. The image shows wild barley *Hordeum vulgare* sps. *spontaneum* (in front) growing in the Kidron wadi near the Dead Sea. Twenty accessions of wild barley were collected from this harsh growth niche and from another 50 diverse sites around Israel to create the Barley1K (B1K) collection of wild barley. Together the B1K accessions represent many of the widely differing adaptive niches of the modern barley ancestor (Hubner et al. 2009). In this issue, Dakhiya et al. (pp. 1724–1734) have used a non-invasive, high-throughput technique, based on prompt chlorophyll fluorescence (F), for measuring circadian rhythms in B1K populations. This analysis shows that there is variability for circadian traits in the wild barley lines. Furthermore, they observed that circadian period lengths were correlated with temperature and aspect at the sites of origin of the plants, and that the amplitudes of the rhythms were correlated with soil composition. Design and photograph by Sariel Hubner and Eyal Fridman.

## ON THE INSIDE

*Peter V. Minorsky*

1527

## LETTER TO THE EDITOR

Considering Microbial CO<sub>2</sub> during Microbe-Plant Cocultivation. *Birgit Piechulla*

1529

## UPDATE

<sup>[OPEN]</sup>Understanding and Manipulating Meiotic Recombination in Plants. *Christophe Lambing, F. Chris H. Franklin, and Chung-Ju Rachel Wang*

*Advances in understanding meiotic recombination have informed attempts to manipulate crossover formation with implications for meiotic recombination in polyploidy.*

1530

## BREAKTHROUGH TECHNOLOGIES

<sup>[OPEN]</sup>Bioorthogonal Noncanonical Amino Acid Tagging (BONCAT) Enables Time-Resolved Analysis of Protein Synthesis in Native Plant Tissue. *Weslee S. Glenn, Shannon E. Stone, Samuel H. Ho, Michael J. Sweredoski, Annie Moradian, Sonja Hess, Julia Bailey-Serres, and David A. Tirrell*

*Pulsing the noncanonical amino acid azidohomoalanine into Arabidopsis seedlings enables in-gel visualization, physical enrichment, and identification of newly synthesized proteins.*

1543

<sup>[OPEN]</sup>High-Throughput Phenotyping and QTL Mapping Reveals the Genetic Architecture of Maize Plant Growth. *Xuehai Zhang, Chenglong Huang, Di Wu, Feng Qiao, Wenqiang Li, Lingfeng Duan, Ke Wang, Yingjie Xiao, Guoxing Chen, Qian Liu, Lizhong Xiong, Wanneng Yang, and Jianbing Yan*

*Combining high-throughput phenotyping and large-scale QTL mapping dissects the dynamic genetic architecture of maize development by using a RIL population.*

1554

*Continued on next page*

## RESEARCH REPORTS

<sup>[OPEN]</sup>Transcription Factors PvERF15 and PvMTF-1 Form a Cadmium Stress Transcriptional Pathway. *Tingting Lin, Wanning Yang, Wen Lu, Ying Wang, and Xiaoting Qi*

*A cadmium-induced PvERF15 transcription factor binds to an AC-rich element to enhance the expression of transcription factor PvMTF-1 in bean, thus forming a PvERF15/PvMTF-1 transcriptional pathway.* 1565

A SUMO Ligase AtMMS21 Regulates the Stability of the Chromatin Remodeler BRAHMA in Root Development. *Juanjuan Zhang, Jianbin Lai, Feige Wang, Songguang Yang, Zhipeng He, Jieming Jiang, Qingliang Li, Qian Wu, Yiyang Liu, Mengyuan Yu, Jinju Du, Qi Xie, Keqiang Wu, and Chengwei Yang*

*A plant SUMO ligase regulates the protein stability of a chromatin remodeling factor in root development.* 1574

## RESEARCH ARTICLES

### BIOCHEMISTRY AND METABOLISM

<sup>[OPEN]</sup>A 2-Oxoglutarate-Dependent Dioxygenase Mediates the Biosynthesis of Glucoraphasatin in Radish. *Tomohiro Kakizaki, Hiroyasu Kitashiba, Zhongwei Zou, Feng Li, Nobuko Fukino, Takayoshi Ohara, Takeshi Nishio, and Masahiko Ishida*

