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On the Cover: Primary reactions of photosynthesis are mediated by three multi-subunit pigment-protein complexes including PSII, cytochrome b_6/f (Cyt b_6/f) complex, and PSI, the biogenesis of which requires various nuclear-encoded auxiliary proteins. In this issue, Wang et al. (pp. 1710–1728) study the physiological function of three m-type thioredoxins (TRX m1, TRX m2, and TRX m4) in the biogenesis of photosynthetic complexes in *Arabidopsis thaliana*. Their data demonstrate that three TRX m proteins play a redundant role in the regulation of PSII biogenesis via modulating the redox status of PSII core subunits, suggesting a mechanism to assist the assembly of PSII core subunits into PSII complex. The cover shows the phenotypic comparison between triple TRX m-silenced plant (left) and the control plant (right). Cover image credits: Peng Wang and Hong-Bin Wang.

ON THE INSIDE

Peter V. Minorsky

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COMMENTARIES

Cellulose Biosynthesis: Counting the Chains. Michael C. Jarvis

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TOPICAL REVIEW

Root Systems Biology: Integrative Modeling across Scales, from Gene Regulatory Networks to the Rhizosphere. Kristine Hill, Silvana Porco, Guillaume Lobet, Susan Zappala, Sacha Mooney, Xavier Draye, and Malcolm J. Bennett

Research into the systems biology of roots now encompasses transcriptomic and bioinformatic analysis combined with diverse modeling approaches, in order to relate gene regulatory networks to organ and rhizosphere scale processes, and will ultimately allow researchers to bridge the genotype-to-phenotype gap.

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RESEARCH REPORTS

^[W]A Two-Hybrid-Receptor Assay Demonstrates Heteromer Formation as Switch-On for Plant Immune Receptors. Markus Albert, Anna Kristina Jehle, Ursula Fürst, Delphine Chinchilla, Thomas Boller, and Georg Felix

Receptor/coreceptor pairs with swapped cytosolic domains are fully functional, demonstrating importance of heteromer formation as molecular switch-on for intracellular signaling.

1504

^{[C][W][OPEN]}Characterization of the Heterotrimeric G-Protein Complex and Its Regulator from the Green Alga *Chara braunii* Expands the Evolutionary Breadth of Plant G-Protein Signaling. Dieter Hackenberg, Hidetoshi Sakayama, Tomoaki Nishiyama, and Sona Pandey

The presence of a complete repertoire of heterotrimeric G-protein complex components and its regulator in a green alga confirms that the origin of this signaling mechanism in plants is more ancient than previously thought and is not related to the colonization of land by plants.

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RESEARCH ARTICLES

BIOCHEMISTRY AND METABOLISM

^{[C][W][OPEN]}Proteome Analysis of Peroxisomes from Etiolated *Arabidopsis* Seedlings Identifies a Peroxisomal Protease Involved in β -Oxidation and Development. Sheng Quan, Pingfang Yang, Gaëlle Cassin-Ross, Navneet Kaur, Robert Switzenberg, Kyaw Aung, Jiyang Li, and Jianping Hu

A proteome analysis of peroxisomes from etiolated Arabidopsis seedlings provides a road map of metabolism in a major peroxisomal variant and uncovers the role for a peroxisomal cysteine protease in β -oxidation and development.

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^[W]Lignification in Sugarcane: Biochemical Characterization, Gene Discovery, and Expression Analysis in Two Genotypes Contrasting for Lignin Content. *Alexandra Bottcher, Igor Cesarino, Adriana Brombini dos Santos, Renato Vicentini, Juliana Lischka Sampaio Mayer, Ruben Vanholme, Kris Morreel, Geert Goeminne, Jullyana Cristina Magalhães Silva Moura, Paula Macedo Nobile, Sandra Maria Carmello-Guerreiro, Ivan Antonio dos Anjos, Silvana Creste, Wout Boerjan, Marcos Guimarães de Andrade Landell, and Paulo Mazzafera*

Biochemical, histological, and transcriptional characterization of lignification identifies substantial differences in two sugarcane genotypes. 1539

Wide-Angle X-Ray Scattering and Solid-State Nuclear Magnetic Resonance Data Combined to Test Models for Cellulose Microfibrils in Mung Bean Cell Walls. *Roger H. Newman, Stefan J. Hill, and Philip J. Harris*

