

## Teacher's QDot Technology Lecture Notes

### Vocabulary/Definitions

bioactive material	A materials capable of interacting with living tissues.
covalent bond	An atomic bond that shares two electrons.
electrophoresis	A method of using an electric field to move particles through a channel and separate them by size. The particles move at a rate inverse to their mass and thus larger particles are slower than smaller particles and will not migrate as great a distance down the gel.
fluorescence	A property of some molecules to absorb wavelength of light and then emit light at a higher wavelength.
nano	A Greek word meaning dwarf, one-billionth.
nanometer	One-billionth of a meter.
nanotechnology	Technology development at the atomic and molecular range (1-100 nm) to create and use structures, devices and system that have novel properties due to their small size.
quantum dot	A semiconductor crystal that exhibits quantum behavior in optical or electrical processes.

### Nanotechnology Lecture

The term **nanoparticle** refers to a particle with a diameter between 1 and 100 nanometers. Nano is a prefix of the SI system and is defined as one-billionth of its base unit. Other ways of stating this: there are  $10^9$  nanometers in one meter or 1 nanometer is  $10^{-9}$  of a meter. One would only need 10 hydrogen atoms placed side by side to equal a length of 1 nanometer!

For a fun intro, play the **Nano Song** (3 minutes) at <http://www.youtube.com/watch?v=LFOC-uxRqCg>.

### SI Prefixes

**What qualifies as nanotechnology?** The National Nanotechnology Initiative committee decided that in order to be classified as nanotechnology, the technology must meet the three following characteristics:

1. Nanotechnology involves research and technology development at the 1-100 nanometer range.
2. Nanotechnology creates and uses structures that have novel properties because of their small size.
3. Nanotechnology builds on the ability to control or manipulate at the atomic scale.

Factor	Name	Symbol	Factor	Name	Symbol
$10^{24}$	yotta	Y	$10^{-1}$	deci	D
$10^{21}$	zetta	Z	$10^{-2}$	centi	C
$10^{18}$	exa	E	$10^{-3}$	milli	M
$10^{15}$	peta	P	$10^{-6}$	micro	$\mu$
$10^{12}$	tera	T	<b><math>10^{-9}</math></b>	<b>nano</b>	<b>N</b>
$10^9$	giga	G	$10^{-12}$	pico	P
$10^6$	mega	M	$10^{-15}$	femto	F
$10^3$	kilo	k	$10^{-18}$	atto	A
$10^2$	hecto	h	$10^{-21}$	zepto	Z
$10^1$	deka	da	$10^{-24}$	yocto	Y

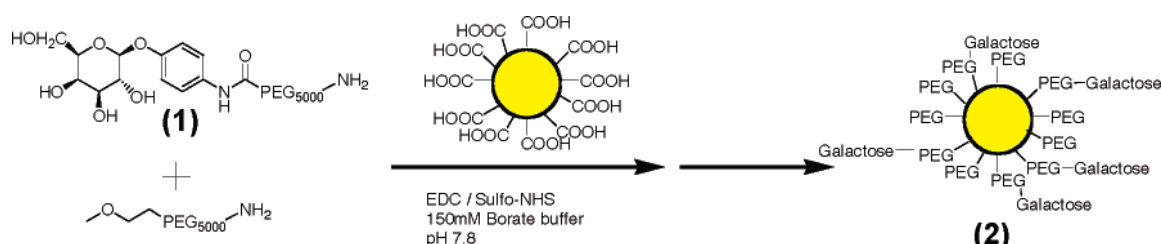
Source: NIST [www.nist.gov](http://www.nist.gov)

**What is quite amazing about nanoparticles?** Properties of nanoparticles differ in behavior from larger samples of the same material. For example a nanoparticle of silver, gold or iron *has different properties* than a 5 kilogram sample of the same substances. It turns out that when examining the behavior of individual nanoparticles, one must not only use the physical laws of chemistry, but also the laws of quantum mechanics. If you remember (from lesson 1), we learned that not only does light have a dual wave-particle nature, but matter does as well—at the quantum level.

Name: \_\_\_\_\_ Date: \_\_\_\_\_

**What can you do with nanotechnology?** The possible applications for nanotechnology seem endless and range from the production of new, lightweight structural materials, to potential new energy sources, and even many medical applications such as the treatment and detection of cancer. Many, many more areas are being investigated by scientists and engineers around the world for nanotechnology applications.

One nanotechnology application currently being investigated is the use of quantum dots to deliver cancer treatment to site-specific locations near cancer tissue. A **quantum dot** (QD) is a semiconductor crystal that exhibits quantum behavior in optical or electrical processes. Traditional cancer treatment causes cytotoxic effects in both cancerous and healthy cells and thus patients become sick and/or lose their hair and fingernails as a result of the treatment. By using a site-specific cancer delivery system, these side-effects would be greatly reduced. Research is currently being conducted in which zinc sulfide (ZnS)-coated quantum dots are being coated with a polyethylene glycol molecule and a cancer cell specific marker antibody. The polyethylene glycol (PEG), which is a covalent, organic molecule, is attached to the quantum dot and masks the quantum dot from the body's immune system. The PEG molecules also prevent the QD from delivering the cancer treatment to healthy tissue. Upon encountering the marker present on the surface of the cancer cell, the PEG is cleaved and the treatment is delivered.



**Attachment of a Polyethylene Glycol (PEG) molecule to a quantum dot.**

Source: Wikimedia Commons

After attaching the PEG to the quantum dot, researchers verify that the attachment was successful. One way this can be done is through the use of electrophoresis. **Electrophoresis** is a method of using an electric field to move particles through a channel, which then separates them by size. The particles move at a rate inverse to their mass and thus larger particles are slower than smaller particles and will not migrate as great a distance down the gel.

Go to <http://learn.genetics.utah.edu/content/labs/gel/> and complete the **virtual electrophoresis lab**.

Another way in which quantum dots are being used in the medicine builds on the fact that quantum dots have **fluorescent properties**. This means that they absorb light at one wavelength and give off light at another wavelength in discrete amounts (quanta)—thus the term quantum dot. The same material of quantum dots can even be made to fluoresce in different colors by varying the particle size, which allows multiple factors to be tagged using the same original light source. The smaller the particle, the more its emission is blue shifted and conversely the larger the particle size, the more its emission is red shifted. These fluorescent quantum dots are tagged with tumor-specific cell marker antibodies and polymer coatings and are then injected into the circulatory system. They primarily accumulate in the area of the tumor by a similar mechanism as described above. Then physicians can better see the areas of cancerous tissues and how they have metastasized.

In addition, nanotechnology has also developed **gold nanoparticles** that absorb light of wavelengths slightly over 800 nanometers. Again, when coated with a tumor-specific antibody, the nanoparticles aggregate around cancer cells. Since the gold nanoparticles absorb light and produce heat, lasers of wavelength in the Infrared range are used to superheat the gold nanoparticle and kill the cancerous cell through heat. This application has been found to show promise in breast and prostate cancer, which are occur fairly close to the body's surface and thus, are readily accessed by the laser light.

#### **Biomedical Engineering Connection: Multiple Perspectives**

Show students video labeled Video 1 of Dr. [Todd Giorgio](#), Department Chair of Biomedical Engineering at Vanderbilt University discussing Nanotechnology in Cancer Research, Biomedical Engineering, and the Key Components of Grant Writing