The Art and Science of Knowing Things

I do my best not to talk shop. When asked what I do for a living I usually just offer that I'm a scientist. Sometimes I'm then asked what I study, or what kind of research I do.

Though they're probably meant interchangeably, in a way these are completely different questions – the how versus the why of focused work. I generally try to respond in some way that surreptitiously changes the subject; they're tough questions to engage in earnest, better suited to quiet contemplation than casual conversation. It's not so different from being asked what sorts of things I make, when it comes up that I craft with clay and fiber. An honest answer to that – proffered variously by many a maker – would be that I'm never really sure just what I'm aiming for, but I keep searching for clues in the studio.

Much of my laboratory's physics research over the past twenty-odd years has focused on light-matter interaction in regimes of strong mean-field nonlinearity and coherent quantum fluctuations. So I guess you could say that I study atoms and photons. As I write this I ask myself how well I feel I really know atoms or photons as a result of all this work. Not how much I know *about* them, in the way that one can know a lot about ancient Rome or about spiral galaxies, but how much I really *know* them, in the way that one knows a beloved pet or a favorite food.

Our work has utilized a single type of atom – Cesium-133, the species used in most atomic clocks. We use it because its internal structure is relatively simple and it's relatively easy to get lasers and optics that are well matched to its particular properties. With specialized tools like tunable single-mode lasers, high finesse micro-resonators, and feedback control systems we can make finely tailored "craft" photons that our atoms interact with especially strongly. Our experiments in recent years have studied aspects of these interactions that inform the design of novel photonic computing technologies that could offer speed and energy-efficiency advantages over conventional electronic devices.

We make photons by the septillions on an ordinary day in the lab – just by running our lasers – and they're as anonymous to me as drops in the ocean. I've never really thought to myself, *now this is a particularly nice photon*, or, *there's something a bit odd about that one*. We don't actually make any atoms – that's done mainly by stars and other nuclear reactors – but we do handle them in more intimate numbers, from wee clouds of hundreds of thousands (using optical and magnetic traps) down to singletons (using a technique called cavity quantum electrodynamics). The sophisticated experimental apparatus we build can register individual atoms and test theories about their internal dynamics, but as a conscious actor I only get to interact with atoms indirectly, through the more quotidian intermediaries that are my lab equipment. It's like interacting with the New York Stock Exchange only through the website of an online brokerage – you can probe the market's true behavior but it's nothing like being there in person. Any type of familiarity a physicist can build with atoms or photons is radically virtual, entirely mediated by rational judgments, anything but visceral.

I've burned my hand grazing a high power laser beam, but never felt the tickle of one photon hitting my skin – our nerve receptors just aren't that sensitive. I've never pinched an atom to feel the degeneracy pressure of its electrons, never learned to tell a bosonic species from fermionic by its heft – atoms are just too miniscule. Such elementary constituents of energy and matter are imperceptible to our bodily

senses; although we believe on the basis of scientific evidence that individual atoms and photons exist, they're not really entities we can ever know for real.

Thinking back over all that time spent assembling and operating complex experiments, what in fact have I best come to know? What kind of research do I actually do?

I think about soldering electrical circuits – the smell of flux and singed insulation; the heat on your face as you lean in for a closer view of what you're doing; the way molten solder wicks onto hot surfaces. I think about the way you brace two or three fingers so that you can turn a knob on an optic mount to precisely tilt a mirror without letting the weight of your hand cause wayward deflections. The feel of a twelve-point box wrench grabbing the shallow crown of a quarter-inch bolt – tenuous, yet somehow sufficient for all the strength you can muster; the hopscotch of alternately torqueing this-bolt-then-that to evenly tighten a knife-edge flange against a copper gasket for an ultra-high vacuum seal. I think about pulling up a trace on an old analog oscilloscope; that ghostly glow of a phosphor screen triggered intermittently. Focusing an electron microscope – watching blurred features stretch and scrunch, hunting for sharpness with the stigmators. Tuning up a laser, any one of the many kinds we've bought or built over the past two decades, asking yourself if your alignment's getting better or worse; having to admit to yourself at 2am that you're on the wrong track.

Such manual skills and labor for such impalpable objects of study! If only we could commune more deeply with our tools and instruments, perhaps we'd osmose some of their more intimate knowledge of those elusive atoms and photons.

Back in the studio I take comfort in feeling that I know my materials first-hand. It takes no effort to recall the feel of spinning clay on my fingers, or of reeling silk warp…

I think about the way my clay burnishes and cracks when I throw it dry; the way it tears as I take rough darts with a pin tool; how much water it takes to reseal the seams without leaving drips or fingerprints. When my clay hits its limit as I'm pulling it up and out, that little bit it sags as my fingers pass over it. Stacking a bisque firing – handling fragile greenware (handling other people's fragile greenware!), stilting or canting thick-bottomed pots to let out the steam; the smell of clay being force-dried in a kiln. The smell of wood-firing, the smell of reduction, the smell of too much reduction when closing up at the end of a firing; the ferocious hue of 2400 degrees in the firebox. I think about the ache I get in my shoulders from weaving wide cloth on my floor loom, leaning over the shed with extended arms spanning a full meter to throw and catch the shuttle. The clatter of the shuttle as it jostles race and reed; the force and friction of beating picks snug against the fell. The magic of seeing a pattern emerge in the second repeat of a long treadling sequence; the frustration of not seeing the right pattern emerge after so many hours spent threading heddles.

Studio equipment and craft processes feel so much like laboratory equipment and experimentation. In the studio, the things we make are our data. But the roles of clay and fiber seem different from those of atoms and photons; I'm not sure that knowing them is really the end. I suspect that craft materials – as central as they are to what one does as a maker – might yet be a kind of medium for some deeper investigation.

So what then would be the aim of my work in craft – what am I trying to study in the studio? My inner physicist intuits that I seek another way of knowing Nature and its habits, parallel and complementary to modern science. I've become fascinated of late with using optical and electron microscopes to study surface development on wood-fired ceramics, and with the surprising connections one finds thereby to mineralogy and volcanology. I like to think this relates to the strong focus on materiality to which I gravitate in my making – it's a story of clay leading me back to atoms and photons in a completely different context than I'd ever considered before, a much messier one that stirs a distinct sense of purpose stemming more from rapt appreciation than Baconian method.

Two centuries ago, Immanuel Kant wrote of an aesthete's urge to explore "the beautiful in nature, in order to find there, as it were, a voluptuousness for the mind in a train of thought that he can never fully unravel" (Kant 300). I wonder what animates raw materials like clay and fiber to reveal such unexpected textures as we work them. I wonder if the quantum behaviors of atoms and photons propound some cryptic new basis for building better computers. I wonder how burning wood can coax brilliant colors from drab weathered rock, and what meaning hides behind the visual resonance of wood-fired ceramic surfaces with the geological terrains clay comes from.

What are the essences of the stuff of earth, and how can we witness their agencies? People have been exploring such trains of thought for millennia, passing down accumulated wisdom from generation to generation. Today we continue to hunt for clues in our laboratories and studios; one hardly imagines that we're anywhere near done. It's not even clear to me what kind of enlightenment we really seek, yet the will to push onward burns bright.

May we never tire in our varied practices of the art and science of knowing things.

Or of examining each other's data.

Works Cited

Kant, Immanuel. *Critique of Judgment*. Trans. Werner Pluhar. Indianapolis: Hackett Publishing, 1987.