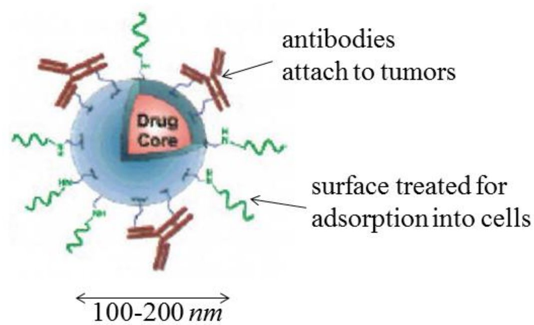
Modeling Nanoparticle Encapsulation

Motivation

The pill or capsule we swallow when we take medicine performs many functions. The pill or capsule may be coated to keep the actual drug from chemically decomposing, or to prevent us from the unpleasant taste of the drug. The drug may be embedded in a material that releases the drug at the right point in the body, or releases it at an optimum rate over time.

Nanoparticles are typically tens to hundreds of nanometers (10^{-9} meter) whose small size can be exploited to perform functions which are not possible for ordinary pills and capsules.



Nanoparticle for drug delivery (from *Nanotherapeutics*, A. Lamprecht, ed. (2009).

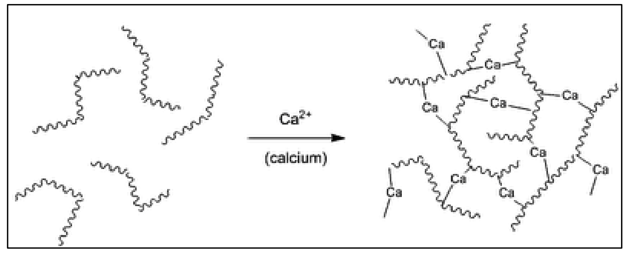
The outer surface nanoparticles coated with antibodies that bind to tumor cells can deliver anti-tumor drugs directly and specifically to cancer cells. Other nanoparticle coatings are used to enhance uptake by cells. In contrast, when patients undergo conventional chemotherapy, the anti-tumor drugs circulate throughout the whole body causing many unwanted and painful side effects.

Pills and capsules dissolve in the digestive track, so all the functionality of their coatings and interior is lost before the particles enter the blood stream. Because of their very small dimension, nanoparticles retain their special properties through the blood stream and right up to the target cells. Typical nanoparticles are roughly 100 times smaller than a red blood cell (100-200 *nm* vs. 6-8 μm), so nanoparticles can slip through the blood stream and diffuse intact to their intended destination.

So far, we have discussed nanoparticles designed for drug delivery. There are many other uses. Nanoparticles loaded with contrast agent help surgeons pinpoint the exact location of brain tumors. (See www.edheads.org/activities/nano1 for an interactive activity on nanoparticles for brain tumor imaging for grades 10-12+). Also, nanoparticles are used as hemoglobin carriers to make artificial blood.

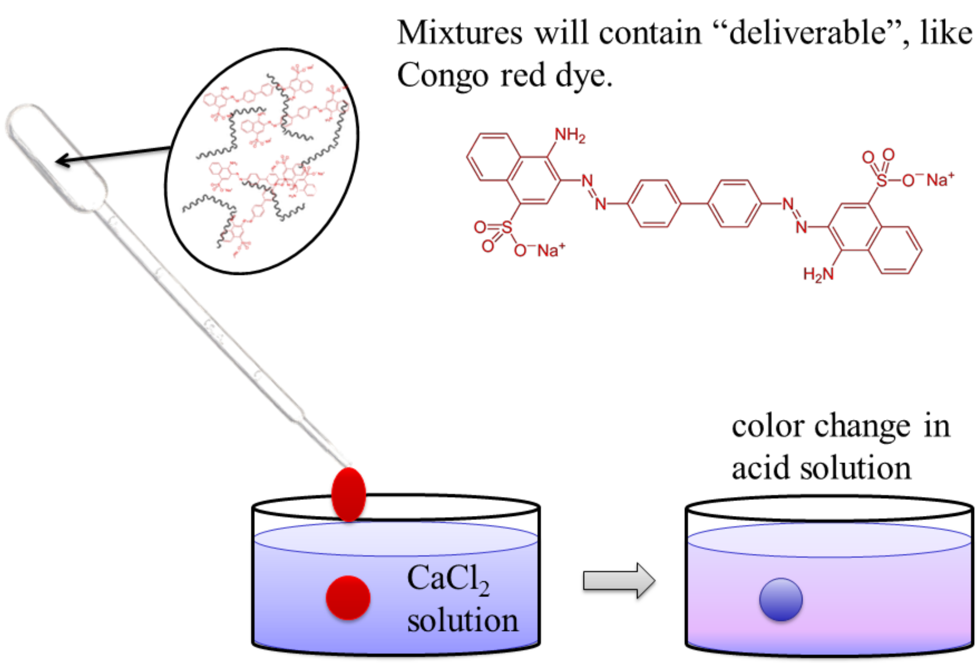
Particle encapsulation activity

This activity is based on a kit sold by Flinn Scientific, “Nanotechnology Modeling – Encapsulation by Sodium Alginate”. It is part of your kit. Here we describe one of the experiments that illustrate how chemicals can be encapsulated a transported in particles. Two other examples are illustrated in the materials from Flinn. Of course, the particles we make are not “nano” and not even “micro”. They are about 3*mm* in diameter. However, they nicely illustrate how particles can deliver chemicals such as drugs, contrast agents, or hemoglobin.



The encapsulation occurs when a viscous sodium alginate solution is dropped into an aqueous calcium chloride solution. Sodium alginate is a starch commonly used in foods. The divalent Ca^{2+} calcium ions bind the alginate chains together, so the drops form spherical particles in the calcium chloride solution. When chemical are mixed in the sodium alginate solution, they are encapsulated in these particles.

1. Prepare a 2% solution of sodium alginate by measuring 5.0g of sodium alginate in 250mL of distilled water. This quantity is sufficient for the full activity for an entire class, and can be scaled down if needed. The sodium alginate takes a long time to dissolve. It is best to leave this stirring with a magnetic stir bar overnight.
2. Remove a 50mL portion of the alginate solution and add 1mL of 0.04% bromphenol blue dye solution.
3. Fill a small petri dish with in 0.3M $CaCl_2$ solution. (We have found that small petri dishes, roughly 3cm in diameter work well if the 6-well plates recommended by Flinn are not readily available.)
4. Using a disposable pipet, let a drop of the alginate/ bromphenol blue mixture fall into the $CaCl_2$ solution. It will form a fairly sturdy spherical particle.
5. Transfer the particle to another petri dish filled with 1M acetic acid. Observe the color change.



In steps 6-10 repeat the same procedure for Congo red dye.

6. Remove a 50mL portion of the alginate solution and add 1mL of 1% Congo red dye solution.

7-10. Repeat steps 3-5.

For further details, consult the instructions that come with your kit from Flinn Scientific.