An unlikely materials scientist

Palucka's First Law of Unintended Incompetence states, "an unfolded map can never be restored to its original state." I derived this law based on years sitting in the passenger seat of cars struggling to return an ungainly map to its flat, native state, only to end up with a puffy mass of paper whose folds were clearly in direct opposition to their original orientation. My wife, in the driver's seat in more ways than one, would watch my fumbling attempts quietly from the corner of her eye until the next stop light, at which she would snatch the thick, mangled map from my mitts, open it, and with a series of brisk, seemingly automatic, flips of her hands, perfectly refold it into factory condition before the light turned green. I always watched in amazement as she handed me the thin, crisp packet with an unspoken air of "why did I marry this guy again?" (She is a Palucka by marriage only, as she likes to remind me, so the First Law of Unintended Incompetence does not apply to her.)

This is just to illustrate my complete lack of spatial sense, which is not a good trait for a materials scientist. I first noticed this problem from a materials viewpoint when I started learning about crystal structure in grad school. I had quit my job as a chemist in my early thirties to pursue a master's degree in materials science, and soon learned that materials scientists, unlike most chemists, were obsessed with crystal structure. At first, this seemed to pose no problem. I could clearly visualize the cubic, face-centered-cubic (FCC), and body-centered-cubic (BCC) structures, despite my spatial difficulties. I bought out the entire supply of small Styrofoam balls from a local craft shop and fashioned each structure using toothpicks as connectors. "This materials stuff is easy!" I thought.

But I spoke too soon. It turns out that the atoms in the FCC structure were not separated by great, toothpick-like distances, but were instead crammed together in a close-packed structure, like a stack of oranges, to minimize the open space. The textbook gave a recipe for making the FCC close-packed structure. First, lay down the A layer of atoms (Styrofoam balls) in close contact; next, place the B layer on top of this one, in one of the two sets of the hollows formed by the A layer; finally, place layer C on top of B so that the C atoms are not directly above the A atoms. I broke my toothpicks in half to join my Styrofoam atoms in a close-packed manner following this recipe, which the book called an ABCABC layered structure. To form a hexagonal close-packed (HCP) structure, one merely had to form ABABAB layers. So I made an HCP structure too—simple enough.

Then I read this in my textbook (from Barrett, Nix, and Tetelman, *The Principles of Engineering Materials*): "In the FCC structure the close-packed planes are perpendicular to the body diagonal. Both structures [FCC and HCP] have equal packing densities and equal number of nearest neighbor atoms." Here the troubles started. My feeble brain exploded. Being unable to visualize in my head these planes "perpendicular to the body diagonal," I pressed an eye up to the FCC model I had made, at what I deemed the appropriate angle. But all I saw was a field of white Styrofoam. Maybe if I disassembled the structure so I could stare this close-packed plane in the face—but how could I be sure I was removing the correct atoms? I quickly reassembled my FCC model, noticing that the toothpick "bonds" were getting looser as the holes they poked into the Styrofoam got bigger. I had invented the wobbly face-centered-cubic (WFCC) structure—funny nobody else had discovered this before.

I struggled to see the equal packing densities, and the equal number of nearest-neighbor atoms. Here I made another trip to the craft store, and bought a blue marker and a red marker. I put a blue dot on some of the foam balls, and a red dot on what appeared to be their nearest neighbors. I did this for both the FCC and HCP models. I sat on the floor of my apartment, staring at the models, twisting them in my hands and contorting my body this way and that to try to convince myself that I could see the equality of nearest neighbors, probably inventing a few new yoga positions along the way—hexagonal-face-packed lotus, anyone? I partially disassembled and reassembled the models, producing the first extremely wobbly face-centered-cubic structure (EWFCC) ever seen. Soon I was sitting among the detritus of my failed attempts, surrounded by broken toothpicks, multicolored Styrofoam balls, and two dried-out markers, convinced that my days as a materials scientist were numbered.

But I rallied from this defeat. Like most good students, I gave up truly trying to understand these concepts and just memorized them. I did well enough answering the few questions on the first test about these crystal structures and moved on. Soon we were learning about stress and strain, which required less spatial visualization. I could spell FCC and HCP and nod knowingly when they came up in conversation, even if I hadn't mastered them. I burned my frequent customer card from the craft shop and never purchased a Styrofoam ball again.

And—oh, yes—I bought my wife a GPS, which hasn't stopped her, though, from telling the story of my map folding difficulties at parties, or reminding me that she's a Palucka by marriage only. But she's more than worth it. A few years ago I spent an hour outside on the porch on a cold December day trying to untangle a hopelessly intertwined string of Christmas lights. Noticing my distress, she came to the rescue; within minutes the lights lay before me in a beautiful, unknotted string. I may be unintentionally incompetent in some things, but I married well.

Tim Palucka