Cancer Detection  (Drs. Fleischman and Zborowski)

Ninety percent of deaths from cancer are caused not by the original tumor but by metastasis, which is the spread of cancer to other parts of the body via cells transported in the blood or lymph system. In the Department of Biomedical Engineering, through the rapidly changing field of medical nanotechnology, we are developing a blood test that will find these cancer cells before they spread. Traditional cancer treatment often includes shrinking tumors, which also lowers the number of cancer cells that could separate and be carried throughout the body. This kind of therapy is critical, because the number of circulating cancer cells gives doctors an idea of how well a cancer treatment will work – the smaller the number of cancer cells, the greater the likelihood of successful treatment.

But detecting a wandering cancer cell is like finding a needle in a haystack: In a typical blood sample (1½ teaspoons, or 7.5 milliliters of drawn blood), we are looking for just 5 out of 40 billion cells! For the patient’s sake, we cannot afford to miss a single one. This is where our research and our newly developed blood test can make a difference. Using a “magnetic separation” technique, we can make either tumor cells or normal blood cells magnetic, allowing us to draw either type out with a magnet and count them. We are excited not only because our research can be applied to many types of cancer, including breast, prostate, colorectal and skin cancers, but also because we can learn much more information in far less time while using a smaller blood sample. This new test will help customize patient care by showing whether cancer treatment is still working over 12 or 24 months, a measurement that was not possible even 15 years ago.

Donor support is needed to bridge the gap between funding available for basic research, which is completed; what is needed now is development – seeing how well our blood test works in people, that is, taking the blood test to clinical trials. We believe that we are on the cusp of providing a life-saving test that may spare thousands of patients from hearing the words “your cancer has spread.”

Summary: Drs. Fleischman and Zborowski have developed a technology that can separate cancer cells from normal healthy blood cells.

Cancer Therapy  (Dr. Labhasetwar)

Cancer is a leading cause of death in the developed world. It is estimated that over 12 million people suffer from the disease and over 500,000 die each year. Surprisingly, 90% of deaths from cancer are caused not by the original tumor but by the spread of cancer cells (metastasis) to other parts of the body via the blood or lymph system. Researchers in BME are working on a ground-breaking technology that involves incorporating tiny “nanoparticles” with cancer-killing drugs and injecting the nanoparticles directly into the bloodstream, where they can seek out the tumor and deliver the drug directly into tumor cells without having the drug act on healthy tissue. Preliminary studies have shown that this targeted delivery system can prevent breast and prostate cancers from growing and spreading.

Summary: Dr. Labhasetwar has developed “nanoparticles” that can treat advanced-stage cancers.
Engineering molecules for ‘one-stop’ cancer imaging and therapy (Drs. Krishna and Grobmyer)

Cancer is the second leading cause of death in the USA; an estimated 1.6 million new cases of cancer will be diagnosed this year and more than half a million people will die of the disease. Getting an accurate picture of changes going on inside the body is vital if cancers are to be caught and treated effectively; however, there is always a delay between scheduling the patient to get images that may show any cancers and actually starting the treatment. We are researching how to combine imaging and treatment so that both can be done at the same visit, with no delay. We work with very tiny structures, much smaller than a human hair (which is about 90,000 nanometers thick). These tiny “nanoengineered materials” (NEMs) improve the contrast and clearness of images from two major imaging methods doctors rely on (one using magnetic forces and one using laser/ultrasound). Certain molecules can be “biomarkers” for cancerous changes; by joining NEMs to these marker molecules, doctors can get very clear images of specific areas in the body, make a more accurate diagnosis, and quickly begin to treat any cancerous areas.

Tumors can be destroyed noninvasively (without surgery) by shining low-intensity lasers on NEMs within the tumors. Our unique NEMs are made to give patients safe, noninvasive, and localized (not whole-body) treatment of their cancer. Early laboratory studies, going on now, have shown that we can use NEMs to “search and destroy”: getting clear pictures of suspicious areas and at the same time destroying any tumor tissue that is found. We think this method would be of great help for cancer patients, lessening any pain or side effects of many standard cancer treatments. Philanthropic funding would help move this unique NEMs technology quickly to our patients.

