1.1: What is a Fluid?

Fluids

What is a fluid? Almost everything that we will discuss is soft matter under physiological temperature conditions: liquids and solutions, cytoplasm and cytosol, DNA and proteins in solution, membranes, micelles, colloids, gels... All of these materials can in some respect be considered a fluid. So, what is a fluid?

- A substance that flows, deforms, and changes shape when subject to a force, or stress.
- It has no fixed shape, but adapts its surface to the shape of its container. Gasses are also fluids, but we will focus on fluids that are mostly incompressible.

For physicists, fluids are commonly associated with flow—a non-equilibrium property—and how matter responds to forces (i.e., "Newtonian fluids"). This topic—"rheology"—will be discussed in more detail later. From this perspective, all soft condensed matter can be considered a fluid. For chemists, fluids most commonly appear as liquids and solutions. Chemists typically use a molecular description for the solute, but less so for the solvent. However, chemists have a clear appreciation of how liquids influence chemical behavior and reactivity, a topic commonly called "solvation". The most common perspective of fluids is as continuous dielectric media, however fluids can be multicomponent heterogeneous mixtures. For our biophysical purposes, we use the perspectives above, with a particular interest in the uniquely biological fluid: water. Since we are particularly interested in molecular-scale phenomena, we will add some additional criteria:

- **Composition:** Fluids are dense media composed of particulate matter (atoms, molecules, proteins...) that can interact with one another. Since no two particles can occupy the same volume, each particle in a fluid has “excluded volume” that is not available to the remaining particles in the system.
- **"Structure"**: Fluids are structured locally on the distance scale of the particle size by their packing and cohesive interactions, but are macroscopically disordered.
- **The midrange or mesoscale distances** involve interactions between multiple particles, leading to correlated motions of the constituents.
- **"Flow"** is a manifestation of these correlated structural motions in the mesoscale structure.
- **Most important**: The cohesive forces (intermolecular interactions) between the constituents of a fluid, and the energy barriers to changing structure, are on the order of k_BT ("thermal energy"). Thermal forces are enough to cause spontaneous flow on a microscopic level even at equilibrium.

Fluids may appear time-invariant at equilibrium, but they are microscopically dynamic. In many cases, "structure" (the positioning of constituents in space) and the "dynamics" (time-dependent changes to position) are intimately coupled.