Drug Delivery and Nanomedicine

The faculty and students in Cornell Biomedical Engineering apply engineering principles to design systems that effectively control the spatial and temporal delivery of medicines, to investigate the effects of medicines on cells and tissues, and to evaluate their preclinical and clinical efficacy. Efforts include systems to target medicines at precise sites, (for example to treat cancers), devices to control the rate at which medicine is made available to the body (for example, injections that last one month or more) and constructs to facilitate specific interactions with systems of cells or to understand their function (for example, to deliver vaccines, to sequence the genome of single cells or to understand the impact of outside influences on cells). The work integrates investigators working across length scales in all fields of engineering and also include investigators in chemistry, cell biology, genetics, immunology, veterinary medicine and human medicine. Resources at Cornell that support these research programs include the Chemistry Nuclear Magnetic Resonance facility, the Cornell Center for Materials Science, the Cornell Nanofabrication facility the Cornell Center for Biotechnology and the Cornell Nanobiotechnology Center. Most projects involve investigators at the Cornell College of Veterinary Medicine and the Weill Cornell College of Medicine.

Some specific faculty projects

Prof. Iwijn De Vlaminck works at the interface of nanotechnology and biology to advance genomic sequencing and to understand gene expression patterns at single cell resolution. Single cell sequencing enables the study of genomic heterogeneity of cells in the context of full tissues and microbe populations in ways not possible with traditional bulk sequencing assays. For example, only a small fraction of the microbes that populate our planet can be propagated in laboratory culture; therefore, little is known about these microbes, other than that they exist. Using single-cell sequencing through the design of new nanofluidic devices, the genomes of these living systems can be investigated to better understand how they work.

Prof. Jan Lammerding’s lab is developing microfluidic devices to measure (sub-)cellular biomechanics to investigate how changes in cellular and nuclear stiffness can contribute to the pathology of muscular dystrophies, premature aging, and cancer. In addition, the lab is using microfluidics approaches to study the migration of cancer cells, taking advantage of the ability to fabricate precisely defined environments that mimic interstitial pores and spaces in physiological tissues.
Prof. William Olbricht’s research focuses on the application of fluid mechanics and mass transfer to investigate new ways of drug delivery through tissues, in particular the brain. One example is his work in convection-enhanced drug delivery, a technique that uses convective fluid flow to actively distribute drug deeper into brain tissue to treat disease. One advantage of convection-enhanced delivery is that it can bypass the blood brain barrier through the infusion of drug through a microfluidic catheter directly into the brain interstitium thereby establishing a penetration depth further than achieved by diffusion alone.

Prof. David Putnam’s lab focuses on the design of new materials and systems to target medicines to specific tissues and cell subpopulations. For example, the group engineers bacteria to spontaneously bud outer membrane vesicles that mimic infectious agents and elicit protective immunity to challenge. The group also has designed vaccine delivery vehicles that can protect against disease with a single dose, and in half the time of traditional vaccines. In addition, the Putnam groups designs drug delivery systems to deliver more complex therapeutics, like bacteriophage, to help modulate the gut microbiome and to treat infections from antibiotic-resistant strains.

One goal of Prof. Michael Shuler’s lab is to couple micro- and nanofabrication techniques with cell cultures to predict toxicology and efficacy of pharmaceuticals. These “body-on-a-chip” systems are microfluidic devices with interconnected compartments to mimic pharmacokinetic response of humans to drugs or environmental chemicals. This system mimics both uptake of drugs through barrier tissues such as the gastrointestinal tract and the response of internal organs (e.g., liver, heart, etc.)

One goal of Prof. Uli Wiesner’s lab is to develop fluorescent core-shell silica nanoparticles referred to as Cornell dots, or simply C dots, that help surgeons better visualize tumor tissue during surgery. Such intraoperative nanotechnological tools for better visualization of cancer tissue are highly desirable, much researched world wide, but have not been translated into the clinic before. In fact C dots are the first ever optical polymer-inorganic hybrid nanoparticles approved by the Food and Drug Administration (FDA) as an investigational new drug (IND) for human clinical trials. Such clinical trials are currently ongoing with cancer patients in collaboration with Memorial Sloan Kettering Cancer Center in New York City. Furthermore, since August 2015 efforts are supported by a National Cancer Institute (NCI) funded Center for Cancer Nanotechnology Excellence (CCNE) that is co-lead by Cornell and MSKCC.

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Representative publications

