

**On the Cover:** In maturing *Arabidopsis* seeds, embryonic vacuoles are remodelled to become protein storage vacuoles. Shown here, the vacuolar membrane is labelled by the potassium channel TPK1-GFP (green) while storage material accumulating in the lumen is stained with the acidotropic dye Neutral Red (red). Credit: Dr Mistianne Feeney, University of Warwick.

## ON THE INSIDE

*Peter V. Minorsky*

1

## COMMENTARIES

The Long and the Short of It: GA 2-oxidaseA9 Regulates Plant Height in Wheat.

*Maria Grazia Annunziata*

3

Improving on the Humble Spud. *Scott Hayes*

5

Photosynthetic Oxygen Production: New Method Brings to Light Forgotten Flux.

*Meisha Holloway-Phillips*

7

Turnover of Tonoplast Proteins. *Rumen Ivanov and David G. Robinson*

10

## UPDATE

<sup>[OPEN]</sup>The Role of Trehalose 6-Phosphate in Crop Yield and Resilience.

*Matthew J. Paul, Asier Gonzalez-Urriarte, Cara A. Griffiths, and Keywan Hassani-Pak*

*T6P can be targeted through genetic and chemical methods for crop yield improvements in different environments through the effect of T6P on carbon allocation and biosynthetic pathways.*

12

## BREAKTHROUGH TECHNOLOGIES

<sup>[OPEN]</sup>Multiplex Fluorescent, Activity-Based Protein Profiling Identifies Active  $\alpha$ -Glycosidases and Other Hydrolases in Plants. *Amjad M. Husaini, Kyoko Morimoto, Balakumaran Chandrasekar, Steven Kelly, Farnusch Kaschani, Daniel Palmero, Jianbing Jiang, Markus Kaiser, Oussama Ahrazem, Hermen S. Overkleeft, and Renier A. L. van der Hoorn*

*Activity profiling with biotinylated and fluorescent probes targeting  $\alpha$ -glycosidases in plants is applied to saffron crocus and combined with other hydrolase probes.*

24

Chloroplast  $Ca^{2+}$  Fluxes into and across Thylakoids Revealed by Thylakoid-Targeted Aequorin Probes. *Simone Sello, Roberto Moscatiello, Norbert Mehlmer, Manuela Leonardelli, Luca Carraretto, Enrico Cortese, Filippo G. Zanella, Barbara Baldan, Ildikò Szabò, Ute C. Vothknecht, and Lorella Navazio*

*Aequorin-based probes targeted to the thylakoid lumen and membrane reveal an integrated role for thylakoids in  $Ca^{2+}$  homeostasis and modulation of chloroplast  $Ca^{2+}$  signals.*

38

*Continued on next page*

[OPEN]Soft X-Ray Imaging of Cellular Carbon and Nitrogen Distributions in Heterocystous Cyanobacteria. Takahiro Teramoto, Chihiro Azai, Kazuki Terauchi, Masashi Yoshimura, and Toshiaki Ohta

*Soft x-ray microscopy is a new method developed to determine cellular carbon and nitrogen concentrations in vivo.*

52

[OPEN]Measurement of Gross Photosynthesis, Respiration in the Light, and Mesophyll Conductance Using  $H_2^{18}O$  Labeling. Paul P. G. Gauthier, Mark O. Battle, Kevin L. Griffin, and Michael L. Bender

*$H_2^{18}O$  labeling and IRMS can be used to measure gross photosynthesis, mesophyll conductance, and respiratory uptake in the light in leaflets exposed to 21% and 2%  $O_2$ .*

62

## RESEARCH REPORTS

[OPEN]Perception of Sunflecks by the UV-B Photoreceptor UV RESISTANCE LOCUS8.

Victoria Moriconi, Melanie Binkert, Cecilia Costigliolo, Romina Sellaro, Roman Ulm, and Jorge J. Casal

*Sunflecks that penetrate through canopy gaps transiently interrupt shade and modify the activity of the UV-B photoreceptor UVR8 to mediate growth and gene expression responses.*

75

Out of Water: The Origin and Early Diversification of Plant R-Genes. Yuxia Gao, Wenqiang Wang, Tian Zhang, Zhen Gong, Huayao Zhao, and Guan-Zhu Han

*Evolutionary analyses suggest that plant R-genes originated in charophytes and plant R-proteins evolved in a modular fashion through frequent gain or loss of protein domains.*

82

[OPEN]Large Crown Root Number Improves Topsoil Foraging and Phosphorus Acquisition.

