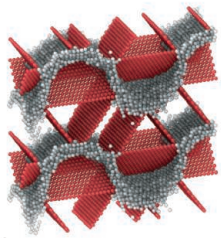
RESEARCH

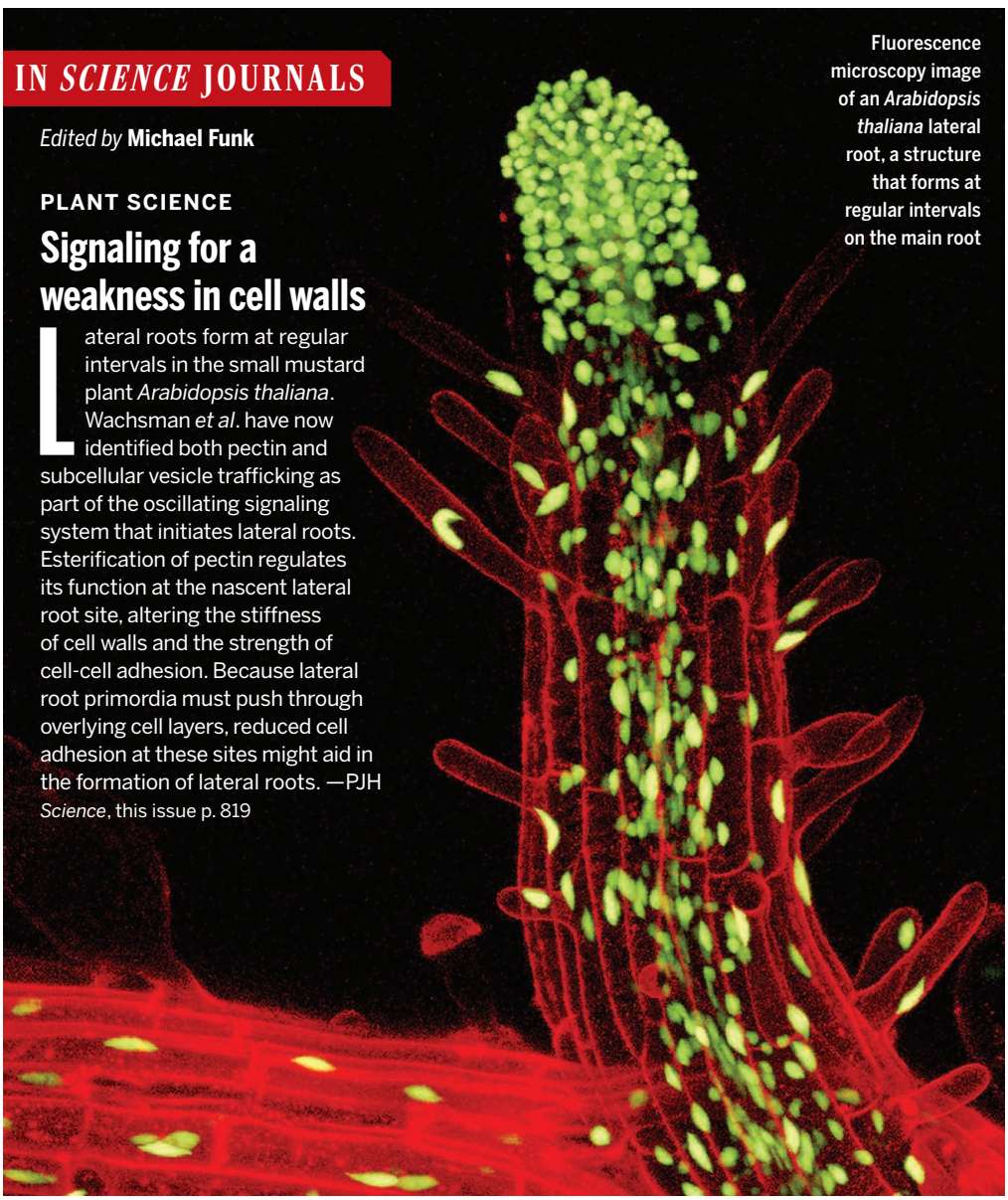
Temperature-stable nanograined copper

Li et al., *p. 831*



IN *SCIENCE* JOURNALS

Edited by **Michael Funk**



Fluorescence microscopy image of an *Arabidopsis thaliana* lateral root, a structure that forms at regular intervals on the main root

