Laidlaw Scholarship: Tahmeed Shafiq

Summary of Summer 1

My research project aimed at analysing a fluid mechanical phenomenon familiar to potters but unfamiliar to physicists: that of ‘mocha diffusion’, a dye-on-clay reaction that forms a self-similar fern like structure. Our running hypothesis was that this particular behaviour was a chemical-dependent variation of the Marangoni effect. The Marangoni effect is a well-characterised fluid process whereby fluids flow down a surface tension gradient (from higher to lower tension).

It would certainly be interesting to discover that fluid surface tension gradients could be coupled to their chemistry somehow, as it would indicate how mocha diffusion could be generalised to other fluid combinations and give insights into how to manipulate fluids at interfaces. This is what we set out to discover, and in some respect, we succeeded.

First, we had to get the phenomenon to work. We needed a reproducible recipe that was robust enough not to be affected by environmental conditions like humidity and room temperature, as these were factors we wouldn’t control in our experiments. I discovered that the simple recipes shared publicly by Robin Hopper, a Canadian ‘mocha master’, worked just fine, and that tinkering with dyes produced different patterns with fingers of varying thickness. It was curious to note that heavy suspensions of dyes did not produce much diffusion—possibly indicating a requirement that dyes be moderate suspensions, and not pure liquids. Indeed, pure acids like citric juices and vinegar barely seemed to disperse on the surface of wet clay at all.

The most startling revelation was that acids are not required to produce mocha diffusion. The process occurs with alkalis too, *but the fingers are thicker*. This prompted the question, Are we looking for a ph *gradient* rather than a specific threshold at which mocha occurs? If so, why would the pH affect the thickness only in one direction, as we observed? Meaning that increasing the acidity of a dye made thinner fingers, but the same was not observed when the dye was made more alkaline.

A good explanation (although perhaps not a satisfactory one) is that there are *multiple* processes going on in our simple Petri dish experiments. Acidity, particulate size, temperature of the dye, all these factors may affect the end result in complex, interconnected ways. This is a far cry from the simple answer we expected to get: that mocha diffusion is just a simple layering of basic chemistry atop fluids with differing surface tensions.

I came away from this summer with a lot of raw data and plans on how to process and analyse it. Contained within that data should be some good hints as to what degree of correlation exists between acidity and dendritic finger thickness. There is a whole world going on in the little puddles of wet clay, and while we cannot say for certain what it contains without further experiment, it certainly seems to raise a lot of questions about our present understanding of fluid-interaction forces.