Baoru Sun, Yingzhi Gao, and Jonathan P. Lynch

*Maize genotypes with more crown roots have more intensive topsoil foraging and superior phosphorus acquisition, growth, and yield in low-phosphorus soil.*

90

[OPEN]Temporal-Specific Interaction of NF-YC and CURLY LEAF during the Floral Transition Regulates Flowering. Xu Liu, Yuhua Yang, Yilong Hu, Limeng Zhou, Yuge Li, and Xingliang Hou

*NF-YC proteins interact with the histone methyltransferase CLF and prevent the trimethylation of H3K27 on chromatin at the FT locus, thereby allowing FT expression and the initiation of flowering.*

105

## RESEARCH ARTICLES

### BIOCHEMISTRY AND METABOLISM

[OPEN]Reduced Arogonate Dehydratase Expression: Ramifications for Photosynthesis and Metabolism. Ricarda Höhner, Joaquim V. Marques, Tetsuro Ito, Yoshiaki Amakura, Alan D. Budgeon, Jr., Karl Weitz, Kim K. Hixson, Laurence B. Davin, Helmut Kirchhoff, and Norman G. Lewis

*Modulation of arogonate dehydratase in Arabidopsis causes changes in secondary metabolism, transient overaccumulation of starch, and lower photosynthetic electron transport rates.*

115

[OPEN]Darkened Leaves Use Different Metabolic Strategies for Senescence and Survival.

Simon R. Law, Daria Chrobok, Marta Juvany, Nicolas Delhomme, Pernilla Lindén, Bastiaan Brouwer, Abdul Ahad, Thomas Moritz, Stefan Jansson, Per Gardeström, and Olivier Keech

*A robust working model delineates the main axes of the divergent metabolic strategies used by Arabidopsis thaliana in response to partial or total darkening treatments.*

132

- [OPEN] Exploiting CELLULOSE SYNTHASE (CESA) Class Specificity to Probe Cellulose Microfibril Biosynthesis. *Manoj Kumar, Laxmi Mishra, Paul Carr, Michael Pilling, Peter Gardner, Shawn D. Mansfield, and Simon Turner*  
*Mutagenesis reveals which CESA protein classes have the greatest influence on the regulation of cellulose microfibril biosynthesis in the Arabidopsis secondary cell wall.* 151
- [OPEN] Rht18 Semidwarfism in Wheat Is Due to Increased GA 2-oxidaseA9 Expression and Reduced GA Content. *Brett A. Ford, Eloise Foo, Robert Sharwood, Miroslava Karafiatova, Jan Vrána, Colleen MacMillan, David S. Nichols, Burkhard Steuernagel, Cristobal Uauy, Jaroslav Doležal, Peter M. Chandler, and Wolfgang Spielmeier*  
*In the wheat Rht18 semidwarf, increased expression of GA2oxA9 metabolizes GA<sub>12</sub> precursor to inactive GA<sub>110</sub>, thereby reducing flux through the GA biosynthetic pathway, lowering the content of bioactive GA and reducing growth.* 168
- [OPEN] Betaine Lipid Is Crucial for Adapting to Low Temperature and Phosphate Deficiency in *Nannochloropsis*. *Hiroki Murakami, Takashi Nobusawa, Koichi Hori, Mie Shimojima, and Hiroyuki Ohta*  
*In Nannochloropsis oceanica, betaine lipid is not only important as a surrogate for phospholipids during phosphate deficiency, but is also required for adaptation to low temperature conditions.* 181
- [OPEN] Scopoletin 8-Hydroxylase-Mediated Fraxetin Production Is Crucial for Iron Mobilization. *Huei-Hsuan Tsai, Jorge Rodríguez-Celma, Ping Lan, Yu-Ching Wu, Isabel Cristina Vélez-Bermúdez, and Wolfgang Schmidt*  
*In Arabidopsis thaliana, scopoletin 8-hydroxylase mediates the final step in the biosynthesis of fraxetin, a coumarin with a catechol moiety, which is secreted by roots of iron-deficient plants at elevated pH to mobilize iron.* 194
- [OPEN] Biotin Attachment Domain-Containing Proteins Irreversibly Inhibit Acetyl CoA Carboxylase. *Jantana Keereetaweep, Hui Liu, Zhiyang Zhai, and John Shanklin*  
*Biotin Attachment Domain-Containing Proteins contribute to irreversible inhibition of ACCase under normal growth conditions and under conditions of fatty acid oversupply in Arabidopsis thaliana.* 208
- CELL BIOLOGY**
- [OPEN] The ADAPTOR PROTEIN-3 Complex Mediates Pollen Tube Growth by Coordinating Vacuolar Targeting and Organization. *Qiang-Nan Feng, Xin Liang, Sha Li, and Yan Zhang*  
*The dynamic organization of vacuoles and the association of tonoplast cargo protein PAT10 are impaired and lead to reduced pollen tube growth in adaptor protein-3 mutants.* 216
- [OPEN] ALY RNA-Binding Proteins Are Required for Nucleocytoplasmic mRNA Transport and Modulate Plant Growth and Development. *Christina Pfaff, Hans F. Ehrnsberger, María Flores-Tornero, Brian B. Sørensen, Thomas Schubert, Gernot Längst, Joachim Griesenbeck, Stefanie Sprunck, Marion Grasser, and Klaus D. Grasser*  
*Arabidopsis expresses four ALY family nuclear RNA-binding proteins that interact with the RNA helicase UAP56, and their depletion causes nuclear mRNA accumulation and developmental defects.* 226
- [OPEN] Protein Storage Vacuoles Originate from Remodeled Preexisting Vacuoles in *Arabidopsis thaliana*. *Mistianne Feeney, Maike Kittelmann, Rima Menassa, Chris Hawes, and Lorenzo Frigerio*  
*Preexisting vacuoles are reprogrammed to give rise to protein storage vacuoles.* 241

