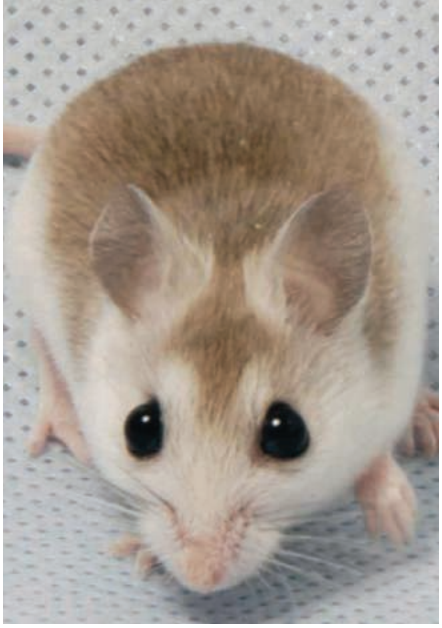

Beached and bleached. Interacting pigment genes helped whiten—and camouflage—mice migrating onto dunes.

ing, a research team described how a key gene aided the animal's colorful transformation. And another group reported that changes in the same gene helped lizards evolve a similar adaptation.

Researchers have studied the genetics of color in lab mice for decades, implicating more than 100 genes, half of which are now sequenced. But Hopi Hoekstra, an evolutionary biologist at the University of California, San Diego, says she "wanted to see what kinds of genes are involved" in shaping color patterns in nature.

In the southeastern United States, deer mice living in forests and dense fields have brown backs and light gray underbellies. But their cousins living on the vegetation-sparse white dunes on islands along the Gulf Coast have lost most of the brown on their backs, and their bellies look bleached. The beach mice have also dropped a characteristic dark stripe running down their face for a more muted look that helps camouflage the animals in their burrows.

To get at the genetics behind such adaptations, Hoekstra and her colleagues bred male beachcombers with female forest mice and vice versa. They now have 600 second-generation mice. "We see a lot of variation in pigmentation" among the animals, says Hoekstra, estimating that about a dozen genes control the pattern of colors distributed across the rodent's flanks, faces, tails, and other body parts. With these crossbred mice, she began testing whether various genes shown to have roles in coloration in lab mice are involved in the beach mouse's new look. "Hoekstra can ask where in the pathway natural selection is working," notes Johanna Schmitt, an evolutionary biologist at Brown University in Providence, Rhode Island. By happenstance, Hoekstra and her colleagues scored a hit with *Mc1R*, a gene involved in the switch between light and dark pigments. A single base change in the gene resulted in the Mc1R protein having abnormally low activity, causing less melanin to be made in the beach mice and resulting in whiter fur. In fact, the change in just this one gene accounts for 34% of the color variation in beach mice, Hoekstra reported. Hoekstra's postdoc Cynthia Steiner subsequently showed that a second gene called *agouti* is more significant for patterning than overall color.

Further analyses indicate that the two genes influence each other, a process called epistasis, in defining the overall patterns of body coloration. "It's the interaction that explains the variation" in color from body part to body part, Hoekstra notes.

Lizards from White Sands, New Mexico, also seem to have exploited changes in *Mc1R* to transform themselves from dark brown to light-colored, Erica Rosenblum of the University of California, Berkeley, reported. She studied three distantly related lizard species that have moved into the dunes in the past 600 years. Rosenblum found that all three had mutations in the gene, dramatically reducing their colors. "What is most striking is the repeating pattern as different species converge on the same phenotype," says Hoekstra.

Lizards and mice are far apart on the tree of life, and scales and fur bear little resemblance, but the metabolic pathways to produce melanin pigment in both animals are very similar. As a result, "it may be evolutionarily 'easy' to evolve color and color pattern differences" by means of the *Mc1R* gene, says Rosenblum.

Wine Yeast's Surprising Diversity

Since the days of the pharaohs, the yeast *Saccharomyces cerevisiae* has enabled us to make bread, as well as wine, beer, and other alcoholic beverages. More recently, it has become a model organism for cell and molecular biologists. Yet it has barely been studied outside the lab. Now, a research team has begun to trace the genetic diversity of this simple eukaryote in the wild.

Evolutionary biologist Jeffrey Townsend of the University of Connecticut, Storrs, and his colleagues have identified several distinct *S. cerevisiae* strains from forests and vineyards in Italy and the United States. Different strains found on grapes from different vineyards "may in part be responsible for the distinctive tastes of naturally fermented wines," Townsend speculates.

Until recently, yeast researchers paid little mind to grapes, thinking that any yeasts on the grapevines were escapees from the nearby vats, where the microbes are often added for the fermentation process. That thinking came into question, however, in 2004, when Paul Sniegowski of the University of Pennsylvania in Philadelphia discovered *S. cerevisiae* just below the bark of oak trees and in the soil around the base of these trees, establishing that this organism had a broader distribution beyond rotting fruit and vineyards. He "demonstrated that there are isolated, variant populations of *S. cerevisiae*," says Townsend.

Sniegowski's finding led researchers to wonder how many yeast strains there are in the wild, how the oak strains are related to those in vineyards, and whether one is derived from the other. While working in John Taylor's lab at the University of California, Berkeley, Townsend and graduate student Erlend Aa of the University of Tromsø in Norway compared DNA of 15 *S. cerevisiae* strains from Italian vineyards—primarily from grapes used in Chianti wine—with two lab samples and a strain from crushed grapes used to make wine. They also analyzed yeast strains provided by Sniegowski that were found on and near oak trees.