Summary: Dr. Krishna and Dr. Grobmyer have developed a single-molecule strategy for imaging and treating cancer without surgery – diagnosis and treatment may soon be done in one visit to the doctor.

Sunscreens to prevent UV damage and skin cancer (Drs. Krishna, Anand, Grobmyer, and Maytin)

Every year in the USA, doctors diagnose over one million new cases of skin cancer, more than all other cancers combined. Too much sun exposure causes sunburn immediately and, over the years, premature aging of the skin. But in severe cases, such sun damage can also weaken the disease-fighting power of our immune system, even causing mutations in our genes. All these processes contribute to skin cancers. We know we should avoid too much sun and apply sunscreen whenever we are outdoors. However, current sunscreen formulations have ingredients that degrade with ultraviolet (UV) light exposure, limiting the time the sunscreen is effective, and many ingredients may cause allergic reactions. Our team has designed tiny nanoengineered materials (NEMs) in a unique sunscreen formulation that is safe and can be applied only once daily (or even less often) to protect skin from harmful UV rays. Our NEMs absorb more UV light than other sunscreens do and have a helpful antioxidant effect that can prevent skin cancers from starting. Early laboratory studies have shown that these NEMs can protect skin from UV damage. Now this research could use the help of philanthropic funding to translate our new formulation to the public – before they become patients.

Summary: Dr. Krishna and his coworkers are developing a new, safer, once-a-day sunscreen formulation that can prevent skin cancer and other disorders caused by getting too much sun.

Treating skin cancer with light (Dr. Maytin)

Skin cancers, including basal cell carcinoma (BCC) and squamous cell carcinoma (SCC), are collectively the most common of all human cancers (with more than 3 million cases per year in the U.S., far more than breast and colon cancer combined). Unlike melanoma, BCC and SCC are rarely deadly. However, the process of removing them often leaves scars that can be very disfiguring. We are working on a new technique, Photodynamic Therapy (PDT), which can treat skin cancers without leaving a scar. PDT combines two elements, a drug (called a photosensitizer, PS) and visible light. First, the PS is applied to
the skin tumor (BCC shown, left panel) and after allowing some time for the PS to penetrate, we shine a strong blue light on the tumor. The PS undergoes light/chemical reactions, so that it gives off a red glow (right panel) and special molecules that destroy the cancer cells. After several treatments, skin tumors can “melt away” without leaving any trace.

**Summary:** The Maytin lab is developing new approaches that promise to make PDT more effective for treating skin cancers. Once these approaches are translated to the clinic, the benefit for patients will be a new, nonsurgical treatment for skin cancer that leaves no scar.

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**Ultrasound Biopsy (Dr. Clement)**

Biopsies are common and necessary procedures that provide vital information on the health of tissue. Unfortunately, biopsies are invasive and often associated with pain, bleeding, and in rare cases infection and even organ damage. Our laboratory is investigating an alternative, noninvasive approach that uses ultrasound to help assess the state of certain tissues without the need to cut into the body. To be successful, this ultrasound method must differentiate between healthy and diseased tissue, including differences between benign and cancerous tumors. We are working to achieve this goal with the aid of harmless micro-bubbles injected into the bloodstream from a small syringe. With the aid of these microbubbles, our method can image blood as it travels through the capillaries – the body’s smallest vessels. The unique behavior of blood moving through these tiny spaces provides a signature that is an indicator of diseased tissue. The approach relies on a sophisticated mathematical understanding of blood flow through the capillaries and relies on accurate imaging, using some of the newest detection techniques available. If successful, the method will not only improve the quality of patient care, but will also allow immediate diagnosis of certain conditions such as cancer, buying critical time and potentially saving lives.

**Summary:** We are developing a noninvasive ultrasound test aimed at providing a “virtual biopsy” without actually cutting into tissues.