- [OPEN]Rice Morphology Determinant-Mediated Actin Filament Organization Contributes to Pollen Tube Growth. Gang Li, Xiujuan Yang, Xiaoqing Zhang, Yu Song, Wanqi Liang, and Dabing Zhang  
*RMD, a type II formin, controls pollen tube growth by regulating the direction and distribution of actin filaments arrays in rice.* 255

## ECOPHYSIOLOGY AND SUSTAINABILITY

- [OPEN]The Impacts of Phosphorus Deficiency on the Photosynthetic Electron Transport Chain. Andreas Carstensen, Andrei Herdean, Sidsel Birkelund Schmidt, Anurag Sharma, Cornelia Spetea, Mathias Pribil, and Søren Husted  
*Phosphorus deficiency affects the photosynthetic machinery in barley through a series of sequential events.* 271

## GENES, DEVELOPMENT, AND EVOLUTION

- [OPEN]FERTILIZATION-INDEPENDENT SEED-Polycomb Repressive Complex 2 Plays a Dual Role in Regulating Type I MADS-Box Genes in Early Endosperm Development. Shanshan Zhang, Dongfang Wang, Huajian Zhang, Megan I. Skaggs, Alan Lloyd, Di Ran, Lingling An, Karen S. Schumaker, Gary N. Drews, and Ramin Yadegari  
*A chromatin regulatory complex displays two modes of action in regulating the gene expression of a subclade of a transcription factor family during early endosperm development in Arabidopsis.* 285

- RECX Interacts with Mitochondrial RECA to Maintain Mitochondrial Genome Stability. Masaki Odahara and Yasuhiko Sekine  
*Physcomitrella patens RECX maintains mitochondrial genome stability by interacting with the mitochondrial recombinase RECA1.* 300

- [OPEN]The Linker Histone GH1-HMGA1 Is Involved in Telomere Stability and DNA Damage Repair. Cyril Charbonnel, Oleh Rymarenko, Olivier Da Ines, Fatiha Benyahya, Charles I. White, Falk Butter, and Simon Amiard  
*GH1-HMGA1, an uncharacterised linker histone protein of the high mobility group proteins A (HMGA) family, is a telomere-interacting protein and is required for telomere maintenance and DNA double strand break repair.* 311

