solution for that interval showing that the Solar System experienced a specific resonance transition pattern. These data provide a measure of the duration of the Paleocene-Eocene Thermal Maximum. —HJS

Science, this issue p. 926

PLANT SCIENCE

Microbial tRNA pieces regulate nodulation

To fix nitrogen, leguminous plants enter into a symbiotic relationship with nodulating bacteria. Ren *et al*. now reveal the bacteria as active regulators in this process (see the Perspective by Baldrich and Meyers). Small fragments cleaved from rhizobial tRNA molecules tap into the hosts' RNA interference machinery to silence key host genes. Thus, both host and microbe shape the symbiotic environment. —PJH

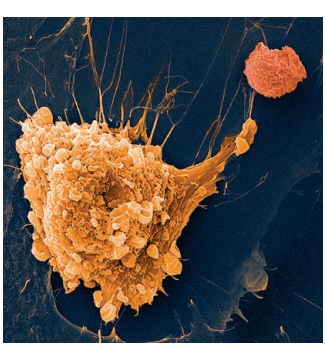
Science, this issue p. 919; see also p. 868

IMMUNOLOGY

Empowering NK cells against cancer

Tumors release factors, such as the cytokine transforming growth factor–β (TGF-β), that block antitumor immunity mediated by natural killer (NK) immune cells by promoting their differentiation into a less suppressive cell type. Rautela *et al.* found that activin-A, another member of the TGF-β family, had similar effects on both mouse and human NK cells but through a pathway independent of TGF-β. Inhibition of activin-A reduced skin cancer growth in a mouse melanoma model, suggesting that targeting this pathway could enhance NK cell function and antitumor immunity. —JFF

Sci. Signal. **12**, eaat7527 (2019).



Natural killer cell (top) and melanoma cell in a scanning electron micrograph

PHOTOS: (LEFT TO RIGHT) FERNANDO S. F. GUIMARAES/WEHI; CAROLINA C. CAMARGO/UFPR AND SIMON TAPLIN/WEHI; DPA PICTURE ALLIANCE/ALAMY STOCK PHOTO

SYNTHETIC BIOLOGY

Programmable genome engineering

The model bacterium *Escherichia coli* has a single circular chromosome. Wang *et al*. created a method to fragment the *E. coli* genome into independent chromosomes that can be modified, rearranged, and recombined. The efficient fission of the unmodified *E. coli* genome into two defined, stable pairs of synthetic chromosomes provides common intermediates for large-scale genome manipulations such as inversion and translocation. Fusion of synthetic chromosomes from distinct cells generated a single genome in a target cell. Precise, rapid, large-scale genome engineering operations are useful tools for creating diverse synthetic genomes. —SYM

Science, this issue p. 922

MICROBIOTA

Superantigens spur IgA secretion

Mucosal immunoglobulin A (IgA) is abundant and interacts with the gut microbiome. To examine microbial induction of IgA in humans, Bunker *et al.* screened microbiota from infants against mouse and human IgA. A subset of samples bound IgA in a way that indicated the presence of superantigens, which bind T cell receptors or B cell receptors outside of the typical antigen-binding region, leading to nonspecific activation. Putative superantigens in commensal members of Lachnospiraceae activated human VH3-positive B cells and induced IgA production in mice. The authors suggest that commensal superantigens may be dominant forces behind IgA production in humans. —LP

Sci. Transl. Med. **11**, eaau9356 (2019).

IN OTHER JOURNALS

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

The ubiquitous protist parasite *Toxoplasma gondii* infects many species but only develops sexually in cats.

PARASITES

Breaking the species barrier

The protozoan parasite *Toxoplasma gondii* is found in most mammals and is spread by ingestion of contaminated food and water. It is a health risk to humans because it can form brain cysts and cause life-changing complications during pregnancy. Despite this parasite's ability to infect many mammals, it can only complete its life cycle in felids, including domestic cats. Martorelli di Genova *et al.* sought to understand the basis for the specificity of the sexual stages for the gut epithelium of cats. Using cat gut organoids, they found that the parasite's sexual stages are stimulated to develop by the plant fat linoleic acid. Cats uniquely lack the enzyme needed for linoleic acid digestion, delta-6-desaturase. To test whether intact linoleic acid acts as a parasite signal, mice were given a chemical treatment to inhibit their desaturase, then fed linoleic acid and infected. *T. gondii* promptly initiated sexual development and the mice shed infectious oocysts in their feces 6 days later. —CA

PLOS Biol. **17**, e3000364 (2019).