PLANT SCIENCE

Signaling for a weakness in cell walls

Lateral roots form at regular intervals in the small mustard plant *Arabidopsis thaliana*. Wachsman *et al*. have now identified both pectin and subcellular vesicle trafficking as part of the oscillating signaling system that initiates lateral roots. Esterification of pectin regulates its function at the nascent lateral root site, altering the stiffness of cell walls and the strength of cell-cell adhesion. Because lateral root primordia must push through overlying cell layers, reduced cell adhesion at these sites might aid in the formation of lateral roots. —PJH

Science, this issue p. 819

STRESS RESPONSES

Cellular adaptation during metabolic stress

Cells respond to environmental stress by down-regulating general protein synthesis and inducing selective expression of proteins required for survival. However, the mechanisms controlling this selective messenger RNA (mRNA) translation response remain poorly understood. Lamper *et al*. report that the noncanonical 5′ cap-binding protein subunit eIF3d is activated upon metabolic stress in mammalian cells to reprogram cellular mRNA translation. eIF3d is activated by a switch in phosphorylation status at sites near the cap-binding pocket and enables cells to express the proteins required for the regulation of metabolism and survival during stresses, including glucose starvation. This work reveals how eIF3d-dependent, noncanonical cap-dependent translation controls the cellular adaptation to stress. —SMH

Science, this issue p. 853

MARTIAN ATMOSPHERE

Dust storms cause Mars to lose water

Mars was once a wet planet, but it has lost most of its water through reactions that produce hydrogen, which escapes from the upper atmosphere into space. Stone *et al*. used data from the Mars Atmosphere and Volatile Evolution spacecraft to study how water is transported to the upper atmosphere and converted to hydrogen. They found that water can reach higher altitudes than previously thought, especially during global or regional dust storms. Photochemical modeling shows that this process dominates the current loss of water from Mars and influenced the evolution of its climate. —KTS

Science, this issue p. 824

SENSORS

Colorful changes

Distributed fiber-optic sensors have been used for monitoring mechanical deformations in stiff infrastructures such as bridges, roads, and buildings, but they either are limited to measuring one variable or require complex optics to measure multiple properties. Bai *et al*. now demonstrate dual-core elastomeric optical fibers, one of which contains patterned dye regions. The waveguides are fabricated by molding out of commercially available elastomers and integrate a clear core and an adjacent core doped with up to three macroscale dye regions. Changes in optical paths in the two cores detect deformation and map it onto a color space. By monitoring changes in the color and intensity in both

IMAGE: DR. JOHN RUNIONS/SCIENCE SOURCE

elastomer-based fibers, the researchers could distinguish bending, stretching, and localized pressing with a spatial resolution down to ~1 centimeter. —MSL

Science, this issue p. 848

OPTOMECHANICS

Getting phonons to hang around

The ideal platform for quantum-computing and quantum-sensing applications is likely to be a hybrid system that combines the best features of different components. Superconducting circuits are relatively advanced, and finding components that can control and manipulate the microwaves will be essential. MacCabe *et al*. explored the use of high-quality microresonators in which the acoustic environment could be engineered such that the phonon lifetime could be extended to more than 1 second. Operating at microwave frequencies of 5 gigahertz, these quantum acoustic-dynamic devices could be coupled with superconducting circuits. —ISO

Science, this issue p. 840

VNEUROSCIENCE

Higher-order thalamus input to the cortex

Sensory information can only be used meaningfully in the brain when integrated with and compared with internally generated top-down signals. However, we know little about the brainwide afferents that convey such top-down signals, their information content, and learning-related plasticity. Pardi *et al*. identified the higher-order thalamus as a major source of top-down input to mouse auditory cortex and investigated a circuit in cortical layer 1 that facilitates plastic changes and flexible responses. These results demonstrate how top-down feedback information can reach cortical areas through a noncortical structure that has received little attention despite its widespread connections with the cortex. —PRS

