# What Is A Particle?©

By Bruce B. Weiner Ph.D., August 2010

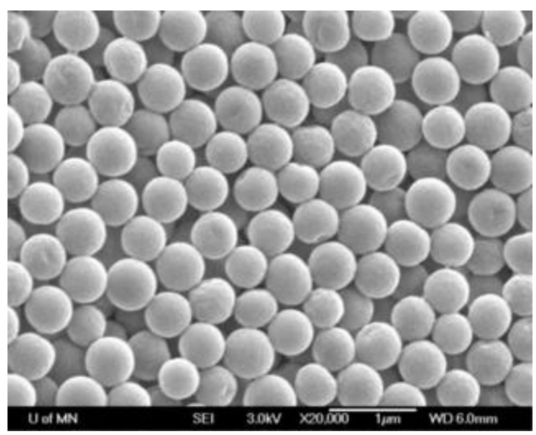
**Elementary vs Fine Particles:** The question embodied in the title might seem strange until you consider the many different ways particles play a part in science and engineering. For example, if you do a web search using just the word particle, you will get more hits for atomic, nuclear, and elementary or subatomic particles than you will for pharmaceutical particles, nanoparticles, clay particles, etc. You will get a lot of hits for particle accelerators, particle colliders, particle physics as well as a few hits that really interest you.

It was once proposed by the Fine Particle Society that the term "fine particle" be used as a keyword grouping to avoid confusion with atomic and nuclear particles. The New York State Department of Health defines a fine particle as any particle causing pollution with a diameter of less than 2.5 micron. Such a partial definition undoubtedly arises because of concerns over respiration, but does not cover the lower end, and, of course, it assumes all fine particles cause pollution. They don't. If you do use the search term "fine particle", you usually don't get hits for particle sizers, possibly because the Fine Particle Society in the U.S.A. is not as strong as it used to be, or perhaps because, ultimately, there is no universally agreed upon keywords in this field.

So the first thing to know about "What Is a Particle?" is to use keywords like these: "particle characterization", which also includes zeta potential and shape; "particle size"; and "particle size analyzer". When you see the term "particle analyzer", do not think it means a chemical analyzer. While a misnomer, a particle analyzer is most often an instrument for measuring particle size not a particle's chemical makeup.

**The Ideal Particle:** From now on when I write "particle", I mean a spec of matter much, much greater than nuclear or subatomic matter, and generally (there are exceptions to everything) larger than small molecules. I am referring to nanoparticles, globular proteins, colloids and larger specs of matter, up into the hundreds of microns.

Now consider what such a particle might look like. Quick, did you picture little, solid spheres mostly of the same size, a monodisperse size distribution? That is the picture most people have when you ask "What is a particle?" Call it the *ideal particle*. Latex particles used as sizing standards are close to ideal particles in this sense. There is a picture of one included, though you can't tell if it is truly monodisperse or whether some of the particles are welded together. More on that in another application note about sizing.




Superdex 200 10/300

**Targeted Drug Delivery with a Spherical Particle:** Liposomes, micelles, and surfactant- or polymer-stabilized oil-in-water microemulsions can all be used to hide drugs inside their structures in the hopes that a judicious choice of surface chemistry will guide the carrier to the site of the disease. If a trigger for releasing the

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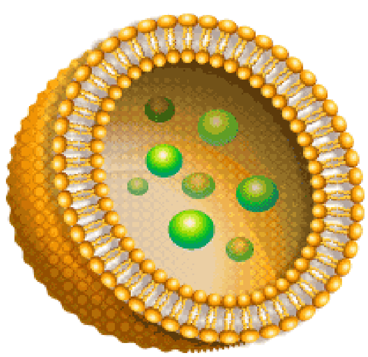
highly concentrated and highly specific drug can be activated, medicine is delivered to just the right spot and not throughout the blood stream with its attendant side effects. Alas, the attack of white blood cells and difficulties in finding the right surface chemistry has made the magic bullets only partially successful.

