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Ellipsoids beat Spheres: Experiments with Candies, Colloids and Crystals

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How many gumballs fit in the glass sphere of a gumball machine? Scientists have been puzzling over problems like this since the Ancient Greeks. Yet it was only recently proven that the standard way of stacking oranges at a grocery store–with one orange on top of each set of three below–is the densist packing for spheres, with a packing fraction $\phi \sim 0.74$. Random (amorphous) packings of spheres have a lower density, with $\phi \sim 0.64$. The density of crystalline and random packings of atoms is intimately related to the melting transition in matter. We have studied the crystal-liquid transition in spherical colloidal systems on earth and in microgravity. The simplest objects to study after spheres are squashed spheres – ellipsoids. Surprisingly we find that ellipsoids can randomly pack more densely than spheres, up to $\phi \sim 0.68$ - 0.71 for a shape close to that of M&M's®Candies, and even approach $\phi \sim 0.75$ for general ellipsoids. The higher density relates directly to the higher number of neighbors needed to prevent the more asymetric ellipsoid from rotating. We have also found the ellipsoids can be packed in a crystalline array to a density, $\phi \sim .7707$ which exceeds the highest previous packing. Our findings provide insights into granular materials, rigidity, crystals and glasses, and they may lead to higher quality ceramic materials.