

On the Cover: Heterotrimeric G-proteins, composed of α , β , and γ subunits, are eukaryotic signal transducers, crucial for cellular responses to multiple stimuli. Plants have evolved specialized types of γ subunits, such as the type B that lack the N-terminal isoprenylation domain. This domain serves the important function of anchoring the subunit to the plasma membrane and is conserved in all known animal γ subunits. In pp. 1117–1134, Subramaniam et al. show that in tomato, the type B γ subunit (SIGGB1) interacts with the β subunit and targets the dimer predominantly to the nucleus, although it can also be observed in the plasma membrane and/or cytosol. Characterization of transgenic lines showing RNAi-mediated downregulation of SIGGB1 expression revealed that SIGGB1 plays specific roles in auxin and abscisic acid signaling. The cover shows transgenic plants with fruits exhibiting pointy tips, indicative of increased auxin sensitivity. Cover image credits: G. Subramaniam, Y. Trusov, and J.R. Botella, School of Agriculture and Food Sciences, University of Queensland, Australia.

ON THE INSIDE

Peter V. Minorsky

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TOPICAL REVIEW

The Physiology of Adventitious Roots. *Bianka Steffens and Amanda Rasmussen*

Adventitious roots have varied origins and functions, as illustrated by three case studies that highlight their physiology under flooding, nutrient deficiency, and wounding stress.

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BREAKTHROUGH TECHNOLOGIES

PPIM: A Protein-Protein Interaction Database for Maize. *Guanghui Zhu, Aibo Wu, Xin-Jian Xu, Pei-Pei Xiao, Le Lu, Jingdong Liu, Yongwei Cao, Luonan Chen, Jun Wu, and Xing-Ming Zhao*

The PPIM contains both accurately predicted and experimentally verified protein-protein interactions, which can help plant biologists better understand maize.

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[OPEN] MultiSite Gateway-Compatible Cell Type-Specific Gene-Inducible System for Plants. *Riccardo Siligato, Xin Wang, Shri Ram Yadav, Satu Lehesranta, Guojie Ma, Robertas Ursache, Iris Sevilem, Jing Zhang, Maartje Gorte, Kalika Prasad, Michael Wrzaczek, Renze Heidstra, Angus Murphy, Ben Scheres, and Ari Pekka Mähönen*

A tissue-specific inducible system allows a combination of inducible promoters, genes, reporters, and plant selection markers in a single cloning step.

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Arabidopsis Pol II-Dependent *In Vitro* Transcription System Reveals Role of Chromatin for Light-Inducible *rbcS* Gene Transcription. *Ayaka Ido, Shinya Iwata, Yuka Iwata, Hisako Igarashi, Takahiro Hamada, Seiji Sonobe, Masahiro Sugiura, and Yasushi Yukawa*

Light-inducible in vitro transcription from an Arabidopsis gene observed only from chromatin but not from naked DNA defines a higher order of DNA structure.

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[OPEN] A Defect in DNA Ligase4 Enhances the Frequency of TALEN-Mediated Targeted Mutagenesis in Rice. *Ayako Nishizawa-Yokoi, Tomas Cermak, Tomoki Hoshino, Kazuhiko Sugimoto, Hiroaki Saika, Akiko Mori, Keishi Osakabe, Masao Hamada, Yuichi Katayose, Colby Starker, Daniel F. Voytas, and Seiichi Toki*

Site-directed mutagenesis via TAL effector nucleases demonstrates that a lack of DNA Ligase4 affects the kinetics of TALEN-induced DSB repair.

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[OPEN] Biallelic Gene Targeting in Rice. Masaki Endo, Masafumi Mikami, and Seichi Toki

Bi-allelic gene targeting can be obtained by Agrobacterium-mediated CRISPR/Cas9 transformation and suppression of DNA ligase 4. 667

RESEARCH REPORT

[OPEN] Plant Nuclei Move to Escape Ultraviolet-Induced DNA Damage and Cell Death. Kosei Iwabuchi, Jun Hidema, Kentaro Tamura, Shingo Takagi, and Ikuko Hara-Nishimura

In leaves exposed to ultraviolet B, nuclei are positioned to the side walls of cells in an actin-dependent manner to mitigate DNA damage and cell death. 678