Peak shapes in an x-ray diffractogram of primary cell walls indicated 18-chain microfibrils with mixed cross-sectional shapes and occasional twinning, consistent with a cellulose-synthesizing complex assembled from six CESA trimers. 1558

^[W]Structure and Function of Nucleoside Hydrolases from *Physcomitrella patens* and Maize Catalyzing the Hydrolysis of Purine, Pyrimidine, and Cytokinin Ribosides. *Martina Kopečná, Hanna Blaschke, David Kopečný, Armelle Vigouroux, Radka Končítiková, Ondřej Novák, Ondřej Kotland, Miroslav Strnad, Solange Moréra, and Klaus von Schwartzberg*

Plant nucleoside N-ribohydrolases, which exist in two subclasses, play roles in cytokinin conversion and activation as well as in purine and pyrimidine metabolism. 1568

^{[C][W]}A Pair of Tabersonine 16-Hydroxylases Initiates the Synthesis of Vindoline in an Organ-Dependent Manner in *Catharanthus roseus*. *Sébastien Besseau, Franziska Kellner, Arnaud Lanoue, Antje M.K. Thamm, Vonny Salim, Bernd Schneider, Fernando Geu-Flores, René Höfer, Grégory Guirimand, Anthony Guïhur, Audrey Oudin, Gaëlle Glevarec, Emilien Foureau, Nicolas Papon, Marc Clastre, Nathalie Giglioli-Guivarc'h, Benoit St-Pierre, Danièle Werck-Reichhart, Vincent Burlat, Vincenzo De Luca, Sarah E. O'Connor, and Vincent Courdavault*

A newly identified cytochrome P450 isoform initiates the synthesis of valuable alkaloids in leaves of Catharanthus roseus by hydroxylating tabersonine. 1792

CELL BIOLOGY

^{[C][W]}Deciphering the Responses of Root Border-Like Cells of Arabidopsis and Flax to Pathogen-Derived Elicitors. *Barbara Plancot, Catherine Santaella, Rim Jaber, Marie Christine Kiefer-Meyer, Marie-Laure Follet-Gueye, Jérôme Leprince, Isabelle Gattin, Céline Souc, Azeddine Driouich, and Maïté Vicré-Gibouin*

Root border-like cells of flax and Arabidopsis activate innate immunity responses to elicitors involving both callose deposition and cell wall extensin reorganization. 1584

^[OPEN]Chloroplast Phosphoglycerate Kinase Is Involved in the Targeting of *Bamboo mosaic virus* to Chloroplasts in *Nicotiana benthamiana* Plants. *Shun-Fang Cheng, Ying-Ping Huang, Li-Hung Chen, Yau-Heiu Hsu, and Ching-Hsiu Tsai*

The BaMV RNA binds to chloroplast phosphoglycerate kinase and is targeted to chloroplast for replication. 1598

^{[C][W]}Purification and Characterization of Novel Microtubule-Associated Proteins from Arabidopsis Cell Suspension Cultures. *Takahiro Hamada, Nahoko Nagasaki-Takeuchi, Takehide Kato, Masayuki Fujiwara, Seiji Sonobe, Yoichiro Fukao, and Takashi Hashimoto*

A high-quality proteome database identifies novel microtubule-associated proteins in Arabidopsis. 1804

ECOPHYSIOLOGY AND SUSTAINABILITY

^{[C][W][OPEN]}Stress-Induced Cytokinin Synthesis Increases Drought Tolerance through the Coordinated Regulation of Carbon and Nitrogen Assimilation in Rice. *Maria Reguera, Zvi Peleg, Yasser M. Abdel-Tawab, Ellen B. Tumimbang, Carla A. Delatorre, and Eduardo Blumwald*

Cytokinin enhances the capacity of plants to tolerate water deficit by improving carbon and nitrogen assimilation processes during stress. 1609

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[C][W]The Tomato 14-3-3 Protein TFT4 Modulates H⁺ Efflux, Basipetal Auxin Transport, and the PKS5-J3 Pathway in the Root Growth Response to Alkaline Stress. Weifeng Xu, Liguojia, Weiming Shi, František Baluška, Herbert J. Kronzucker, Jiansheng Liang, and Jianhua Zhang

A tomato 14-3-3 protein integrates H⁺ efflux, basipetal auxin transport, and the PKS5-J3 pathway in root acclimation to alkaline stress.