Science, this issue p. 844

STROKE

Measuring brain damage using the blood

The outcome of a stroke varies greatly between patients, from temporary mild symptoms to permanent disability and death. The clinical scale for measuring disease severity shows poor correlation with brain tissue damage. Identification of better markers of tissue damage could improve the ability to predict outcome and promote the development of better therapies. Gendron *et al*. found that the presence of the axonal cytoskeletal protein neurofilament light (NFL) in the blood was increased in multiple cohorts of patients with stroke compared with controls and was correlated with brain tissue damage. Additionally, blood concentration of NFL was correlated with functional outcome and mortality. These results suggest that blood NFL might be used as a prognostic marker after stroke. —MM

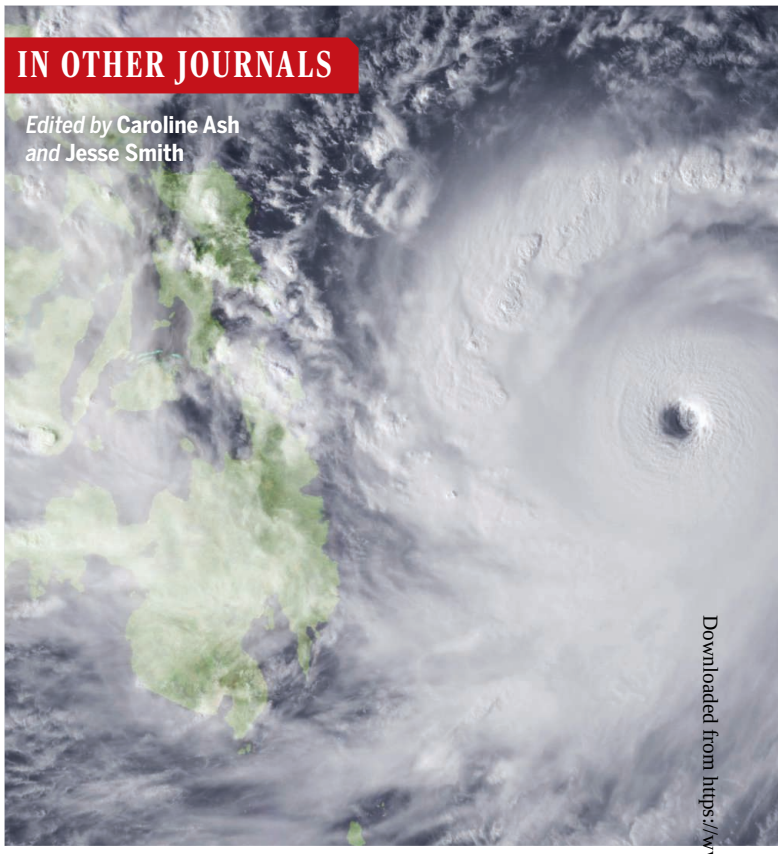
Sci. Transl. Med. **12**, eaay1913 (2020).

ANTIVIRAL IMMUNITY

Role reversal for aged T cells

Age-related changes to the adaptive immune system are associated with impaired host response and increased morbidity and mortality after respiratory virus infection. Goplen *et al*. used a murine model of influenza virus infection to compare the function of lung tissue–resident memory T (TRM) cells in young and aged mice. Although TRM cells typically promote robust antiviral immunity, aged mice displayed increased accumulation of dysfunctional, influenza-specific TRM cells. These cells facilitated pathological lung fibrosis and provided less protection against heterologous infection compared with TRM cells from young mice. This study provides insight into how age and prior infection may affect T cell–mediated immunity to respiratory viruses. —CO

Sci. Immunol. **5**, eabc4557 (2020).



IN OTHER JOURNALS

Edited by **Caroline Ash** *and* **Jesse Smith**

IMAGE: NOAA VIA GETTY IMAGES

BIOMATERIALS

Cell spreading affects energy consumption

The stiffness of a substrate is known to affect how cells spread on its surface, and for stem cells, stiffness also can affect their proliferation pathway. Xie *et al*. attempted to quantify another aspect of cell behavior, the influence of matrix stiffness on the availability of energy expenditure. Stiffer substrates cause the formation of focal adhesions and reorganization of the actin cytoskeleton. This leads to an intracellular drop in adenosine triphosphate (ATP) levels and the subsequent activation of adenosine monophosphate–activated protein kinase (AMPK) and glucose uptake to produce ATP and to support cell tension and adhesion. AMPK activation altered the mitochondrial morphology, causing it to be more fragmented. When the authors tested AMPKα-null cells, they observed limited spreading, a less well-developed actin cytoskeleton, and fewer focal adhesions on stiff substrates relative to the wild type. —MSL

Biomaterials **267**, 120494 (2020).