RESEARCH ARTICLES

BIOCHEMISTRY AND METABOLISM

[OPEN] Nitro-Fatty Acids in Plant Signaling: Nitro-Linolenic Acid Induces the Molecular Chaperone Network in Arabidopsis. Capilla Mata-Pérez, Beatriz Sánchez-Calvo, María N. Padilla, Juan C. Begara-Morales, Francisco Luque, Manuel Melguizo, Jaime Jiménez-Ruiz, Jesús Fierro-Risco, Antonio Peñas-Sanjuán, Raquel Valderrama, Francisco J. Corpas, and Juan B. Barroso

Endogenous nitro-fatty acids support signaling in defense against abiotic-stress. 686

[OPEN] Engineering Triterpene and Methylated Triterpene Production in Plants Provides Biochemical and Physiological Insights into Terpene Metabolism. Zuodong Jiang, Chase Kempinski, Caroline J. Bush, S. Eric Nybo, and Joe Chappell

Targeting nonnative triterpene biosynthesis within the cell sheds light on cofactor and substrate distributions and uncovers a new homeostatic mechanism. 702

CCoAOMT Down-Regulation Activates Anthocyanin Biosynthesis in Petunia. Nur Fariza M. Shaipulah, Joëlle K. Muhlemann, Benjamin D. Woodworth, Alex Van Moerkercke, Julian C. Verdonk, Aldana A. Ramirez, Michel A. Haring, Natalia Dudareva, and Robert C. Schuurink

Silencing of a caffeoyl-CoA O-methyltransferase activates anthocyanin biosynthesis and uncovers a link between color and scent production. 717

[OPEN] Structural Basis of Reversible Phosphorylation by Maize Pyruvate Orthophosphate Dikinase Regulatory Protein. Lun Jiang, Yi-bo Chen, Jiangge Zheng, Zhenhang Chen, Yujie Liu, Ye Tao, Wei Wu, Zhongzhou Chen, and Bai-chen Wang

The structure and mechanism of an ADP-dependent bifunctional enzyme may be important for the development of selective modulators to regulate photosynthesis. 732

[OPEN] A Tandem Array of *ent*-Kaurene Synthases in Maize with Roles in Gibberellin and More Specialized Metabolism. Jingye Fu, Fei Ren, Xuan Lu, Hongjie Mao, Meimei Xu, Jörg Degenhardt, Reuben J. Peters, and Qiang Wang

Characterization of a maize tandem gene array reveals three kaurene synthases with varied roles in gibberellin and phytoalexin metabolism. 742

NdhV Is a Subunit of NADPH Dehydrogenase Essential for Cyclic Electron Transport in *Synechocystis* sp. Strain PCC 6803. *Fudan Gao, Jiaohong Zhao, Xiaozhuo Wang, Shen Qin, Lanzhen Wei, and Weimin Ma*

NdhV is a subunit of cyanobacterial NADPH dehydrogenase constituting ferredoxin-binding domain essential for cyclic electron flow.

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A Salt-Inducible Mn-Catalase (KatB) Protects Cyanobacterium from Oxidative Stress. *Dhiman Chakravarty, Manisha Banerjee, Subhash C. Bihani, and Anand Ballal*

A salt-inducible Mn-catalase from Anabaena plays a vital role in combating oxidative and salinity stress.

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[OPEN] Cooperative Protein Folding by Two Protein Thiol Disulfide Oxidoreductases and ERO1 in Soybean. *Motonori Matsusaki, Aya Okuda, Taro Masuda, Katsunori Koishihara, Ryuta Mita, Kensuke Iwasaki, Kumiko Hara, Yurika Naruo, Akiho Hirose, Yuichiro Tsuchi, and Reiko Urade*

Two soybean protein thiol disulfide oxidoreductases achieve cooperative and efficient oxidative protein folding by relaying an oxidizing equivalent supplied from endoplasmic reticulum oxidoreductin-1a.

774

[OPEN] Phloem-Specific Methionine Recycling Fuels Polyamine Biosynthesis in a Sulfur-Dependent Manner and Promotes Flower and Seed Development. *Wolfgang Zierer, Mohammad R. Hajirezaei, Kai Eggert, Norbert Sauer, Nicolaus von Wirén, and Benjamin Pommerrenig*

Phloem-specific methionine recycling is sufficient to overcome sulfur-deficient growth conditions that would otherwise result in polyamine shortage and impair flower and seed development.

