human exploration: positioning a small space station at the L1 Earth-moon Lagrangian point, where the gravitational pulls of Earth and its moon cancel each other out. Located only 65,000 kilometers from the moon—one sixth the distance between the moon and Earth—this point would provide easy access to the lunar surface (and to Mars as well). But with NASA still struggling to assemble the International Space Station in low-Earth orbit, nobody is expecting to see a replay of Apollo anytime soon.

BIOTECH

Fixing Food

ALLERGEN-FREE COMESTIBLES MIGHT BE ON THE WAY **BY CAROL EZZELL**

A bite of a cookie containing peanuts could cause the airway to constrict fatally. Sharing a toy with another child who had earlier eaten a peanut butter and jelly sandwich could raise a case of hives. A peanut butter cup dropped in a Halloween bag could contaminate the rest of the treats, posing an unknown risk.

These are the scenarios that "make your bone marrow turn cold," according to L. Val Giddings, vice president for food and agriculture of the Biotechnology Industry Organization. Besides representing the policy interests of food biotech companies in Washington, D.C., Giddings is the father of a four-year-old boy with a severe peanut allergy. Peanuts are among the most allergenic foods; estimates of the number of people who experience a reaction to the legumes hover around 2 percent of the population.

Giddings says that peanuts are only one of several foods that biotechnologists are altering genetically in an attempt to eliminate the proteins that wreak havoc with some people's immune systems. Although soy allergies do not usually cause life-threatening reactions, the scientists are also targeting soybeans, which can be found in two thirds of all manufactured food, making the supermarket a minefield for people allergic to soy. Biotechnologists are zeroing in on wheat, too, and might soon expand their research to the rest of the "big eight" allergy-inducing foods: tree nuts, milk, eggs, shellfish and fish.

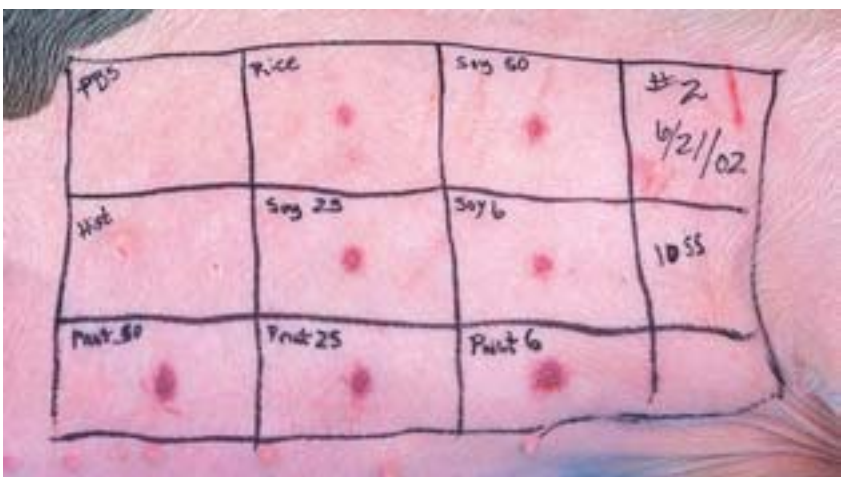
Last September, for example, Anthony J. Kinney, a crop genetics researcher at DuPont Experimental Station in Wilmington, Del., and his colleagues reported using a technique called RNA interference (RNAi) to silence the genes that encode p34, a protein responsible for causing 65 percent of all soybean allergies. RNAi exploits the mechanism that cells use to protect themselves against foreign genetic material; it causes a cell to destroy RNA transcribed from a given gene, effectively turning off the gene.

Whether the public will accept food genetically modified to be low-allergen is still unknown. Courtney Chabot Dreyer, a spokesperson for Pioneer Hi-Bred International, a subsidiary of DuPont, says that the company will conduct studies to determine whether a niche market exists for low-allergen soy before developing the seeds for sale to farmers. She estimates that Pioneer Hi-Bred is seven years away from commercializing the altered soybeans.

Doug Gurian-Sherman, scientific director of the biotechnology project at the Center for Science in the Public Interest—a group that has advocated enhanced Food and Drug Administration oversight for genetically modified

COUNTERING INTOLERANCE

Although relatively few people have outright food allergies—in which the body raises an immune attack against proteins within a food—many more have difficulty digesting some foods. Dairy products are already on the market for those who develop gas, bloating and diarrhea from drinking milk or eating ice cream. A similar product could soon emerge for those allergic to, or intolerant of, wheat gluten. Scientists led by Chaitan Khosla of Stanford University have found an enzyme that when orally administered might allow people with celiac sprue, an allergy to gluten, to eat some wheat products. It could also help buffer the effect of less severe gluten intolerance.