STRUCTURAL BIOLOGY

Mapping a dynamic structural ensemble

Many biological complexes are conformationally dynamic, which makes it difficult to determine the structures required to understand the mechanism. Marx *et al*. used an integrative approach to study the dynamic process of outer membrane protein (OMP) biogenesis that occurs in the periplasm of Gram-negative bacteria. Using a combination of photo–cross-linking, mass spectroscopy, solution scattering, and molecular modeling, they mapped interactions of a key chaperone, SurA, with unfolded OMPs (uOMPs) and determined an ensemble of models of the SurA:uOMP complex. The data show that a groove in SurA can bind several regions in uOMPs. Binding results in an expansion of the rest of the uOMP. Structural models indicate how

ALSO IN *SCIENCE* JOURNALS

Edited by **Michael Funk**

CORONAVIRUS

Estimating vaccine efficacy

Numerous coronavirus disease 2019 (COVID-19) vaccines are under development in clinical trials, but what do we need to know to ensure that they are used correctly? There are two vaccination strategies: direct protection of vulnerable populations and vaccination of the general population to indirectly protect those at highest risk of severe disease. In a Perspective, Lipsitch and Dean outline the important features of vaccine responses, particularly efficacy in high-risk groups and reduction of infectiousness. These end points are not routinely examined in phase 3 trials, so it is important to develop trials and subsequent studies to assess how vaccines perform so that they can be used optimally. —GKA

Science, this issue p. 763

HUMAN GENOMICS

The genomics of human development

Understanding the trajectory of a developing human requires an understanding of how genes are regulated and expressed. Two papers now present a pooled approach using three levels of combinatorial indexing to examine the single-cell gene expression and chromatin landscapes from 15 organs in fetal samples. Cao *et al*. focus on measurements of RNA in broadly distributed cell types and provide insights into organ specificity. Domcke *et al*. examined the chromatin accessibility of cells from these organs and identify the regulatory elements that regulate gene expression. Together, these analyses generate comprehensive atlases of early human development. —LMZ

Science, this issue p. 808, p. 809

PLANT SCIENCE

Roots primed for better phosphate uptake

Phosphate is a key resource for plants, and remediating phosphate deficiency drives considerable fertilizer use. In low-phosphate conditions, roots make more root hairs, which makes them better able to take up what little phosphate can be found. Wendrich *et al*. performed single-cell transcriptomics on the developing *Arabidopsis* root and queried the resulting gene-expression atlas for responses related to vascular development. The authors found that signals regulating root hair development began in the inner vasculature of the root with transcription factors that drove the production of the hormone cytokinin. Response cascades identified through the transcriptome database pointed to genes in epidermal cells that regulate root hair development. —PJH

Science, this issue p. 810

CORONAVIRUS

Imperfect future immunity

Humans are infected by several seasonal and cross-reacting coronaviruses. None provokes fully protective immunity, and repeat infections are the norm. Vaccines tend to be less efficient than natural infections at provoking immunity, and there are risks of adverse cross-reactions. Saad-Roy *et al*. used a series of simple models for a variety of immune scenarios to envisage immunological futures for severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) with and without vaccines. The model outcomes show that our imperfect knowledge about the imperfect coronavirus immune landscape can give rise to diverging scenarios ranging from recurring severe epidemics to elimination. It is critical that we accurately characterize immune responses to SARS-CoV-2 for translation into managing disease control. —CA

Science, this issue p. 811

COSMOCHEMISTRY

Timing Solar System formation

The oldest solids that formed in the Solar System are calcium-aluminium–rich inclusions (CAIs), small metallic droplets that were later incorporated into meteorites. The ages of CAIs are conventionally taken as the age of the Solar System, but which exact moment in star formation they correspond to has been unclear. Brennecka *et al*. measured molybdenum isotope ratios in CAIs and found a wide range of origins in both the inner and outer Solar System. They propose that CAIs formed from heterogeneous material accreting from the presolar nebula and that the ages of CAIs coincide with the Sun's transition from a protostar to a pre–main sequence star. —KTS