Aa sequenced four genes from each yeast and found 78 single-base differences

Unexpected diversity. Once thought to be one strain worldwide, *S. cerevisiae* species collected from oaks and vineyards are quite distinctive.

CREDITS (LEFT TO RIGHT): HOPI HOEKSTRA/UCSD; JUPITER IMAGES; M. LACHANCE/WESTERN ONTARIO UNIVERSITY

in these genes among the strains. Various combinations of these altered genes established distinguishable genotypes for each sample. Aa and Townsend demonstrated that the yeast found on grapes were not that similar to the yeast recovered from the wine must in fermentation vats. Instead, yeast from wine vineyards around the world include many wild strains and greater genetic diversity than that of yeast from the must. "The wine yeast does not represent a [global] population of domesticated strains as has been suggested," notes Christian Landry of Harvard University in Cambridge, Massachusetts. The vineyard yeast were also quite different than the yeast recovered from oaks.

Two samples from Italy's Elba Island also hinted that the yeast found on grapes may differ significantly from vineyard to vineyard within a region. Townsend discovered that yeast from the Elba samples resembled mainland strains but also contained genotypes unique to the island. He plans to expand the study to determine whether other places have distinctive yeast populations and, perhaps as a result, distinctive wines.

Two of the four yeast genes studied by Townsend and Aa had telling changes that may explain some of the vineyard-to-vineyard strain variation. One, the *SSU1* gene, is involved in transporting sulfite—a toxin—out of the yeast cell. The second is a gene whose protein regulates *SSU1*'s activity. The more active *SSU1* is, the more resistant the yeast is to this toxin. The *SSU1* regulatory gene showed the greatest number of differences from strain to strain, which translated into slightly different proteins and indicated that it had evolved the fastest of the four genes studied. Viniculture practices could explain this rapid change, says Townsend. In the vineyard, grapes are treated with sulfite and sulfite-containing compounds that destroy mold and other microbes, presumably killing all but those yeast with high *SSU1* activity. Also, winemakers add sulfite to sterilize fermentation vats, again presumably killing all but the most tolerant yeast.

Townsend notes that with such treatments, winemakers end up with ever more useful strains. The more resistant a *S. cerevisiae* strain is to sulfur-based chemicals, the longer the yeast cells will survive in vats treated with sulfite, and the more alcohol they make. "[Wild] wine yeast has inadvertently been domesticated," concludes Townsend. That's worth a celebratory drink.

–ELIZABETH PENNISI

Nanomaterials

'Smart Coatings' Research Shows The Virtues of Superficiality

Thin, shallow, and out to strike it rich—high-tech protective paints and varnishes look poised to become the first "killer apps" for nanotechnology

BERLIN—Clothing with computers woven into the fabric. Microscopic robots that make repairs with tools the size of a virus. No question about it: Nanotechnology, the applied science of the very small, has generated its share of megahype. For companies researching nanomaterials, however, profitability is the priority—and not in the dreamy future but now. Many are concluding that the beauty of the technology is literally skin deep.


Hot and heavy. This Fraunhofer Institute test furnace measures how much weight treated wood can bear after burning.

CREDIT: FRAUNHOFER INSTITUTE

At a recent meeting here,* researchers from around the world swapped news about efforts to spin nanotech into products based on surfaces with novel properties. "Coatings applications are among the first true everyday uses of nanotechnology," says Dirk Meine, a chemist who organized the conference for Vincentz Network, a coatings industry media group. Examples include nanoparticle-laden varnishes that combine the scratch resistance of an inorganic crystal with the versatility of an organic plastic. (Super–scratch-resistant coatings are already on the market.) Researchers offered a glimpse of what may be the next wave of nano applications to enter daily life.

Combating corrosion

The biggest task in the coatings industry is to slow down corrosion. Pipes rust, bricks crumble, and timbers rot, calling for repairs that add up to 4% of the gross national product of Western countries, according to Ubbo Gramberg, a corrosion chemist at Bayer in Leverkusen, Germany. "Not all these corrosion problems can be solved by coatings, but a considerable percentage can," says Michael Rohwerder, a physicist at the Max Planck Institute for Iron Research in Düsseldorf, Germany.

Top prize will go to a coating that prevents the corrosion of steel. Today, even the best protective coatings allow oxygen to diffuse slowly through to the metal surface. Corrosion kicks into overdrive when coatings begin to peel off, a process called delamination.

The trouble starts at microscopic nicks or pits on the surface introduced during manufacturing or through wear and tear. These defects form miniature circuits in which electrons flow through the metal in one direction while positive ions such as sodium flow back along the metal surface, leaving a degraded metal-coating interface in their wake. The coating becomes separated from the metal and flakes away, exposing fresh metal and accelerating the process.

That is where nanotechnology could come to the rescue. Rohwerder's group is working on coatings that allow a corroding metal surface to "self-heal." The oxidative attack at the site of a defect triggers nanoparticles to release corrosion-inhibiting ions—in this case, negatively charged molybdate ions—that stand in for the metal and form a protective oxide skin. Once the defect is sealed, the coating stops releasing ions until the next attack.

But there's a catch. Because these coatings sense corrosion with innately conductive polymers (ICPs)—carbon chains that allow charge to flow along their length like the semiconductors in microchips—they actually pro-

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* Fourth Annual Smart Coatings Conference, 9–10 June.

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