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GENES, DEVELOPMENT, AND EVOLUTION

[W][OPEN]The REIL1 and REIL2 Proteins of *Arabidopsis thaliana* Are Required for Leaf Growth in the Cold. Stefanie Schmidt, Frederik Dethloff, Olga Beine-Golovchuk, and Joachim Kopka

Mutations in evolutionarily conserved zinc finger proteins of Arabidopsis thaliana are silent at optimal growth temperature but arrest leaf growth at 10°C, a response which arises from their roles in the maturation of the eukaryotic ribosome.

1623

[C][W][OPEN]The Conserved Chimeric Transcript UPGRADE2 Is Associated with Unreduced Pollen Formation and Is Exclusively Found in Apomictic *Boechera* Species. Martin Mau, José M. Corral, Heiko Vogel, Michael Melzer, Jörg Fuchs, Markus Kuhlmann, Nico de Storme, Danny Geelen, and Timothy F. Sharbel

A conserved chimeric genomic sequence found exclusively in apomictic Boechera species generates a putative long non-protein-coding transcript with secondary structure folding capability and is highly expressed in antherheads characterized by meiotically unreduced pollen formation.

1640

[W][OPEN]A Conserved Apomixis-Specific Polymorphism Is Correlated with Exclusive Exonuclease Expression in Premeiotic Ovules of Apomictic *Boechera* Species. José M. Corral, Heiko Vogel, Olawale M. Aliyu, Götz Hensel, Thomas Thiel, Jochen Kumlehn, and Timothy F. Sharbel

A single gene characterized by a conserved apomixis-specific polymorphism is exclusively expressed in the ovules of genetically diverse apomictic Boechera species while being repressed in ovules of sexuals.

1660

[W][OPEN]The F-Box Protein OsFBK12 Targets OsSAMS1 for Degradation and Affects Pleiotropic Phenotypes, Including Leaf Senescence, in Rice. Yuan Chen, Yunyuan Xu, Wei Luo, Wenxuan Li, Na Chen, Dajian Zhang, and Kang Chong

An F-box protein in the 26S proteasome pathway targets substrates specific degradation to trigger changes in ethylene levels for the regulation of leaf senescence and grain size.

1673

[C][W]Multiple Checkpoints for the Expression of the Chloroplast-Encoded Splicing Factor MatK. Stefanie Hertel, Reimo Zoschke, Laura Neumann, Yujiao Qu, Ilka M. Axmann, and Christian Schmitz-Linneweber

Expression of a chloroplast-encoded splicing factor is regulated on the level of mRNA stability and translation, including a possible autoregulatory loop.

1686

[C][W][OPEN]Evolution of Bacterial-Like Phosphoprotein Phosphatases in Photosynthetic Eukaryotes Features Ancestral Mitochondrial or Archaeal Origin and Possible Lateral Gene Transfer. R. Glen Uhrig, David Kerk, and Greg B. Moorhead

Bacterial-like phosphoprotein phosphatase genes entered eukaryotes from archaea or with ancestral mitochondrial formation, their various protein types showing important differences in subcellular localization, and differing at specific sequence motifs that could serve as accessory protein-binding sites.

1829

[C][W]Seedling Lethal1, a Pentatricopeptide Repeat Protein Lacking an E/E⁺ or DYW Domain in *Arabidopsis*, Is Involved in Plastid Gene Expression and Early Chloroplast Development. Young Jae Pyo, Kwang-Chul Kwon, Anna Kim, and Myeon Haeng Cho

A pentatricopeptide repeat protein is involved in plastid gene expression required for normal chloroplast development.

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MEMBRANES, TRANSPORT, AND BIOENERGETICS

^[W]Roles of BOR2, a Boron Exporter, in Cross Linking of Rhamnogalacturonan II and Root Elongation under Boron Limitation in Arabidopsis. *Kyoko Miwa, Shinji Wakuta, Shigeki Takada, Koji Ide, Junpei Takano, Satoshi Naito, Hiroyuki Omori, Toshiro Matsunaga, and Toru Fujiwara*

An efflux-type boron transporter facilitates efficient borate cross-linking of rhamnogalacturonan II in cell walls and root cell elongation under boron deficiency. 1699