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Ester Cross-Link Profiling of the Cutin Polymer of Wild-Type and Cutin Synthase Tomato Mutants Highlights Different Mechanisms of Polymerization. *Glenn Philippe, Cédric Gaillard, Johann Petit, Nathalie Geneix, Michèle Dalgalarondo, Cécile Bres, Jean-Philippe Mauxion, Rochus Franke, Christophe Rothan, Lukas Schreiber, Didier Marion, and Bénédicte Bakan*

A synthase impacts ester cross-links of tomato cutin.

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CELL BIOLOGY

[OPEN] TEF30 Interacts with Photosystem II Monomers and Is Involved in the Repair of Photodamaged Photosystem II in *Chlamydomonas reinhardtii*. *Ligia Segatto Muranaka, Mark Rütgers, Sandrine Bujaldon, Anja Heublein, Stefan Geimer, Francis-André Wollman, and Michael Schroda*

A protein conserved in the green cell lineage binds quantitatively to PSII monomers at the stromal side of thylakoid membranes and facilitates supercomplex assembly during PSII repair.

821

[OPEN] Arabidopsis RhoGDIs Are Critical for Cellular Homeostasis of Pollen Tubes. *Qiang-Nan Feng, Hui Kang, Shi-Jian Song, Fu-Rong Ge, Yu-Ling Zhang, En Li, Sha Li, and Yan Zhang*

In planta GDIs for ROP GTPases support pollen germination and tube growth.

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[OPEN] Chloroplast Hsp93 Directly Binds to Transit Peptides at an Early Stage of the Preprotein Import Process. *Po-Kai Huang, Po-Ting Chan, Pai-Hsiang Su, Lih-Jen Chen, and Hsou-min Li*

A heat-shock protein binds to transit peptides at an early stage during preprotein import, while a second chaperone ATPase is found in the same complexes as a preprotein at both the early stage and a later stage after transit peptide removal.

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[OPEN] Phosphorylation of the C Terminus of RHD3 Has a Critical Role in Homotypic ER Membrane Fusion in Arabidopsis. Haruko Ueda, Etsuo Yokota, Keiko Kuwata, Natsumaro Kutsuna, Shoji Mano, Tomoo Shimada, Kentaro Tamura, Giovanni Stefano, Yoichiro Fukao, Federica Brandizzi, Teruo Shimmen, Mikio Nishimura, and Ikuko Hara-Nishimura

The Arabidopsis dynamin-like GTPase RHD3 has membrane fusion activity needed to form a proper endoplasmic reticulum network, and this activity is regulated by phosphorylation of its C terminus.

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ECOPHYSIOLOGY AND SUSTAINABILITY

[OPEN] Last-Century Increases in Intrinsic Water-Use Efficiency of Grassland Communities Have Occurred over a Wide Range of Vegetation Composition, Nutrient Inputs, and Soil pH. Iris H. Köhler, Andy J. Macdonald, and Hans Schnyder

Intrinsic water-use efficiency of grasslands increased over a wide range of nutrient inputs, soil pH, and plant community compositions during the last century.

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Differential Costs of Two Distinct Resistance Mechanisms Induced by Different Herbivore Species in Arabidopsis. Nawaporn Onkokesung, Michael Reichelt, Arjen van Doorn, Robert C. Schuurink, and Marcel Dicke

Aphid and caterpillar feeding induce different resistance mechanisms against subsequent feeding by a specialist caterpillar, and these entail different costs in terms of plant growth.

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Increased Sucrose Accumulation Regulates Iron-Deficiency Responses by Promoting Auxin Signaling in Arabidopsis Plants. Xian Yong Lin, Yi Quan Ye, Shi Kai Fan, Chong Wei Jin, and Shao Jian Zheng

Increased sucrose accumulation is required for regulating Fe deficiency responses in plants, with auxins acting downstream in transmitting the Fe deficiency signal.

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[OPEN] Localization of the Transpiration Barrier in the Epi- and Intracuticular Waxes of Eight Plant Species: Water Transport Resistances Are Associated with Fatty Acyl Rather Than Alicyclic Components. Reinhard Jetter and Markus Riederer

The cuticular transpiration barrier is formed by very-long-chain acyls rather than alicyclic wax compounds, primarily in the intracuticular layer and complemented by epicuticular wax in some species.