PORCINE PREDICTOR: Various proteins from foods such as soybeans are injected underneath the skin of pigs to help identify those items that are most allergenic.

AGRICULTURAL RESEARCH SERVICE, USDA; SCOTT BAUER

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foods—comments that his organization would not oppose low-allergen foods if they prove to be safe. But he wonders about "identity preservation," a term used in the food industry to describe the deliberate separation of genetically engineered and nonengineered products. A batch of nonengineered peanuts or soybeans might contaminate machinery reserved for low-allergen versions, he suggests, reducing the benefit of the gene-altered food. Such issues of identity preservation could make low-allergen genetically modified foods too costly to produce, Chabot Dreyer admits. But, she says, "it's still too early to see if that's true."

Biotech's contributions to fighting food allergies need not require gene modification of the foods themselves, Giddings notes. He suggests that another approach might be to design monoclonal antibodies that bind to and eliminate the complexes formed between allergens and the subclass of the body's own antibodies that trigger allergic reactions. "Those sorts of therapeutics could offer a huge potential," Giddings states, and may be more acceptable to a public wary of genetically modified foods. He definitely sees an untapped specialty market. "When you find out your child has a life-threatening food allergy, your life changes in an instant," Giddings remarks. "You never relax." Not having to worry about every bite will enable Giddings—and his son—to breathe a lot easier.

MATHEMATICS

Color Madness

ODDBALL MAPS CAN REQUIRE MORE THAN FOUR COLORS

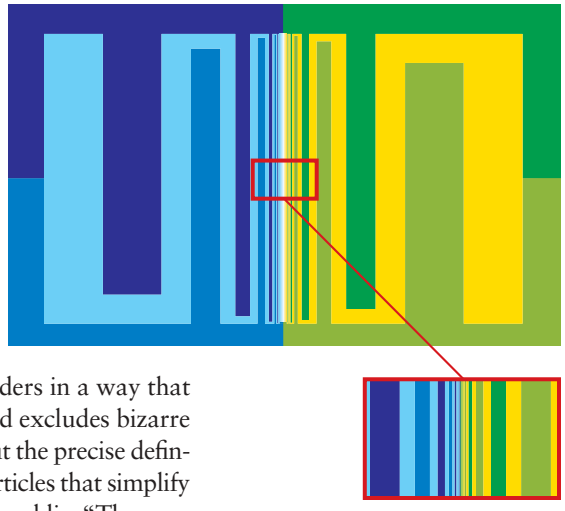
BY GEORGE MUSSER

Science operates according to a law of conservation of difficulty. The simplest questions have the hardest answers; to get an easier answer, you need to ask a more complicated question. The four-color theorem in math is a particularly egregious case. Are four colors enough to identify the countries on a planar map, so that two bordering countries (not counting those that meet at a point) never have the same color? The answer is yes, but the proof took a century to develop and filled a 50-page article plus hundreds of pages of supplementary material.

More complicated versions of the theorem are easier to prove. For instance, it takes a single page to show that a map on a torus requires at most seven colors. The latest example of unconventional cartography comes from philosopher Hud Hudson of Western Washington University in a forthcoming *American Mathematical Monthly* paper. He presents a hypothetical rectangular island with six countries. Four occupy the corners, and two are buffer states that zigzag across the island. The twist is that the zigs and zags change in size and spacing as they go from the outskirts toward the middle of the island: each zigzag is half the width of the previous one. As the zigzags narrow to nothingness, an infinite number of them get squeezed in.

Consequently, the border that runs down the middle of the island is a surveyor's nightmare. If you draw a circle around any point of the border, all six countries will have slivers of territory within that circle. No matter how small you draw the circle, it will still intersect six countries. In this sense, the border is the meeting place of all six countries. So you need six colors to fill in the map. By extending the procedure, you can prepare maps that require any number of colors.

The standard four-color theorem defines borders in a way that hews to common sense and excludes bizarre cases such as Hudson's. But the precise definition is usually left out of articles that simplify the theorem for the general public. "The popular formulation of the four-color problem, 'Every map of countries can be four-colored,' is not true, unless properly stated," says Robin Thomas of the Georgia Institute of Technology. Thomas is one of the co-authors of a shorter proof of the theorem—just 42 pages.



SIX COLORS are needed to fill in this map, with its infinitely meandering countries.

HUD HUDSON *Western Washington University*

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