^{[C][W][OPEN]}Evidence for a Role of Chloroplastic m-Type Thioredoxins in the Biogenesis of Photosystem II in Arabidopsis. *Peng Wang, Jun Liu, Bing Liu, Dongru Feng, Qingen Da, Peng Wang, Shengying Shu, Jianbin Su, Yang Zhang, Jinfa Wang, and Hong-Bin Wang*

M-type thioredoxins directly regulate the biogenesis of the photosystem II complex. 1710

^{[C][W]}Aspen SUCROSE TRANSPORTER3 Allocates Carbon into Wood Fibers. *Amir Mahboubi, Christine Ratke, András Gorzsás, Manoj Kumar, Ewa J. Mellerowicz, and Totte Niittylä*

Reduction of a plasma membrane-localized sucrose transporter decreases carbon allocation to secondary walls of wood fibers. 1729

^{[C][W]}Rapid Ammonia Gas Transport Accounts for Futile Transmembrane Cycling under NH₃/NH₄⁺ Toxicity in Plant Roots. *Devrim Coskun, Dev T. Britto, Mingyuan Li, Alexander Becker, and Herbert J. Kronzucker*

Fluxes of NH₃, but not NH₄⁺, account for futile cycling across both plasmalemma and tonoplast in roots of barley, resulting in a thermodynamic NH₃ equilibrium between cytosol, vacuole, and external solution, and aquaporins are likely mediators of these fluxes. 1859

SIGNALING AND RESPONSE

^{[W][OPEN]}The CALMODULIN-BINDING PROTEIN60 Family Includes Both Negative and Positive Regulators of Plant Immunity. *William Truman, Suma Sreekanta, You Lu, Gerit Bethke, Kenichi Tsuda, Fumiaki Katagiri, and Jane Glazebrook*

The Arabidopsis gene CBP60a encodes a negative regulator of immunity that represses salicylic acid synthesis and defense gene expression. 1741

^{[W][OPEN]}An S-Domain Receptor-Like Kinase, OsSIK2, Confers Abiotic Stress Tolerance and Delays Dark-Induced Leaf Senescence in Rice. *Li-Juan Chen, Hada Wuriyanghan, Yu-Qin Zhang, Kai-Xuan Duan, Hao-Wei Chen, Qing-Tian Li, Xiang Lu, Si-Jie He, Biao Ma, Wan-Ke Zhang, Qing Lin, Shou-Yi Chen, and Jin-Song Zhang*

A receptor-like kinase, part of a family of proteins contributing to plant development and defense, is involved in abiotic stress and the senescence process, integrating stress signals into a developmental program for adaptive growth. 1752

^[OPEN]S-Nitrosylation of Ascorbate Peroxidase Is Part of Programmed Cell Death Signaling in Tobacco Bright Yellow-2 Cells. *Maria Concetta de Pinto, Vittoria Locato, Alessandra Sgobba, Maria del Carmen Romero-Puertas, Cosimo Gadaleta, Massimo Delledonne, and Laura De Gara*

S-Nitrosylation of ascorbate peroxidase is part of the signaling pathway for programmed cell death induction in plants. 1766

^[W]GDSL LIPASE1 Modulates Plant Immunity through Feedback Regulation of Ethylene Signaling. *Hye Gi Kim, Sun Jae Kwon, Young Jin Jang, Myung Hee Nam, Joo Hee Chung, Yun-Cheol Na, Hongwei Guo, and Ohkmae K. Park*

A GDSL lipase regulates ethylene-dependent pathogen resistance and ethylene-salicylic acid signaling interactions in plants. 1776

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[C][W][OPEN] Rice WRKY13 Regulates Cross Talk between Abiotic and Biotic Stress Signaling Pathways by Selective Binding to Different cis-Elements. *Jun Xiao, Hongtao Cheng, Xianghua Li, Jinghua Xiao, Caiguo Xu, and Shiping Wang*

A WRKY transcription factor regulates the antagonistic interactions between drought and disease resistance pathways by complementary gene suppression and by regulating its own expression via specific DNA elements on the promoters of these genes in guard cells and impacting on drought resistance.

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CORRECTIONS

ANTI-SILENCING FUNCTION1 Proteins Are Involved in Ultraviolet-Induced DNA Damage Repair and Are Cell Cycle Regulated by E2F Transcription Factors in Arabidopsis. *Lario L.D., Ramirez-Parra E., Gutierrez C., Spampinato C.P., and Casati P.*

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