921

[OPEN] Ultrastructure of the Epidermal Cell Wall and Cuticle of Tomato Fruit (*Solanum lycopersicum* L.) during Development. Patricia Segado, Eva Domínguez, and Antonio Heredia

The epidermal cell wall is a highly dynamic structure that reveals a deep interconnection and coordination of cutin and cell wall polysaccharides assembly.

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GENES, DEVELOPMENT AND EVOLUTION

Seed Dormancy in Arabidopsis Is Controlled by Alternative Polyadenylation of DOG1. Malgorzata Cyrek, Halina Fedak, Arkadiusz Ciesielski, Yanwu Guo, Aleksandra Sliwa, Lien Brzezniak, Katarzyna Krzyczmonik, Zbigniew Pietras, Szymon Kaczanowski, Fuquan Liu, and Szymon Swiezewski

A major quantitative trait locus is alternatively polyadenylated and its proximally polyadenylated form is required for seed dormancy.

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[OPEN] PHABULOSA Mediates an Auxin Signaling Loop to Regulate Vascular Patterning in Arabidopsis. Christina Joy Müller, Ana Elisa Valdés, Guodong Wang, Prashanth Ramachandran, Lisa Beste, Daniel Uddenberg, and Annelie Carlsbecker

The influence of a developmental regulator on auxin response ensures proper patterning of the water-conducting xylem cells in the growing root. 956

[OPEN] Maize *reas1* Mutant Stimulates Ribosome Use Efficiency and Triggers Distinct Transcriptional and Translational Responses. Weiwei Qi, Jie Zhu, Qiao Wu, Qun Wang, Xia Li, Dongsheng Yao, Ying Jin, Gang Wang, Guifeng Wang, and Rentao Song

Impaired ribosome biogenesis enhances ribosome use efficiency, triggers distinct transcriptional and translational cellular responses, and affects cell growth and proliferation. 971

[OPEN] Nitrate-Regulated Glutaredoxins Control Arabidopsis Primary Root Growth. Kurt Patterson, Laura A. Walters, Andrew M. Cooper, Jocelyn G. Olvera, Miguel A. Rosas, Allan G. Rasmusson, and Matthew A. Escobar

Nitrate activates a set of glutaredoxin proteins that act to slow the growth of the root. 989

Dynamic Distribution and Interaction of the Arabidopsis SRSF1 Subfamily Splicing Factors. Nancy Stankovic, Marie Schloesser, Marine Joris, Eric Sauvage, Marc Hanikenne, and Patrick Motte

The RNA-binding domains of Arabidopsis SRSF1 splicing factors are required for nucleocytoplasmic dynamics and protein-protein interactions. 1000

MEMBRANES, TRANSPORT AND BIOENERGETICS

[OPEN] Identification of a Stelar-Localized Transport Protein That Facilitates Root-to-Shoot Transfer of Chloride in Arabidopsis. Bo Li, Caitlin Byrt, Jiaen Qiu, Ute Baumann, Maria Hrmova, Aurelie Evrard, Alexander A.T. Johnson, Kenneth D. Birnbaum, Gwenda M. Mayo, Deepa Jha, Sam W. Henderson, Mark Tester, Mathew Gilliam, and Stuart J. Roy

Identification and functional analysis of a gene encoding a Cl⁻ transporter responsible for loading Cl⁻ into root xylem. 1014

[OPEN] The Vacuolar Manganese Transporter MTP8 Determines Tolerance to Iron Deficiency-Induced Chlorosis in Arabidopsis. Seekin Eroglu, Bastian Meier, Nicolaus von Wirén, and Edgar Peiter

The cation diffusion facilitator MTP8 transports manganese into root vacuoles of iron-deficient plants and thereby prevents the inhibition of iron deficiency-induced ferric chelate reductase by manganese. 1030

SIGNALING AND RESPONSE

[OPEN] Arabidopsis CML38, a Calcium Sensor That Localizes to Ribonucleoprotein Complexes under Hypoxia Stress. Ansul Lokdarshi, W. Craig Conner, Carlee McClintock, Tian Li, and Daniel M. Roberts

The calcium sensor protein CML38 is a core hypoxia-induced calcium sensor protein that associates with stress granule mRNA complexes during the response of Arabidopsis to low-oxygen stress. 1046

[OPEN] CYTOKININ OXIDASE/DEHYDROGENASE3 Maintains Cytokinin Homeostasis during Root and Nodule Development in *Lotus japonicus*. Dugald E. Reid, Anne B. Heckmann, Ondřej Novák, Simon Kelly, and Jens Stougaard

A Cytokinin oxidase/dehydrogenase in Lotus japonicus regulates cytokinin levels to prevent inhibition of root growth and rhizobial infection during symbiosis.