*Biosynthesis of glucoraphasatin, a major glucosinolate in radish, is mediated by 2-oxoglutarate-dependent dioxygenase.* 1583

<sup>[OPEN]</sup>Genome Wide Analysis of Fatty Acid Desaturation and Its Response to Temperature. *Guillaume N. Menard, Jose Martin Moreno, Fiona M. Bryant, Olaya Munoz-Azcarate, Amélie A. Kelly, Keywan Hassani-Pak, Smita Kurup, and Peter J. Eastmond*

*The polyunsaturated fatty acid content of Arabidopsis seeds is determined by both cis-acting variants in FATTY ACID DESATURASE2 and an independent temperature-responsiveness locus on chromosome 2.* 1594

<sup>[CC-BY]</sup>Identification of Phosphorylation Sites Altering Pollen Soluble Inorganic Pyrophosphatase Activity. *Deborah J. Eaves, Tamanna Haque, Richard L. Tudor, Yoshimi Barron, Cleidiane G. Zampronio, Nicholas P. J. Cotton, Barend H. J. de Graaf, Scott A. White, Helen J. Cooper, F. Christopher H. Franklin, Jeffery F. Harper, and Veronica E. Franklin-Tong*

*Phosphoregulation of key sites on pollen soluble inorganic pyrophosphatases inhibits their catalytic responsiveness in concert with key intracellular events.* 1606

The Formation and Sequestration of Nonendogenous Ketocarotenoids in Transgenic *Nicotiana glauca*. *Cara L. Mortimer, Norihiko Misawa, Laura Perez-Fons, Francesca P. Robertson, Hisashi Harada, Peter M. Bramley, and Paul D. Fraser*

*In Nicotiana glauca, plastids adapt to sequester nonendogenous carotenoids, demonstrating the robustness of plant metabolism to these changes.* 1617

<sup>[OPEN]</sup>The Liverwort, *Marchantia*, Drives Alternative Electron Flow Using a Flavodiiron Protein to Protect PSI. *Ginga Shimakawa, Kimitsune Ishizaki, Shigeyuki Tsukamoto, Moeko Tanaka, Takehiro Sejima, and Chikahiro Miyake*

*Flavodiiron protein drives an oxygen-dependent alternative electron flow to stimulate the protective mechanisms of PSI against photooxidative damage in the liverwort *Marchantia polymorpha*.* 1636

[OPEN] Loss of the Chloroplast Transit Peptide from an Ancestral C<sub>3</sub> Carbonic Anhydrase Is Associated with C<sub>4</sub> Evolution in the Grass Genus *Neurachne*. Harmony Clayton, Montserrat Saladié, Vivien Rolland, Robert Sharwood, Terry Macfarlane, and Martha Ludwig

*In Neurachne, the loss of the sequence encoding a functional chloroplast transit peptide from an ancestral C<sub>3</sub> carbonic anhydrase is associated with the evolution of C<sub>4</sub> photosynthesis.*

1648

## CELL BIOLOGY

[OPEN] Analysis of Exocyst Subunit EXO70 Family Reveals Distinct Membrane Polar Domains in Tobacco Pollen Tubes. Juraj Sekereš, Přemysl Pejchar, Jiří Šantrůček, Nemanja Vukašinović, Viktor Žárský, and Martin Potocký

*Comparative analysis of tobacco EXO70 isoforms reveals their distinct functional properties in tip growth and subcellular localization to several compartments, including specific plasma membrane domains.*

1659

[OPEN] Heteroblastic Development of Transfer Cells Is Controlled by the microRNA miR156/SPL Module. Suong T. T. Nguyen, Teighan Greaves, and David W. McCurdy

*Development of wall ingrowth deposition in phloem parenchyma transfer cells of Arabidopsis appears to be a novel trait of heteroblasty, which is controlled by the miRNA156/SPL regulatory module.*

1676

[OPEN] The IQD Family of Calmodulin-Binding Proteins Links Calcium Signaling to Microtubules, Membrane Subdomains, and the Nucleus. Katharina Büstenbinder, Birgit Möller, Romina Plötner, Gina Stamm, Gerd Hause, Dipannita Mitra, and Steffen Abel

