

On the Cover: Mycorrhizal associations play an important role in determining processes at the plant, community, and ecosystem levels. Thus, characterizing mycorrhizal responses to rising atmospheric carbon dioxide concentration ($[\text{CO}_2]$) is critical to predicting global change effects across biological scales. Becklin et al. (pages 789–801) assessed mycorrhizal associations in native and invasive *Taraxacum* spp. across a broad $[\text{CO}_2]$ gradient representing glacial ($180 \mu\text{L L}^{-1}$) through future ($700\text{--}1000 \mu\text{L L}^{-1}$) conditions. They found that mycorrhizal associations were generally weaker under low $[\text{CO}_2]$ and became more beneficial with rising $[\text{CO}_2]$. For some plant species, nonlinear effects may limit plant responses to mycorrhizal fungi under future conditions. Differential plant growth rates and vegetative plasticity were also associated with species-specific mycorrhizal- CO_2 responses. Thus, these traits may provide a framework for predicting global change effects on mycorrhizal associations. The cover image shows arbuscular mycorrhizal fungi colonizing the roots of *Taraxacum ceratophorum* (Asteraceae, native dandelion, insert) grown at $1,000 \mu\text{L L}^{-1} [\text{CO}_2]$. To create this image, *T. ceratophorum* fine roots were stained with Trypan Blue and imaged at $400\times$ magnification with a Nikon AZ100 stereomicroscope. This image was produced by Katie M. Becklin and George W. R. Mullinix, University of Kansas.

FOCUS ISSUE

EDITORIAL

Focus on Ecophysiology. Elizabeth A. Ainsworth, Carl J. Bernacchi, and Frank G. Dohleman

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UPDATES

^[OPEN]The Quest for Understanding Phenotypic Variation via Integrated Approaches in the Field Environment. Duke Pauli, Scott C. Chapman, Rebecca Bart, Christopher N. Topp, Carolyn J. Lawrence-Dill, Jesse Poland, and Michael A. Gore

Field-based, high-throughput phenotyping enables the detailed characterization of plant populations under relevant conditions, providing valuable biological insight into the life history of plants.

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^[OPEN]Examining Plant Physiological Responses to Climate Change through an Evolutionary Lens. Katie M. Becklin, Jill T. Anderson, Laci M. Gerhart, Susana M. Wadgymar, Carolyn A. Wessinger, and Joy K. Ward

Integrating knowledge from physiological ecology, evolutionary biology, phylogenetics, and paleobiology provides novel insights into factors driving plant physiological responses to both past and future climate change.

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BREAKTHROUGH TECHNOLOGIES

^[OPEN]Quantitative, Image-Based Phenotyping Methods Provide Insight into Spatial and Temporal Dimensions of Plant Disease. Andrew M. Mutka, Sarah J. Fentress, Joel W. Sher, Jeffrey C. Berry, Chelsea Pretz, Dmitri A. Nusinow, and Rebecca Bart

Novel, image-based phenotyping methods enhance characterization of plant-pathogen interactions.

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RESEARCH REPORT

[OPEN] **Herbaceous Angiosperms Are Not More Vulnerable to Drought-Induced Embolism Than Angiosperm Trees.** Frederic Lens, Catherine Picon-Cochard, Chloé E.L. Delmas, Constant Signarbieux, Alexandre Buttler, Hervé Cochard, Steven Jansen, Thibaud Chauvin, Larissa Chacon Doria, Marcelino del Arco, and Sylvain Delzon

Herbs display a wide range of embolism resistance and do not show pronounced embolism formation throughout the growing season.

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RESEARCH ARTICLES

[OPEN] **Transcriptomes of Eight *Arabidopsis thaliana* Accessions Reveal Core Conserved, Genotype- and Organ-Specific Responses to Flooding Stress.** Hans van Veen, Divya Vashisht, Melis Akman, Thomas Girke, Angelika Mustroph, Emilie Reinen, Sjon Hartman, Maarten Kooiker, Peter van Tienderen, M. Eric Schranz, Julia Bailey-Serres, Laurentius A.C.J. Voesenek, and Rashmi Sasidharan

*Eight *Arabidopsis* accessions highlight early transcriptional and posttranscriptional responses to starvation and flooding stress.*