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[OPEN] Mechanosensitivity below Ground: Touch-Sensitive Smell-Producing Roots in the Shy Plant *Mimosa pudica*. Rabi A. Musah, Ashton D. Lesiak, Max J. Maron, Robert B. Cody, David Edwards, Kristen Fowble, A. John Dane, and Michael C. Long

Plant roots can exhibit a type of mechanosensitivity whereby they emit noxious organosulfur compounds in response to touch.

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[OPEN] TH11, a Thiamine Thiazole Synthase, Interacts with Ca²⁺-Dependent Protein Kinase CPK33 and Modulates the S-Type Anion Channels and Stomatal Closure in Arabidopsis. Chun-Long Li, Mei Wang, Xiao-Meng Wu, Dong-Hua Chen, Hong-Jun Lv, Jian-Lin Shen, Zhu Qiao, and Wei Zhang

TH11, a thiamine thiazole synthase, interacts to suppress the CPK33 kinase activity, and thus to regulate guard cell ion channels and stomatal aperture in response to drought and ABA.

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[OPEN] Light and CO₂/cAMP Signal Cross Talk on the Promoter Elements of Chloroplastic β -Carbonic Anhydrase Genes in the Marine Diatom *Phaeodactylum tricorutum*. Atsushi Tanaka, Naoki Ohno, Kensuke Nakajima, and Yusuke Matsuda

Light interacts via photosynthesis with the carbon dioxide signaling and controls gene expression crucial to oceanic production in a marine diatom.

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[OPEN] Type B Heterotrimeric G Protein γ -Subunit Regulates Auxin and ABA Signaling in Tomato. Gayathery Subramaniam, Yuri Trusov, Carlos Lopez-Encina, Satomi Hayashi, Jacqueline Batley, and José Ramón Botella

A tomato heterotrimeric G protein γ -subunit suppresses auxin-induced root development while it facilitates ABA inhibition of seed germination.

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The Vacuolar Proton-Cation Exchanger EcNHX1 Generates pH Signals for the Expression of Secondary Metabolism in *Eschscholzia californica*. Sophie Weigl, Wolfgang Brandt, Renate Langhammer, and Werner Roos

A lysolipid generated by an elicitor-stimulated phospholipase A2 activates a distinct vacuolar Na⁺/H⁺ antiporter and the resulting peak of cytosolic H⁺ induces alkaloid biosynthesis.

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OsBRI1 Activates BR Signaling by Preventing Binding between the TPR and Kinase Domains of OsBSK3 via Phosphorylation. Baowen Zhang, Xiaolong Wang, Zhiying Zhao, Ruiju Wang, Xiahe Huang, Yali Zhu, Li Yuan, Yingchun Wang, Xiaodong Xu, Alma L. Burlingame, Yingjie Gao, Yu Sun, and Wenqiang Tang

The rice brassinosteroid receptor protein OsBRI1 disrupts the interaction between the tetratricopeptide repeat and kinase domains of the complementary brassinosteroid kinase via phosphorylation; this activates brassinosteroid signaling by increasing the binding between the kinase domain and the brassinosteroid suppressor BSU1.

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CORRECTIONS

Cheng M.-C., Hsieh E.-J., Chen J.-H., Chen H.-Y., and Lin T.-P. Arabidopsis RGLG2, Functioning as a RING E3 Ligase, Interacts with AtERF53 and Negatively Regulates the Plant Drought Stress Response. 1162

Smykowski A., Zimmermann P., and Zentgraf U. G-Box Binding Factor1 Reduces *CATALASE2* Expression and Regulates the Onset of Leaf Senescence in Arabidopsis. 1164

Liu, T.L., Newton, L., Liu M.-J., Shiu, S.-H., and Farré E.M. A G-Box-Like Motif Is Necessary for Transcriptional Regulation by Circadian Pseudo-Response Regulators in Arabidopsis. 1168

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