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Gold Nanoparticles: The Future of Cancer Diagnosis and Treatment

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There has recently been a great deal of interest in the scientific community concerning the application of nanotechnology in medicine. One particularly exciting field of research involves the use of gold nanoparticles in the detection and treatment of cancer cells (Soppimath, Betageri, & Cho, 2008). Current methods of cancer diagnosis and treatment are costly and can be very harmful to the body. Gold nanoparticles, however, offer an inexpensive route to targeting only cancerous cells, leaving healthy cells untouched (Pellequer & Lamprecht, 2009). The unique light absorption and emission characteristics of gold nanoparticles have made them one of the most studied entities in recent cancer diagnostic research (Pellequer & Lamprecht, 2009; "Using gold nanoparticles," 2009). Research has found that, when gold nanoparticles are subjected to light, the light is scattered in a highly specific pattern. These specific patterns are determined by the orientation of the nanoparticles ("Using gold nanoparticles," 2009).

The diagnosis of cancer is an area in which the light absorption and emission characteristics of gold nanoparticles have become a key advantage. It has been proposed that these aspects of gold nanoparticles themselves can be utilized in the diagnosis of cancer (Birch, 2009a; Cheong, Krishnan & Cho, 2009; Mayoral, Vazquez-Duran, Barron & Jose-Yacaman, 2009). A currently developing technique involves attaching a specialized antibody that is attracted to cancerous cells to the end of a gold nanoparticle, and mixing this compound with blood or tissue samples containing cancerous cells. The blood or tissue samples are then subjected to white light and examined using standard microscopy. Since each type of cancer has a unique protein on its cell surface, the gold nanoparticles will be oriented differently, depending on which type of cancer cells they have been attached to. This results in each type of cancer having its own unique pattern of scattered light. Doctors would then be able to determine both the location and type of cancer with this method.

Gold nanoparticles have a high usability level when compared to other similar methods of cancer detection. One of these other methods employs quantum dots instead of gold nanoparticles to illuminate the location of cancerous tissue. The problem with these quantum dots, however, is that they burn out after extended exposure to light (Birch, 2009a). Gold nanoparticles, on the other hand, will not burn out after extended light exposure, allowing them to illuminate cancerous cells for much longer periods of time then the quantum dots (Birch, 2009a). Gold nanoparticle luminescence is also a more highly sensitive technique, permitting doctors to use fewer chemical markers in order to obtain the same information (Birch, 2009a; Soppimath et al., 2008).

As well as being able to diagnose cancer, gold nanoparticles have the potential to treat cancer without any of the harmful side effects associated with current treatment methods. Two of the most common forms of cancer treatment, chemotherapy and radiation therapy, are both extremely aggressive and can have fatal side effects even on young and otherwise healthy individuals. Side effects with these treatments occur because healthy cells are killed along with diseased cells in an effort to rid the body of cancer (Pellequer & Lamprecht, 2009). Two very promising methods of cancer treatment involving gold nanoparticles are currently being investigated for their ability to target only cancerous cells while leaving healthy cells unharmed (Pellequer & Lamprecht, 2009). The first method utilizes gold nanoparticles to absorb light in the near-infrared wavelength range (Mayoral, Vazquez-Duran, Barron, & Jose-Yacaman, 2009; Soppimath et al., 2008) and the second involves a synthesis of chemotherapy and gold nanoparticles.

The first possible method of treatment is based on gold nanoparticles that have either a trigonal pyramidal or star shape. These specific shapes are extremely efficient at absorbing near-infrared light and turning it into heat (Cheong, Krishnan, & Cho, 2009; Mayoral et al., 2009). The proposed procedure is to attach a cancer-attracted protein to these triangular or star-shaped gold nanoparticles in order to have the nanoparticles "stick" to the cancer cells, as they do in the cancer detection method. Meanwhile, they have no interaction with healthy cells (Pellequer & Lamprecht, 2009). Once the gold nanoparticles are attached, the cancerous location is subjected to a highly concentrated beam of near

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infra-red light from an external source. This combination will cause the gold nanoparticles to heat up enough that they will actually 'cook' the cancerous cells. Even though the cancerous cells will be destroyed, there will be little or no damage to surrounding cells since the infra-red light is harmless to any cells without an attached gold nanoparticle. Although this method is completely non-invasive, it does require the cancer to be relatively near to the surface of the patient's body in order for the gold nanoparticles to absorb enough of the light to kill the cancer cells (Cheong et al., 2009). This method is a technologically evolved form of a procedure that is currently being used called photoablation therapy (PAT). Unfortunately, current PAT techniques use such high frequency lasers to burn cancerous cells that they are very dangerous to the skin of the patient and are not always a viable option (Bernstein, 2009). Overall, the effectiveness, inexpensiveness, and safety of using gold nanoparticles make them an ideal candidate for use in next generation PAT.

The other method involving gold nanoparticles that scientists are hoping to use in the treatment of cancer is their synthesis with chemotherapy. In 2007, scientists found that gold nanoparticles in the shape of 'nanorods' were able to penetrate the cell membrane. They wanted to use this technology to help deliver chemotherapy in small doses directly to cancer cells, as opposed to subjecting the entire body to harmful chemotherapy (Mayoral et al., 2009). Unfortunately, this proved to be an ineffective delivery method due to the nanorods being too bulky for sufficient cell membrane penetration. More recently, in 2009, scientists fabricated a gold nanoparticle in the shape of a sphere. This new shape greatly increased the rate of cell penetration by the nanoparticles when compared to the larger and less agile 'nanorods' (Bernstein, 2009). Chemists used this new discovery to pair spherically shaped gold and iron oxide nanoparticles together into a 'dumbbell' formation, attaching a cancer-detecting molecule on one side and a cancer-fighting molecule to the other (Birch, 2009b). Cisplatin, a powerful anticancer drug, is fixed to the gold nanoparticle, and Herceptin, an antibody that specifically seeks out breast cancer cells, is applied to the iron oxide (Bernstein, 2009). Once the Herceptin end of the compound locates a cancer cell, the spherical gold nanoparticle is able to penetrate the membrane and enter the cell, taking the small Cisplatin molecule along with it. As the gold-Cisplatin nano compound enters the cell, the sudden drop in intracellular pH causes the Cisplatin molecule to be hydrolyzed and separated from the gold nanoparticle (Bernstein, 2009). The cancer cell is now treated internally so as not harm any of the surrounding cells. Although this test was specifically targeted at breast cancer using Herceptin, the same technique can be employed against any type of cancer as long as it has an active antibody. As with the other treatment method, the main appeal of this technique is that the cancer treatment can be applied locally and non-invasively, and has the ability to not only treat the cancer, but detect and illuminate it as well.

Nanoscience has had a huge impact in medicine in recent years due to its non-invasive applications. The use of gold nanoparticles to diagnose and treat cancer has been, and will continue to be, on the forefront of this exciting research. While cancer detection using gold nanoparticles in common medical practice is just around the corner (Pellequer & Lamprecht, 2009), treatment using gold nanoparticle photothermal ablation and nano-chemotherapy will be in clinical trials for some time before they are being used on patients regularly. With nanotechnology advancing as fast as it currently is, scientists will hopefully be able to utilize the characteristics of compounds such gold nanoparticles in the detection and treatment of many more deadly diseases in the years to come.

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