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[OPEN] **Phosphate-Dependent Root System Architecture Responses to Salt Stress.** Dorota Kawa, Magdalena M. Julkowska, Hector Montero Sommerfeld, Anneliek ter Horst, Michel A. Haring, and Christa Testerink

**Arabidopsis* accessions show different patterns of integrating root responses to phosphate starvation and salt stress.*

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[OPEN] **Surveying Rubisco Diversity and Temperature Response to Improve Crop Photosynthetic Efficiency.** Douglas J. Orr, André Alcântara, Maxim V. Kapralov, P. John Andralojc, Elizabete Carmo-Silva, and Martin A.J. Parry

Species diversity in Rubisco catalysis shows consistencies in temperature response, which can be used to improve crop photosynthetic efficiency.

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[OPEN] **Ethylene- and Shade-Induced Hypocotyl Elongation Share Transcriptome Patterns and Functional Regulators.** Debatosh Das, Kate R. St. Onge, Laurentius A.C.J. Voesenek, Ronald Pierik, and Rashmi Sasidharan

*Ethylene and shade share a conserved set of molecular regulators to control the plasticity of hypocotyl elongation in *Arabidopsis*.*

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[OPEN] **Promises and Challenges of Eco-Physiological Genomics in the Field: Tests of Drought Responses in Switchgrass.** John T. Lovell, Eugene V. Shakirov, Scott Schwartz, David B. Lowry, Michael J. Aspinwall, Samuel H. Taylor, Jason Bonnette, Juan Diego Palacio-Mejia, Christine V. Hawkes, Philip A. Fay, and Thomas E. Juenger

Physiological and gene expression analyses across field and greenhouse experiments highlight diverse gene expression patterns that produce physiologically similar responses to soil water deficits.

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[OPEN] **Genome-Wide Analysis of Yield in Europe: Allelic Effects Vary with Drought and Heat Scenarios.** Emilie J. Millet, Claude Welcker, Willem Kruijer, Sandra Negro, Aude Coupel-Ledru, Stéphane D. Nicolas, Jacques Laborde, Cyril Bauland, Sebastien Praud, Nicolas Ranc, Thomas Presterl, Roberto Tuberosa, Zoltan Bedo, Xavier Draye, Björn Usadel, Alain Charcosset, Fred Van Eeuwijk, and François Tardieu

A genome-wide analysis of maize yield in identify genomic regions associated with adaptation to scenarios with drought or heat stresses.

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[OPEN] Adaptation of the Long-Lived Monocarpic Perennial *Saxifraga longifolia* to High Altitude. *Sergi Munné-Bosch, Alba Cotado, Melanie Morales, Eva Fleta-Soriano, Jesús Villellas, and Maria B. Garcia*

Adaptation of an endemic long-lived monocarpic perennial to high altitude is influenced by multiple mechanisms operating at various levels.

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[OPEN] Dynamic Precision Phenotyping Reveals Mechanism of Crop Tolerance to Root Herbivory. *Wenchao Qu, Christelle A. M. Robert, Matthias Erb, Bruce E. Hibbard, Maxim Paven, Tassilo Gleede, Barbara Riehl, Lena Kersting, Aylin S. Cankaya, Anna T. Kunert, Youwen Xu, Michael J. Schueller, Colleen Shea, David Alexoff, So Jeong Lee, Joanna S. Fowler, and Richard A. Ferrieri*

Whole-plant glutamine mobilization aids local tissue, pathway-specific auxin biosynthesis in maize roots as a way to stimulate root regrowth after herbivory by the western corn rootworm.

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[OPEN] Host Plant Physiology and Mycorrhizal Functioning Shift across a Glacial through Future [CO₂] Gradient. *Katie M. Becklin, George W. R. Mullinix, and Joy K. Ward*

Plant physiological and growth characteristics drive linear and nonlinear shifts in the functioning of mycorrhizal associations across a 180 to 1,000 $\mu\text{L L}^{-1}$ [CO₂] gradient.