PHYSICS

Twisted multilayer graphene

Since the recent discovery of superconductivity in twisted bilayer graphene, physicists have been exploring other twisted heterostructures, including those in which two bilayers of graphene are twisted with respect to each other. These experiments have shown signatures of exotic states, inspiring theorists to try to understand their properties. Liu *et al.* undertook a theoretical study of the general case of two graphene multilayers, each of which could contain an arbitrary number of graphene monolayers, twisted with respect to each other. They found that such heterostructures retained the approximately flat bands characteristic of twisted bilayer graphene at the same "magic" twist angle. Additionally, twisted

The fairy ring–forming fungus *Marasmius oreades*

FUNGAL GENETICS

Fairy rings magically prevent mutation

Mutation can often occur as part of the process of cellular division and may have deleterious consequences for multicellular organisms. Through genomic sequencing of *Marasmius oreades*, a species of fairy ring mushroom, Hiltunen *et al.* found that in this relatively long-lived species, the accumulation of mutations is an order of magnitude less than previously discovered for any organism. This could not be attributed to purifying selection and indicates that this species has evolved high-fidelity replication and/or repair mechanisms to prevent mutation accumulation. Given that fungi, unlike mammals, do not sequester their reproductive germ cells, this is of interest in understanding how an organism can police its own cell division to maintain a low rate of mutation accumulation. —LMZ

Curr. Biol. **29**, 2758 (2019).

multilayer graphene showed interesting topological properties that depended on the number and stacking of monolayers in each multilayer. —JS

Phys. Rev. X **9**, 031021 (2019)

BIOSYNTHESIS

Building psychoactives with purpose

Plants are skilled, if unwitting, organic chemists that produce a panoply of natural products that influence human biochemistry and cognition. Farrow *et al.* identified a suite of enzymes in the iboga plant, *Tabernanthe iboga*, that produce (−)-ibogaine from a complex precursor alkaloid. The carbon scaffold is rearranged in a series of steps that follow or mirror the synthesis of (+)-catharanthine, an intermediate in the formation of the anticancer drug vinblastine. Knowledge of their biosynthetic pathways may stimulate research into the psychoactive properties of iboga alkaloids, including potential antiaddictive activities. —MAF

J. Am. Chem. Soc. **141**, 12979 (2019).

CELL BIOLOGY

Born in the ribosomal tunnel

The correct folding and processing of nascent polypeptides requires ribosome-associated chaperones. One such chaperone, the ribosome-bound nascent polypeptide–associated complex (NAC), cross-links to newly assembled polypeptides. Gamerdinger *et al.* discovered that NAC is positioned above the ribosomal exit site, from where it antagonizes incorrect endoplasmic reticulum protein targeting. Remarkably, the extended N-terminal tail of the β subunit inserts deeply inside the ribosomal tunnel to facilitate their folding and sorting. As the peptide elongates, it displaces NAC from the ribosomal tunnel. NAC then rearranges on the surface of the ribosome, ready to coordinate further cotranslational activities. —SMH

Mol. Cell 10.1016/j.molcel.2019.06.030 (2019).

PHYSICS

Controlling exciton lifetimes

Excitons are electron-hole pairs optically induced in condensed matter systems which reemit a photon when they recombine. Monolayer transition metal dichalcogenides, e.g., $MoSe_2$, are of particular interest owing to the strong binding energy of the excitons and an ultrafast response time. By sandwiching the monolayers of $MoSe_2$ between layers of hexagonal boron nitride (hBN), Fang *et al.* show that the lifetime of the excitons can be controlled across an order of magnitude from 1 to 10 picoseconds with the lifetime determined simply by the thickness of the hBN sandwiching layers. Such control of the exciton lifetime and transport properties should be applicable to other two-dimensional materials and could be exploited for use in a variety of ultrafast optoelectronic applications. —ISO

Phys. Rev. Lett. **123**, 067401 (2019).

REGENERATIVE MEDICINE

Improving heart muscle

Heart failure is caused by injury to the myocardium, the heart muscle, which results in irreversible loss because this tissue cannot regenerate itself. Bargehr *et al.* investigated whether regenerative medicine approaches involving human embryonic stem cell (hESC)–derived epicardial cells, which produce stromal cells, smooth muscle cells, and growth factors, can remuscularize injured heart. They showed that hESC-derived epicardial cells improved the structure and function of heart tissue in vitro and improved hESC-derived cardiomyocyte grafts in rats with heart tissue loss. The improvements to heart function in vivo persisted for 3 months, suggesting an approach for improving heart regenerative medicine. —GKA

Nat. Biotech. **37**, 895 (2019).

PHOTO: WALLY EBERHART/GETTY IMAGES