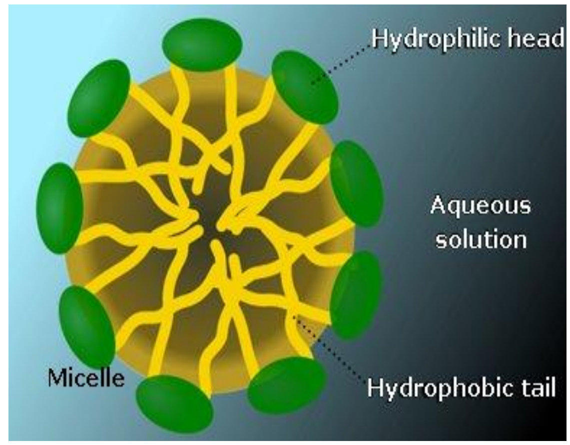
The liposome shown here is cut away to expose the active agents in the interior. The shell of the liposome is most often a bilayer lipid, perhaps 5 nm in thickness. The shell of this liposome is closer to a thin, core-shell than it is to a thick, core-shell particle model. Such models are useful when trying to interpret data for it is often necessary to estimate the refractive index or density of a composite particle such as a liposome.



Liposome

The surfactant micelle shown here is typical. It consists of a large number of surfactant molecules with a polar head (sulphate, for example) and non polar tails (methyl groups, for example). At a certain concentration in water, the critical micelle concentration (CMC), the surfactant molecules self-assemble into a spherical micelle shape. This reduces the free energy by grouping the non polar tails together into an oily interior (perfect for trapping not only water insoluble medicines but also greasy or oily dirt, thus forming the basis for detergency).

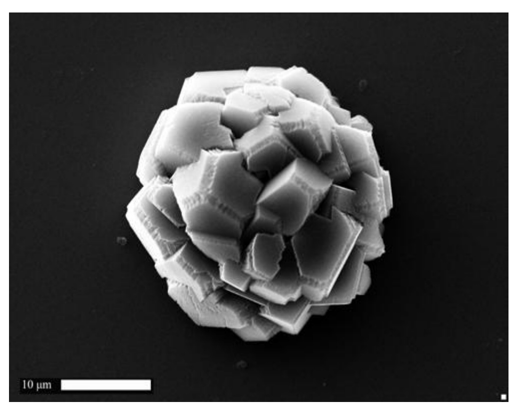
At higher concentrations, other shapes form. In addition, polymers with a polar head and a non-polar tail can also form micelles, though far fewer are needed to do so, compared to surfactant micelles.




Micelle

Compared to a solid latex particle, neither a liposome nor a micelle is solid. Indeed, when a micelle is filtered, the shear forces can break it apart into individual molecules which then reassemble spontaneously downstream of the filter: self-assembly particle. A filtered liposome, once broken up, does not form again into a spherical particle.

**Spherical Agglomerates:** The calcium carbonate particle shown here is perhaps 35 micron in diameter and it is clearly made up of a lot of smaller, non-spherical building blocks that may or may not be primary aggregates.

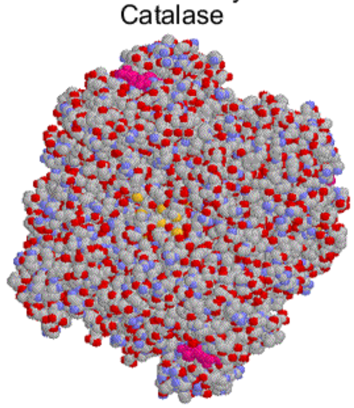



Agglomerate of calcium carbonate.

They are held together by a very large number of attractive forces but not by covalent chemical bonds.When this particle is rotating, it is easy to imagine a nice globe defining its circumference. Such particles are called globular.

**Other Globular Particles:** The math that defines a sphere's volume or surface area is trivially easy; the math that describes its behavior in a gravity or centrifugal field requires simple Newtonian physics and a few lines of calculus; and the math that defines its interaction with light, while difficult, was solved about 100 years ago and is, thankfully, available on a computer. For these reasons, any particle that resembles a sphere, as it will when rapidly rotating in a liquid at low to modest viscosity, will be called globular. From globular to spherical is one easy conceptual step away and then the size is defined by a diameter or radius.