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[OPEN] Elevated Temperature and CO₂ Stimulate Late Season Photosynthesis But Impair Cold Hardening in Pine. *Christine Y. Chang, Emmanuelle Fréchet, Faride Unda, Shawn D. Mansfield, and Ingo Ensminger*

*Concurrent elevated temperature and CO₂ may extend late-season photosynthesis at the cost of impaired freezing tolerance in Eastern white pine (*Pinus strobus* L.) seedlings.*

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A Fresh Look at the Role of Auxin in PIN Trafficking. *Emily R. Larson*

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[OPEN] 3D Sorghum Reconstructions from Depth Images Identify QTL Regulating Shoot Architecture. *Ryan F. McCormick, Sandra K. Truong, and John E. Mullet*

A phenotyping platform that generates 3D plant reconstructions identifies genetic loci regulating shoot architecture in the agriculturally important crop sorghum.

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[OPEN] Multi-Element Bioimaging of *Arabidopsis thaliana* Roots. *Daniel Pergament Persson, Anle Chen, Mark G. M. Aarts, David E. Salt, Jan K. Schjoerring, and Søren Husted*

Multielement imaging of ion transport and distribution in Arabidopsis roots shows distinct spatial and dynamic gradients.

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RESEARCH REPORT

Histidine Regulates Seed Oil Deposition through Abscisic Acid Biosynthesis and β -Oxidation.
Huimin Ma and Shui Wang

Histidine regulates β -oxidation through abscisic acid in plant seed oil deposition and may serve as an important signal molecule in plant metabolism and development.

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RESEARCH ARTICLES

BIOCHEMISTRY AND METABOLISM

[^{OPEN}] Glutaredoxin GRXS17 Associates with the Cytosolic Iron-Sulfur Cluster Assembly Pathway.
Sabrina Iñigo, Astrid Nagels Durand, Andrés Ritter, Sabine Le Gall, Martin Termathe, Roland Klassen, Takayuki Tohge, Barbara De Coninck, Jelle Van Leene, Rebecca De Clercq, Bruno P. A. Cammue, Alisdair R. Fernie, Kris Gevaert, Geert De Jaeger, Sebastian A. Leidel, Raffael Schaffrath, Mieke Van Lijsebettens, Laurens Pauwels, and Alain Goossens

As in yeast and humans, Arabidopsis cytosolic monothiol glutaredoxins are involved in cytosolic iron-sulfur cluster assembly and the delivery of iron-sulfur clusters to client proteins.

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[^{OPEN}] The Allelochemical MDCA Inhibits Lignification and Affects Auxin Homeostasis.
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The phytotoxicity in Arabidopsis of the plant-derived phenylpropanoid pathway inhibitor 3,4-(methylenedioxy)cinnamic acid (MDCA) is based on the perturbation of auxin homeostasis.

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[^{OPEN}] ORM Expression Alters Sphingolipid Homeostasis and Differentially Affects Ceramide Synthase Activity. *Athen N. Kimberlin, Gongshe Han, Kyle D. Lutgeharm, Ming Chen, Rebecca E. Cahoon, Julie M. Stone, Jonathan E. Markham, Teresa M. Dunn, and Edgar B. Cahoon*

AtORM1 and AtORM2 negatively regulate serine palmitoyltransferase, and altered expression differentially affects functionally distinct ceramide synthase activities to maintain sphingolipid homeostasis.

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D-Lactate Dehydrogenase Links Methylglyoxal Degradation and Electron Transport through Cytochrome *c*. *Elina Welchen, Jessica Schmitz, Philippe Fuchs, Lucila García, Stephan Wagner, Judith Wienstroer, Peter Schertl, Hans-Peter Braun, Markus Schwarzländer, Daniel H. Gonzalez, and Veronica G. Maurino*

*Mitochondrial D-lactate dehydrogenase links the last step of methylglyoxal detoxification to the mitochondrial electron transport chain through cytochrome *c*.*

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[^{OPEN}] In Planta Localization of Stilbenes within *Picea abies* Phloem. *Tuula Jyske, Katsushi Kuroda, Jussi-Petteri Suuronen, Andrey Pranovich, Silvia Roig-Juan, Dan Aoki, and Kazuhiko Fukushima*

The axial parenchyma cells of Norway spruce phloem accumulate stilbenes, the amount of which varies with changes in cell type and cell volume from the inner to the outer phloem.