Science, this issue p. 837

CORONAVIRUS

Another host factor for SARS-CoV-2

Virus-host interactions determine cellular entry and spreading in tissues. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and the earlier SARS-CoV use angiotensin-converting enzyme 2 (ACE2) as a receptor; however, their tissue tropism differs, raising the possibility that additional host factors are involved. The spike protein of SARS-CoV-2 contains a cleavage site for the protease furin that is absent from SARS-CoV (see the Perspective by Kielian). Cantuti-Castelvetri *et al*. now show that neuropilin-1 (NRP1), which is known to bind furin-cleaved substrates, potentiates SARS-CoV-2 infectivity. NRP1 is abundantly expressed in the respiratory and olfactory epithelium, with highest expression in endothelial and epithelial cells. Daly *et al*. found that the furin-cleaved S1 fragment of the spike protein binds directly to cell surface NRP1 and blocking this interaction with a small-molecule inhibitor or monoclonal antibodies reduced viral infection in cell culture. Understanding the role of NRP1 in SARS-CoV-2 infection may suggest potential targets for future antiviral therapeutics. —SMH

Science, this issue p. 856, p. 861; see also p. 765

PREBIOTIC CHEMISTRY

Cysteine as peptide precursor and catalyst

Among amino acids, cysteine is highly reactive as a nucleophile, metal ligand, and participant in redox and radical reactions. These properties make cysteine attractive as a component of prebiotic chemistry, but traditional Strecker synthesis of α-aminonitriles, which can serve as peptide precursors, cannot produce free cysteine. Foden *et al*. found that a simple acylation of the free amine prevented degradation of cysteine nitrile and enabled synthesis of this cysteine precursor from acetyl dehydroalanine nitrile and a sulfide donor (see the Perspective by Muchowska and Moran). When combined with other proteinogenic α-aminonitriles, acetylcysteine or derivative thiols catalyzed efficient peptide ligation in water. These results highlight how prebiotic synthesis of precursors can also generate function by creating a catalyst for polymerization. —MAF

Science, this issue p. 865; see also p. 767

MOLECULAR GENETICS

Circular RNAs protect male fertility

Eukaryotes make thousands of circular RNAs (circRNAs) by noncanonical RNA splicing. The functions of most are mysterious, but many sequester microRNAs or RNA-binding proteins. Gao *et al*. examined the functions of circRNAs from the conserved reproductive gene *BOULE* (circBoule RNAs). Loss of these RNAs reduced male fertility in fruit flies and mice under heat stress, with reduced sperm levels and altered sperm morphology. During spermatogenesis, circBoule RNAs interact with heat shock proteins and control their levels by promoting their ubiquitination. circBoule RNA interaction with heat shock proteins is conserved in human sperm, and low circBoule RNA levels correlate with low sperm motility. These findings reveal conserved molecular and physiological functions of circBoule RNAs over some 600 million years of evolution. —DD

Sci. Adv. 10.1126/sciadv.abb7426 (2020).

CANCER

Converging on DKK1 to drive metastasis

Hepatocellular carcinoma (HCC) is a common form of liver cancer. The Wnt signaling protein Dickkopf-1 (DKK1) and epidermal growth factor receptor (EGFR) are both associated with metastatic progression and poor prognosis in HCC patients. Niu *et al*. found that these molecular markers are linked. The activation of EGFR in HCC cells induced *DKK1* expression through parallel pathways that promoted nuclear translocation of the kinase PKM2 and activation of the acetyltransferase p300. These pathways converged on modifying histone H3 at the *DKK1* promoter to activate *DKK1* transcription. —LKF

Sci. Signal. **13**, eabb5727 (2020).

METALLURGY

Locking in nanoscale strength

Metals with nanometer-sized crystal grains are super strong, but they do not generally retain their structure at higher temperatures. This property undermines their high strength and makes their use in applications challenging. Li *et al*. found a minimum-interface structure in copper with 10-nanometer-sized grains that, when combined with a nanograin crystallographic twinning network, retains high strength to temperatures just below the melting point. This discovery suggests a different path forward for stabilizing nanograined metals. —BG

Science, this issue p. 831