Density and Calorimetry Explorations of the Lamellar Phases of Lipid Molecules

I, Brian Seper, worked with Professor Paul Harper studying the lipids: monomyristin, monolaurin, monocaprin, and monocaprylin. These lipids are, in principle, identical except for the length of their hydrocarbon tails. Lipids molecules, in general, are present in our everyday lives because they are used as emulsifiers (making two liquids mix that normally would not) in food, as surfactants (lowering the surface tension between liquids) in cosmetic products, and make up the membranes of the cells in our bodies. Given their presence in the body and usage in products, understanding the physical properties of lipids is an important area of research.

Lipids are composed two components: a non-polar, water-hating hydrocarbon tail and a polar, water-loving head group. In the case of our lipids, and many other lipids, depending on their environment (temperature and amount of water) these lipids will self-assemble into different shapes, which we call phases. In limited amounts of water our lipids form bilayer sheets, where the head groups are in contact with the water, while the tails are 'inside' the sheet, protecting them from water contact. These sheets are called lamellar phases, and at lower temperatures the molecules are frozen into place (this is called the L_C phase) and as the temperature increases the lipid molecules are free to rotate in place (this is called the L_β phase), and at even higher temperatures the molecules become free to move about in the plane of the sheet (this is called the fluid lamellar or L_α phase). In higher water amounts of water and in higher temperatures their tails curve more, which encourages them to form more "curvy" phases such as the cubic phases and the H_{II} or hexagonal phase.

My research was focused on confirming the transition temperatures for the lamellar phases from last year by Mr. Aaron Abma. To study the transition temperatures we prepare amount of lipid in a small aluminum pan with some water and this pan is then placed in a differential scanning calorimeter (DSC). We heated and cooled our samples at different rates from 0.01 ˚C/second to 0.2 ˚C/second over a wide temperature range to see all transitions, or over a range that only encapsulated a transition we wanted to study in particular. We still find the L_α to L_β transition temperatures for monomyristin, monolaurin, and monocaprin to be: 35.8 ºC, 17.2 ºC, and -7.8 ºC, respectively. Of a higher priority for the lab this summer was to analyze the densities of our lipids as a function of temperature, and from this are able to state the following: The volume ratio of a methyl group (CH_3) to a methylene group (CH_2) is not constant as it has previously been assumed, and that the volume of a methylene group is larger in a bilayer (in the L_α phase) than in liquid alkanes (which is a molecule that is very similar to the hydrocarbon tail of our lipids) by about 2%. I spent much of my summer writing, and reading, on the aforementioned findings.

The research benefitted me in four key ways. Firstly, I gained a deeper conceptual understanding of what lipids are, how they behave in varying environments, and the phases they form. I learned about instrumentation, including: differential scanning calorimetry, small angle x-ray scattering, vibrating tube densitometry, and what each instrument can tell me about the lipids I study. Secondly, I learned problem solving methods, in particular how one forms a relevant research question, and then how you would go about answering that question. Thirdly, I learned about how to explain and display what I have learned to many different types of audiences. This research project gave me the opportunity to continue the paper started by Mr. Aaron Abma last summer and bring it closer to completion. Thus, I needed to learn how to write scientifically, but also carefully investigate the literature to get an understanding of where this paper fits in the context of other papers. In addition to learning how communicating ideas to Professor Harper (an expert in lipid physics), I also had to learn how to explain my research to other members of the physics department and other researchers (who are not necessarily experts in lipid physics). From this experience I now have a better understanding of what research entails, which has informed me on whether or not graduate school is the path I want to follow after leaving Calvin College.