*Members of the Arabidopsis IQD family of calmodulin targets localize to microtubules, plasma membrane subdomains, and nuclear compartments and mediate calcium signaling during cell growth.*

1692

5' to 3' mRNA Decay Contributes to the Regulation of Arabidopsis Seed Germination by Dormancy. Isabelle Basbous-Serhal, Stéphanie Pateyron, Françoise Cochet, Juliette Leymarie, and Christophe Bailly

*The regulation of seed germination by dormancy is controlled by the degradation of specific subsets of mRNA during imbibition through the involvement of a 5' to 3' decay machinery.*

1709

[OPEN] Correlations between Circadian Rhythms and Growth in Challenging Environments. Yuri Dakhiya, Duaa Hussien, Eyal Fridman, Moshe Kiflawi, and Rachel Green

*Environmental conditions are associated with different aspects of circadian rhythmicity in wild barley.*

1724

Function of the Plant DNA Polymerase Epsilon in Replicative Stress Sensing, a Genetic Analysis. José-Antonio Pedroza-García, Christelle Mazubert, Ivan del Olmo, Mickael Bourge, Séverine Domenichini, Rémi Bounon, Zakia Tariq, Etienne Delannoy, Manuel Piñeiro, José A. Jarillo, Catherine Bergounioux, Moussa Benhamed, and Cécile Raynaud

*DNA polymerase epsilon plays a key role in replicative stress sensing and signaling.*

1735

[OPEN] ABA Suppresses Root Hair Growth via the OBP4 Transcriptional Regulator. Bart Rymen, Ayako Kawamura, Sabine Schäfer, Christian Breuer, Akira Iwase, Michitaro Shibata, Miho Ikeda, Nobutaka Mitsuda, Csaba Koncz, Masaru Ohme-Takagi, Minami Matsui, and Keiko Sugimoto

*The DOF transcription factor OBP4 suppresses root hair growth by down-regulating RSL2 expression in Arabidopsis.*

1750

## ECOPHYSIOLOGY AND SUSTAINABILITY

<sup>[OPEN]</sup>The Sites of Evaporation within Leaves. *Thomas N. Buckley, Grace P. John, Christine Scoffoni, and Lawren Sack*

*Vapor transport within leaves influences tissue water potentials, requiring the reassessment of hypotheses related to the sites of evaporation, including that measured hydraulic and stomatal conductances are directly influenced by where evaporation occurs.*

1763

## GENES, DEVELOPMENT, AND EVOLUTION

Gain-of-Function Mutants of the Cytokinin Receptors AHK2 and AHK3 Regulate Plant Organ Size, Flowering Time and Plant Longevity. *Isabel Bartrina, Helen Jensen, Ondřej Novák, Miroslav Strnad, Tomáš Werner, and Thomas Schumling*

*Gain-of-function variants of two Arabidopsis cytokinin receptors show the impact of cytokinin on regulating shoot organ size, flowering time, plant longevity, and seed yield.*

1783

## MEMBRANES, TRANSPORT, AND BIOENERGETICS

The *Synechocystis* Manganese Exporter Mnx Is Essential for Manganese Homeostasis in Cyanobacteria. *Fabian Brandenburg, Hanan Schoffman, Samantha Kurz, Ute Krämer, Nir Keren, Andreas P. M. Weber, and Marion Eisenhut*

*In cyanobacteria, the manganese transporter Mnx is central in maintaining Mn homeostasis by avoiding toxic cytoplasmic Mn accumulation and ensuring Mn provision to photosystem II in the thylakoid lumen.*

1798

<sup>[OPEN]</sup>Physiological Responses and Gene Co-Expression Network of Mycorrhizal Roots under K<sup>+</sup> Deprivation. *Kevin Garcia, Deborah Chasman, Sushmita Roy, and Jean-Michel Ané*

*Arbuscular mycorrhizal symbiosis compensates the transcriptional response of *M. truncatula* roots at low potassium level and activates specific mechanisms to tolerate long-term potassium deprivation.*

1811

The Transcription Factor MYB29 Is a Regulator of ALTERNATIVE OXIDASE1a. *Xinhua Zhang, Aneta Ivanova, Klaas Vandepoele, Jordan Radomiljac, Jan Van de Velde, Oliver Berkowitz, Patrick Willems, Yue Xu, Sophia Ng, Olivier Van Aken, Owen Duncan, Botao Zhang, Veronique Storme, Kai Xun Chan, Dries Vanechoutte, Barry James Pogson, Frank Van Breusegem, James Whelan, and Inge De Clercq*

