Carbon nanoallotropes are classified as zero dimensional (0D), one dimensional (1D), or two dimensional (2D) based on their geometry. To investigate the relationship between dimensional properties and potential toxicity, we used three commercial types of carbon nanomaterials: spherical, 0D carbon black particles (M120, Cabot); 1D carbon nanotubes (MWCNT-7; Mitsui); and 2D graphene nanoplatelets (Cabot). These commercial products are manufactured as dry powders and are respirable, posing a potential health hazard for workers. High aspect ratio, 1D carbon nanotubes are recognized as hazardous based on their dimensions and biopersistence in the lungs. Recent theoretical modeling studies identified an additional factor, mechanical bending stiffness, that contributes to toxicity of fibrous, 1D nanomaterials. Long, rigid 1D nanomaterials induce lysosomal permeabilization leading to cell death and release of proinflammatory mediators from lung target cells. Graphene nanoplatelets can also be toxic depending on their lateral dimensions, layer number, and surface reactivity. Rigid nanoplatelets greater than 5um in lateral dimension trigger intracellular oxidative stress and plasma membrane damage resulting in cell death. Spherical 0D carbon black particles of similar surface area do not induce lysosomal or plasma membrane damage and are nontoxic. Interdisciplinary research teams are essential for identification of physicochemical and mechanical properties of engineered carbon nanomaterials related to toxicity. This combined theoretical and experimental approach will enable safe design of carbon nanomaterials for biomedical and environmental applications. This research was supported by a Superfund Research Program grant from the National Institute of Environmental Health Sciences (P42 ES013660) and a National Science Foundation grant (CBET-1344097).