Nitrogen’s Past and Future

Microorganisms have been controlling Earth’s nitrogen cycle since life originated. With life evolving around it, nitrogen became both an essential nutrient and a major regulator of climate. Canfield et al. (p. 192) review the major changes in the nitrogen cycle throughout Earth’s history. Most of the time, perturbations typically coincided with the evolution of new metabolic pathways in various Bacteria or Archaea. The last century, however, has seen humans push the biological nitrogen cycle into a new stage altogether. The addition of large quantities of fixed nitrogen to crops in the form of fertilizer chokes out aquatic life that relies on runoff and adds significant amounts of NO—a potent greenhouse gas—to the atmosphere. Although microorganisms may one day restore balance to the nitrogen cycle that they helped shape for billions of years, humans must modify their behavior or risk causing irreversible changes to life on Earth.

Feeling the Pinch

Nanoparticles exhibit many different properties compared to their larger counterparts, but how the stability of certain phases relative to others is affected by a change in particle size is often unclear. Using a thermodynamic probe sensitive to nanoparticle surfaces, Navrotsky et al. (p. 199) show that surface energy strongly influences the stability of some metal oxides relative to others. For example, nanoparticles of CoO, which are stable at larger sizes, are only stable over a very narrow range of conditions due to their high surface energies. Cobalt oxides are catalysts that may one day promote the cost-effective generation of hydrogen from water, but nanoparticles in soils and biological systems—including iron and manganese oxides—also feel the pinch of surface energy on their range of stability.

Slip Sliding Away

The initiation of frictional motion, or slip, along ideal surfaces typically behaves as predicted by rupture models. When stress heterogeneities—similar to irregularities in fault zones in Earth’s crust—are introduced, rupture propagation speeds are not as well constrained by models. To improve understanding of slip behavior, Ben-David et al. (p. 211; see the Perspective by Zapperi) measured rupture speeds and stress profiles along an extended frictional interface between two polymer blocks. The experiments revealed a slow mode of slip that occurs when the local ratio of shear to normal stress is sufficiently low. The selection and arrest of three distinct modes of rupture depended on the value of the local stress ratio.

Polysaccharide Breakdown

One of the current challenges in the biofuels industry is achieving efficient bioconversion of complex polysaccharides like cellulose and chitin. Recently, chitin-binding proteins (CBPs) have been identified that potentiate chitin hydrolysis. Now, Vaaje-Kolstad et al. (p. 219) show that a CBP from the chitinolytic bacterium Serratia marcescens appears to catalyze an oxygenase reaction on the surface of crystallized chitin, leading to chain breakage and generating oxidized ends that can be degraded by chitinases. A structurally similar enzyme, GH61, may play a similar role in the degradation of cellulose.

Economic Benefits of Bt Maize

Maize containing a transgenically expressed toxin originating from Bacillus thuringiensis (Bt maize) is planted across the United States to combat insect herbivory. Non-Bt Maize is also planted alongside Bt maize fields to provide refuges for the insects, which helps to prevent a large area and their facile removal. However, the process is somewhat limited to the incorporation of materials that will flow easily into the templated areas. Arora et al. (p. 214) show that current techniques can be extended to the patterning of metals, through guided epitaxial growth. An excimer laser was used to control the flow of material into patterned templates formed from block copolymers.

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resistance to Bt maize from evolving. Hutchison et al. (p. 222; see the Perspective by Tabashnik) analyzed how Bt maize affected the economic impact of the European corn borer moth in the midwestern United States, as well as its population dynamics. Larval density, a predictor of corn borer population size, has dropped in correlation with the percentage of Bt maize planted. In the highest Bt maize producing state, the positive effects of Bt maize in controlling insect herbivore populations extended to non-Bt maize. Furthermore, the decrease in insect populations demonstrated an overall economic benefit outweighing the overall extra costs associated with planting Bt maize.

Freezing Tolerance Explained

Freezing temperatures exact a toll on plant cells through various mechanisms, including disruption of water balances as ice crystals form. Cellular and organelle lipid bilayers are also put under stress. Moelling et al. (p. 226, published online 26 August; see the Perspective by Browse) analyzed the function of a protein in the model plant, Arabidopsis thaliana, that, when disrupted, leaves plants more susceptible to damage by freezing. The protein, SENSITIVE TO FREEZING 2 (SFR2), shifts and swaps lipid headgroups, altering the chemistry of the chloroplast lipid bilayer membranes to stabilize them during freezing.

Location, Location, Location

Cell division is orchestrated by a complex signaling pathway that ensures the correct segregation of newly replicated chromosomes to the two daughter cells. The pathway is controlled in part by restricting the activity of critical regulators to specific subcellular locations. For example, the chromosomal passenger complex (CPC) is recruited to chromosomes during mitosis where it oversees kinetochore activity and cytokinesis (see Perspective by Musacchio). Wang et al. (p. 231, published online 12 August), Kelly et al. (p. 235, published online 12 August), and Yamagishi et al. (p. 239) now show that the phosphorylation of the chromatin protein, histone H3, acts to bring the CPC to chromosomes, thereby activating its aurora B kinase subunit. The Survivin subunit of CPC binds specifically to phosphorylated H3, with the phosphorylation at centromeres being carried out by the mitosis-specific kinase, haspin. Furthermore, Bub1 phosphorylation of histone H2A recruits shugoshin, a centromeric CPC adapter. Thus, these two histone marks in combination define the inner centromere.

Remodeling Gone Awry

The identification of genes that are mutated at high frequency in human tumors can provide important clues to the molecular pathways that drive tumor growth, which in turn can potentially lead to more effective therapies. Jones et al. (p. 228, published online 9 September; see the cover) looked for such mutations in ovarian clear cell carcinoma, a rare but particularly lethal form of ovarian cancer. Of 42 tumors examined, 57% were found to harbor inactivating mutations in ARID1A, a gene coding for a subunit of the SWI/SNF chromatin remodeling complex, which functions as a master regulator of transcription factor action and gene expression. Thus, proteins associated with the epigenetic control of gene expression can contribute to the development of human cancer.

Web of Parasite Interactions

We live under constant assault from a variety of pathogens. Pathogen exposure will be more or less harmful depending on host factors, including immune status, and, as Teller et al. (p. 243; see the Perspective by Lafferty) point out, the presence of co-infecting pathogens. In a time-series study of wild voles and four pathogens, co-infection had a larger effect on disease than any other factor. For example, infection with cowpox virus increased susceptibility and prolonged bacterial co-infections. Conversely, an ongoing infection with the bacterium Anaplasma reduced the rodents’ susceptibility to the protozoan Babesia. In turn, chronic infection with Babesia limited susceptibility to the bacterium Bartonella.