## MEMBRANES, TRANSPORT, AND BIOENERGETICS

- [OPEN]VIPP1 Involved in Chloroplast Membrane Integrity Has GTPase Activity in Vitro. Norikazu Ohmishi, Lingang Zhang, and Wataru Sakamoto  
*A chloroplast protein known to be involved in membrane biogenesis and maintenance displays a novel type of GTPase activity requiring oligomerization through its N-terminus.* 328

## SIGNALING AND RESPONSE

- [OPEN]Polyamines Regulate Strawberry Fruit Ripening by Abscisic Acid, Auxin, and Ethylene. Jiaxuan Guo, Shufang Wang, Xiaoyang Yu, Rui Dong, Yuzhong Li, Xurong Mei, and Yuanyue Shen  
*Polyamines play an important role in strawberry fruit ripening by integration of multiple plant hormones, including abscisic acid, auxin, and ethylene.* 339

- [OPEN]Magnaporthe oryzae Induces the Expression of a MicroRNA to Suppress the Immune Response in Rice. Xin Zhang, Yalin Bao, Deqi Shan, Zhihui Wang, Xiaoning Song, Zhaoyun Wang, Jiansheng Wang, Liqiang He, Liang Wu, Zhengguang Zhang, Dongdong Niu, Hailing Jin, and Hongwei Zhao  
*Magnaporthe oryzae (Guy11) infection induces osa-miR319 expression, which stalls host jasmonic acid signaling and intensifies its pathogenicity.* 352

- [OPEN] Heterologous Expression of *AtBBX21* Enhances the Rate of Photosynthesis and Alleviates Photoinhibition in *Solanum tuberosum*. Carlos D. Crocco, Gabriel Gomez Ocampo, Edmundo L. Ploschuk, Anita Mantese, and Javier F. Botto  
*Expression of AtBBX21 in potato causes morphological and physiological changes that improve photosynthetic rates in high-irradiance conditions without negatively affecting water use efficiency.* 369
- [OPEN] Ribosomal RNA Biogenesis and Its Response to Chilling Stress in *Oryza sativa*. Runlai Hang, Zhen Wang, Xian Deng, Chunyan Liu, Bin Yan, Chao Yang, Xianwei Song, Beixin Mo, and Xiaofeng Cao  
*Pre-rRNA processing in rice involves two coexisting pathways and responds to chilling stress.* 381
- [OPEN] The Potato MAP3K StVIK Is Required for the *Phytophthora infestans* RXLR Effector Pi17316 to Promote Disease. Fraser Murphy, Qin He, Miles Armstrong, Licida M. Giuliani, Petra C. Boevink, Wei Zhang, Zhendong Tian, Paul R. J. Birch, and Eleanor M. Gilroy  
*The RXLR effector Pi17316 from Phytophthora infestans targets a MAP3K, VIK, and supports its activity as a susceptibility factor to promote late blight disease.* 398
- [OPEN] Interaction of 2',3'-cAMP with Rbp47b Plays a Role in Stress Granule Formation. Monika Kosmacz, Marcin Luzarowski, Olga Kerber, Ewa Leniak, Emilio Gutiérrez-Beltrán, Juan Camilo Moreno, Michał Gorka, Jagoda Szlachetko, Daniel Veyel, Alexander Graf, and Aleksandra Skirycz  
*2',3'-cAMP associates with Arabidopsis Rbp47b and plays a role in stress granule formation.* 411

## SYSTEMS AND SYNTHETIC BIOLOGY

- [OPEN] Predicted Arabidopsis Interactome Resource and Gene Set Linkage Analysis: A Transcriptomic Analysis Resource. Heng Yao, Xiaoxuan Wang, Pengcheng Chen, Ling Hai, Kang Jin, Lixia Yao, Chuanzao Mao, and Xin Chen  
*The Predicted Arabidopsis Interactome Resource (PAIR) is a database of high-confidence functional associations between Arabidopsis genes that integrates functional association evidence and enables a network-driven approach for interpreting transcriptomic changes functionally impacting biological processes.* 422

## CORRECTION

- Thioredoxin-Mediated ROS Homeostasis Explains Natural Variation in Plant Regeneration. Zhang H., Zhang T.T., Liu H., Shi D.Y., Wang M., Bie X.M., Li X.G., and Zhang X.S. 434

[CC-BY] Article free via Creative Commons CC-BY 4.0 license.

[OPEN] Articles can be viewed without a subscription.