*The transcription factor MYB29 integrates different hormonal, growth, and stress signals with mitochondrial retrograde signaling in Arabidopsis.*

1824

## SIGNALING AND RESPONSE

Three Pectin Methyltransferase Inhibitors Protect Cell Wall Integrity for Arabidopsis Immunity to *Botrytis*. *Vincenzo Lionetti, Eleonora Fabri, Monica De Caroli, Aleksander R. Hansen, William G.T. Willats, Gabriella Piro, and Daniela Bellincampi*

*Pectin methyltransferase inhibitors control PME activity to hinder pectin degradation as part of the plant immune response.*

1844

Jasmonate Regulates Plant Responses to Postsubmergence Reoxygenation through Transcriptional Activation of Antioxidant Synthesis. *Li-Bing Yuan, Yang-Shuo Dai, Li-Juan Xie, Lu-Jun Yu, Ying Zhou, Yong-Xia Lai, Yi-Cong Yang, Le Xu, Qin-Fang Chen, and Shi Xiao*

*Jasmonates play an indispensable role in plant responses to reoxygenation after submergence by regulating the homeostasis of antioxidant defenses.*

1864

Continued on next page

Suppressor of Overexpression of CO 1 Negatively Regulates Dark-Induced Leaf Degreening and Senescence by Directly Repressing Pheophytinase and Other Senescence-Associated Genes in *Arabidopsis*. Junyi Chen, Xiaoyu Zhu, Jun Ren, Kai Qiu, Zhongpeng Li, Zuokun Xie, Jiong Gao, Xin Zhou, and Benke Kuai

*SOC1* inhibits dark-induced leaf degreening and senescence by directly binding to the *CArG* box of *PPH*, *NYE1*, and *SAG113* promoters and inhibiting their expression at the transcriptional level in *Arabidopsis*. 1881

[OPEN] An Aphid Effector Targets Trafficking Protein VPS52 in a Host-Specific Manner to Promote Virulence. Patricia A. Rodriguez, Carmen Escudero-Martinez, and Jorunn I.B. Bos

*A secreted salivary protein from an herbivorous insect targets a protein in host plants to promote infestation.* 1892

Molecular Regulation of Temperature-Dependent Floral Induction in *Tulipa gesneriana*. Hendrika A.C.F. Leeggangers, Harm Nijveen, Judit Nadal Bigas, Henk W.M. Hilhorst, and Richard G.H. Immink

*Identification of putative regulatory genes in the ambient temperature flowering time pathway of tulip highlights several orthologs in Arabidopsis flowering control.* 1904

[OPEN] A Salivary Endo- $\beta$ -1,4-Glucanase Acts as an Effector That Enables the Brown Planthopper to Feed on Rice. Rui Ji, Wenfeng Ye, Hongdan Chen, Jiamei Zeng, Heng Li, Haixin Yu, Jiancai Li, and Yonggen Lou

*A salivary endo- $\beta$ -1,4-glucanase in the rice brown planthopper Nilaparvata lugens facilitates access to the phloem by degrading celluloses in plant cell walls.* 1920

## CORRECTIONS

Ferredoxin:NADP(H) Oxidoreductase Abundance and Location Influences Redox Poise and Stress Tolerance. Kozuleva M., Goss T., Twachtmann M., Rudi K., Trapka J., Selinski J., Ivanov B., Garapati P., Steinhoff H.-J., Hase T., Scheibe R., Klare J.P., and Hanke G.T. 1933

Light-Dependent Regulation of *DEL1* Is Determined by the Antagonistic Action of E2Fb and E2Fc. Berckmans B., Lammens T., Van Den Daele H., Magyar Z., Bögre L., and De Veylder L. 1934

The Nonspecific Lipid Transfer Protein AtLtpI-4 Is Involved in Suberin Formation of *Arabidopsis thaliana* Crown Galls. Deeken R., Saupé S., Klinkenberg J., Riedel M., Leide J., Hedrich R., and Mueller T.D. 1936

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