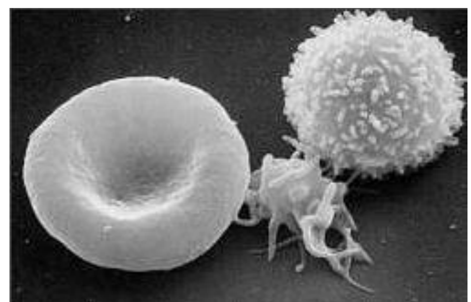
Globular proteins are single, macromolecules with thousands of covalent and hydrogen bonds that allow the folded structure (tertiary structure) to be much more compact than a linear macromolecule. Note that other particles are made up of lots of individual molecules but the single protein particle is a single molecule, though sometimes made of tightly bound subunits.




Globular Protein

A 15 nm gold sol particle suspended in a liquid is made up of lots of gold atoms that are not covalently bonded. The latex particle, made using emulsion polymerization, is made up of a lot of long-chain, polymer molecules that are stuck together. The particle is not a single molecule. Likewise, micelles and liposomes are not single molecules.

The image of the red blood cell shown here (unfortunately in black-and-white) has the typical biconcave disc shape. Its disc diameter is, on average, about 7 micron. The larger, 12-15 micron, but also globular white blood cell is shown. Its surface is studded with pseudo-pods.



Scanning electron microscope image of a red blood cell (left), platelet (center), and white blood cell (right). Credit: NCI-Frederick

A highly non-spherical particle, a blood plasma platelet, is also shown. Its resemblance to an alien-invading insect is obvious and it is hard to call it globular. Perhaps its cousins look more disc-like and plate-like to deserve the name platelet.

**Non-spherical Particles, Rods:** Not all particles are globular. Some pigments, even some molecules large enough to be called particles, and especially some primary aggregates and loosely-held agglomerates can become elongated enough to be called rods. Though there is no exact length-to-width ratio (called the aspect ratio) that defines the cutoff for rods, something like 5 or greater certainly *begins* to deserve the name long, thin rod. The math that defines its properties in gravitational and electromagnetic



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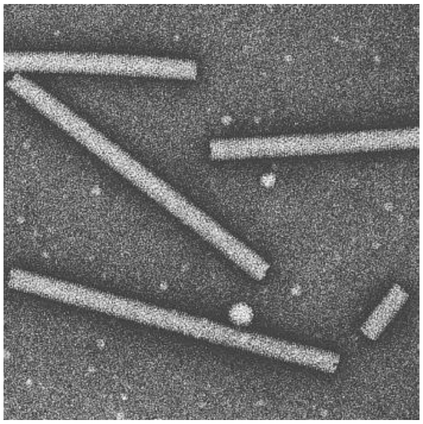
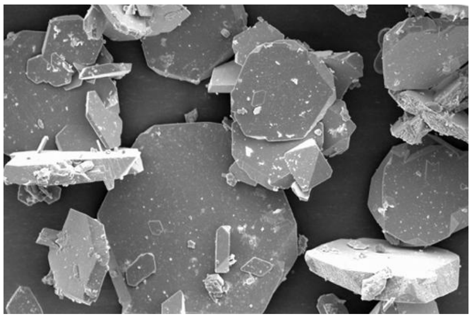
fields begins to differ significantly from that of globular particles and one is left with the question of how important would image analysis be compared to automated techniques that result in an equivalent spherical diameter (ESD). The ESD concept is explored further in the "What is a Particle Size?" discussion. The rods shown here are helically-assembled, tobacco mosaic virus rods of length 275 nm and diameter 17 nm.



Rod Shaped Particle, tobacco mosaic virus

**Non-spherical Particles, Discs or Platelets:** An example from the inorganic world of clay platelets is shown here. These may have started out as hexagonal thin discs but abrasion has taken its toll.



Refined kaolin clay platelets

While this shape too has an ESD, the bigger the ratio of longest disc surface chord to thickness, the more important shape analysis becomes.

**Summary:** Particle characterization covers a vast array of interesting specs of matter all the way from large molecules (globular proteins, polymers), to micelles, microemulsions, viruses, liposomes, latexes, pigments, clays, organic and inorganic oxides, sand, gravel, etc. By learning about particle characterization in several of these seemingly different fields, one can gain a better perspective about one's own field of interest.

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