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[^{OPEN}] High CO₂ Primes Plant Biotic Stress Defenses through Redox-Linked Pathways.
Anna Mhamdi and Graham Noctor

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[OPEN] **The Interplay between Carbon Availability and Growth in Different Zones of the Growing Maize Leaf.**
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Local differences in carbon storage strategy, metabolism and gene expression in maize leaves delay the inhibition of growth and allow partial recovery of growth after transfer to darkness. 943

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Chronic Iron Limitation Confers Transient Resistance to Oxidative Stress in Marine Diatoms.
Shiri Graff van Creveld, Shilo Rosenwasser, Yishai Levin, and Assaf Vardi

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[OPEN] **Exocyst SEC3 and Phosphoinositides Define Sites of Exocytosis in Pollen Tube Initiation and Growth.**
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The SEC3 exocyst subunit serves as a landmark for secretory vesicles, and its localization and differential regulation by membrane lipids determine pollen tube initiation and polar growth. 980

[OPEN] **A Distinct Pathway for Polar Exocytosis in Plant Cell Wall Formation.**
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*A distinct Golgi-derived polar exocytosis pathway occurs in *Nicotiana tabacum* for pectin methylesterase 1 and contributes to cell wall and cell plate formation during cytokinesis.* 1003

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Novel Insights into the Organization of Laticifer Cells: A Cell Comprising a Unified Whole System.
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Laticifer- and latex-deficient mutants identify multiple loci regulating laticifer differentiation, growth, and metabolic activity. 1032

[OPEN] **The Dehydratase ADT3 Affects ROS Homeostasis and Cotyledon Development.**
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**Arabidopsis* seedlings mutated in the phenylalanine biosynthetic enzyme ADT3 cannot buffer reactive oxygen species, produce a defective cuticle, and display impaired cotyledon development.* 1045

[OPEN] **Glycosylphosphatidylinositol (GPI) Modification Serves as a Primary Plasmodesmal Sorting Signal.**
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A glycosylphosphatidylinositol modification is a necessary and sufficient signal for enriched protein accumulation in a plasma membrane domain associated with plasmodesmata. 1061

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[OPEN] Proline Coordination with Fatty Acid Synthesis and Redox Metabolism of Chloroplast and Mitochondria. *Suhas Shinde, Joji Grace Villamor, Wendar Lin, Sandeep Sharma, and Paul E. Verslues*

A Proline Dehydrogenase1 promoter:luciferase screen and transcriptome of the proline synthesis mutant p5cs1-4 find coordination between proline and multiple redox-related metabolic pathways. 1074

GENES, DEVELOPMENT, AND EVOLUTION

[OPEN] The DEK1 Calpain Linker Functions in Three-Dimensional Body Patterning in *Physcomitrella patens*. *Wenche Johansen, Ako Eugene Ako, Viktor Demko, Pierre-François Perroud, Stephan A. Rensing, Ahmed Khaleel Mekhlif, and Odd-Arne Olsen*

Full and partial deletion of the DEK1 Linker implicate DEK1 in the three major developmental phases of the moss Physcomitrella patens. 1089

[OPEN] The Exonuclease Homolog OsRAD1 Promotes Accurate Meiotic Double-Strand Break Repair by Suppressing Nonhomologous End Joining. *Qing Hu, Ding Tang, Hongjun Wang, Yi Shen, Xiaojun Chen, Jianhui Ji, Guijie Du, Yafei Li, and Zhukuan Cheng*

The 9-1-1 complex member RAD1 directly interacts with HUS1 and RAD9 and facilitates accurate meiotic recombination by suppressing nonhomologous end joining in rice. 1105

Chloroplast Translation Initiation Factors Regulate Leaf Variegation and Development. *Mengdi Zheng, Xiayan Liu, Shuang Liang, Shiyong Fu, Yafei Qi, Jun Zhao, Jingxia Shao, Lijun An, and Fei Yu*

SVR9 and its homolog SVR9L1 encode functionally redundant chloroplast translation initiation factors essential for chloroplast and leaf development in Arabidopsis. 1117

Cooperation between the H3K27me3 Chromatin Mark and Non-CG Methylation in Epigenetic Regulation. *Shaoli Zhou, Xiaoyun Liu, Chao Zhou, Qiangwei Zhou, Yu Zhao, Guoliang Li, and Dao-Xiu Zhou*

