A major challenge in nanoparticle engineering is to devise a flexible and robust synthetic strategy to pack sufficient multifunctionality into nanoparticles smaller than ~100 nm. A general paradigm is presented for engineering nanoparticle clusters from primary nanoparticles, instead of from atoms and molecules. The nanocluster size and particle spacing within the clusters is controlled by manipulation of the particle concentration pathways and the colloidal interaction potential. This “bricks and mortar” interfacial dynamic assembly technique provides great flexibility in choosing and mixing nanoparticle building blocks to engineer desired function. For treatment of cancer and many other diseases, proteins are formulated at very high concentrations where they often undergo irreversible aggregation, gelation or precipitation. We create highly concentrated antibody dispersions comprising dense nanoclusters of therapeutic protein molecules, which upon dilution in vitro or administration in vivo, remain conformationally stable and biologically active. A hierarchy of intracluster and intercluster interactions are manipulated to control the nanocluster size, as well as to obtain low viscosities and stable protein. The same approach is utilized to form Au nanoclusters of controlled size which reversible dissociate back to primary particles upon biodegradation of the stabilizing polymer. The close spacings of the Au nanoparticles in the clusters produce strong NIR extinction, which is of practical interest in biomedical imaging and therapy. The Au nanoparticles are stabilized ligands with buried charges that unexpectedly resist the adsorption of protein molecules, despite the substantial surface charge.