Mechanisms involved in H3K27 trimethylation interact with non-CG DNA methylation in epigenetic regulation of rice gene expression. 1131

Dissimilar Manifestation of Heterosis in Superhybrid Rice at Early-Tillering Stage under Nutrient-Deficient and Nutrient-Sufficient Condition. *Longjiang Gu, Ying Wu, Mengmeng Jiang, Weina Si, Xiaohui Zhang, Dacheng Tian, and Sihai Yang*

Hybrids may benefit from both activating metabolism-related pathways and alleviating fitness cost through down-regulating genes responsible for stress tolerance. 1142

[OPEN] Sporophyte Formation and Life Cycle Completion in Moss Requires Heterotrimeric G-Proteins. *Dieter Hackenberg, Pierre-François Perroud, Ralph Quatrano, and Sona Pandey*

Physcomitrella patens heterotrimeric G-proteins affect gametophore elongation and are essential for sporophyte formation, suggesting their unique role in life cycle completion in early land plants. 1154

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Vacuolar Chloride Fluxes Impact Ion Content and Distribution during Early Salinity Stress. *Ulrike Baetz, Cornelia Eisenach, Takayuki Tohge, Enrico Martinoia, and Alexis De Angeli*

A vacuolar anion channel in vascular cells of Arabidopsis contributes affects long-distance Na⁺ and Cl⁻ transport rapidly after onset of salinity stress. 1167

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SIGNALING AND RESPONSE

[OPEN] The Heat Stress Factor HSFA6b Connects ABA Signaling and ABA-Mediated Heat Responses. *Ya-Chen Huang, Chung-Yen Niu, Chen-Ru Yang, and Tsung-Luo Jinn*

HSFA6b acts as a positive regulator downstream of ABA signaling, mediates salinity and drought stress responses, and is required for establishing thermotolerance. 1182

The Chloroplast Protease AMOS1/EGY1 Affects Phosphate Homeostasis under Phosphate Stress. *Fang Wei Yu, Xiao Fang Zhu, Guang Jie Li, Herbert J. Kronzucker, and Wei Ming Shi*

AMOS1 modulates P homeostasis in response to P deficiency through ABA-antagonized ethylene signaling. 1200

[OPEN] Reactive Oxygen Species Tune Root Tropic Responses. *Gat Krieger, Doron Shkolnik, Gad Miller, and Hillel Fromm*

ROS accelerates gravitropism but attenuates hydrotropism of Arabidopsis roots. 1209

[OPEN] Class I and II Small Heat Shock Proteins Together with HSP101 Protect Protein Translation Factors during Heat Stress. *Fionn McLoughlin, Eman Basha, Mary E. Fowler, Minsoo Kim, Juliana Bordowitz, Surekha Katiyar-Agarwal, and Elizabeth Vierling*

Small HSPs are important for heat tolerance, interacting with and protecting an overlapping set of heat-sensitive proteins in protein translation together with HSP101. 1221

Nitrate Controls Root Development through Posttranscriptional Regulation of the NRT1.1/NPF6.3 Transporter/Sensor. *Eléonore Bouguyon, Francine Perrine-Walker, Marjorie Pervent, Juliette Rochette, Candela Cuesta, Eva Benkova, Alexandre Martinière, Lien Bach, Gabriel Krouk, Alain Gojon, and Philippe Nacry*

Although nitrate stimulates NRT1-1 transcription in all root tissues, it represses protein accumulation in lateral primordia, explaining that NRT1-1 controls lateral root development only in low nitrate medium. 1237

[OPEN] Cytokinin Response Factor 6 Represses Cytokinin-Associated Genes during Oxidative Stress. *Paul J. Zwack, Inge De Clercq, Timothy C. Howton, H. Tucker Hallmark, Andrej Hurny, Erika A. Keshishian, Alyssa M. Parish, Eva Benkova, M. Shahid Mukhtar, Frank Van Breusegem, and Aaron M. Rashotte*

Arabidopsis CYTOKININ RESPONSE FACTOR 6 represses a module of cytokinin-associated genes during exposure to oxidative stress. 1249

[OPEN] Systemic Induction of Photosynthesis via Illumination of the Shoot Apex Is Mediated Sequentially by Phytochrome B, Auxin and Hydrogen Peroxide in Tomato. *Zhixin Guo, Feng Wang, Xun Xiang, Golam Jalal Ahammed, Mengmeng Wang, Eugen Onac, Jie Zhou, Xiaojian Xia, Kai Shi, Xueren Yin, Kunsong Chen, Jingquan Yu, Christine H. Foyer, and Yanhong Zhou*

Red light perceived in the shoot apex by phyB alters IAA and H₂O₂ signaling, accelerating photosynthetic induction in systemic leaves by increasing CEF-dependent ATP production in tomato. 1259

[OPEN] SHORT HYPOCOTYL1 Encodes a SMARCA3-like Chromatin Remodeling Factor Regulating Elongation. *Kailiang Bo, Hui Wang, Yupeng Pan, Tusar K. Behera, Sudhakar Pandey, Changlong Wen, Yuhui Wang, Philipp W. Simon, Yuhong Li, Jinfeng Chen, and Yiqun Weng*

SHORT HYPOCOTYL1 (SH1), a chromatin remodeler, regulates hypocotyl elongation in cucumber through modulating the UVR8-mediated UVB signaling pathway. 1273

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Nucleoporin-Regulated MAP Kinase Signaling in Immunity to a Necrotrophic Fungal Pathogen. Bianca Genencher, Lennart Wirthmueller, Charlotte Roth, Melanie Klenke, Liang Ma, Amir Sharon, and Marcel Wiermer

Arabidopsis nuclear pore complex protein Nup88/MOS7 interacts with Nup98a/b and promotes nuclear accumulation of MPK3 to mount a robust immune response against the necrotrophic fungus *Botrytis cinerea*.

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[OPEN] Opposing Control by Transcription Factors MYB61 and MYB3 Increases Freezing Tolerance by Relieving C-Repeat Binding Factor Suppression. Zhenqian Zhang, Xiaona Hu, Yunqin Zhang, Zhenyan Miao, Can Xie, Xiangzhao Meng, Jie Deng, Jiangqi Wen, Kirankumar S. Mysore, Florian Frugier, Tao Wang, and Jiangli Dong

*Two MYB transcription factors regulate CBF4 in opposing manners, with implications for the understanding of cold acclimation and freezing tolerance in *Medicago truncatula*.*

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SYSTEMS AND SYNTHETIC BIOLOGY

Observability of Plant Metabolic Networks Is Reflected in the Correlation of Metabolic Profiles. Kevin Schwahn, Anika Küken, Daniel J. Kliebenstein, Alisdair R. Fernie, and Zoran Nikoloski

*Correlations of metabolic profiles are reflected in the role of metabolites and describe the state of the entire metabolic network of *Arabidopsis thaliana*.*

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A Transcriptional and Metabolic Framework for Secondary Wall Formation in *Arabidopsis*. Zheng Li, Nooshin Omranian, Lutz Neunetzler, Ting Wang, Thomas Herter, Bjoern Usadel, Taku Demura, Patrick Giavalisco, Zoran Nikoloski, and Staffan Persson

Network analyses reveal metabolic pathways associated with secondary cell wall synthesis and provide a framework for a better understanding of plant biomass formation.

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Lack of FTSH4 Protease Affects Protein Carbonylation, Mitochondrial Morphology, and Phospholipid Content in Mitochondria of *Arabidopsis*: New Insights into a Complex Interplay. Smakowska E., Skibior-Blaszczyk R., Czarna M., Kolodziejczak M., Kwasniak-Owczarek M., Parys K., Funk C., and Janska H.

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Carotenoid Cleavage Dioxygenase (CmCCD4a) Contributes to White Color Formation in *Chrysanthemum* Petals. Ohmiya A., Kishimoto S., Aida R., Yoshioka S., and Sumitomo K.

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Albino Leaf1 That Encodes the Sole Octotricopeptide Repeat Protein Is Responsible for Chloroplast Development. Zhang Z., Tan J., Shi Z., Xie Q., Xing Y., Liu C., Chen Q., Zhu H., Wang J., Zhang J., and Zhang G.

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