APPL698: BME Senior Design
Projects: Spring 2008

This term groups of students will work on one or more of the projects listed below:

#1: Water Degassing System (Prof. Dayton)

Motivation: Tap water is often highly saturated with gas. You can see this if you fill a glass with warm water – air bubbles will form on the side of the glass.

We want to perform some precise ultrasound measurements in a water tank. Air bubbles reflect sound waves very efficiently. Because of this, air bubbles in water will interfere with the ultrasound measurements. Thus, we want to be able to fill our water tank with water that has had the gas removed.

Water can be degassed by applying a vacuum to the water, which pulls out the gas.

Solution: We will make a water degassing system. This is a system which will take clean water and remove the gas from it.

Method:
In order to degas the water, the water will be pumped through a filter which is gas permeable, but not water permeable. A vacuum pump will apply a vacuum to the other side of the filter to remove the gas. The water will be stored in a 5 gallon reservoir so it can be used to fill a fish tank style box when needed. In order to keep the water degassed, the system will have a circulating pump. A dissolved gas meter will read the gas concentration in the reservoir. It will be also be desirable to put a water filter on the system to keep the water clean.

#2: Syringe Pump with Rotating Mixer (Prof. Dayton)

Motivation: Ultrasound contrast agents are microbubbles that are injected into a patient to improve contrast in ultrasound imaging. Since these bubbles are buoyant, they tend to float to the top of the injection syringe, making it difficult to keep the solution mixed.

Solution: We will modify a commercial syringe pump to keep the syringe mixed by rolling the syringe back and forth 180 degrees continuously.

Method: A mount will be made which will allow the syringe to rotate and be injected at the same time. A motor will be connected to the syringe, with a link that allows the syringe to be moved in a rolling motion, back and forth, at a variable rate. The assembly will be integrated into a commercial syringe pump.

#3: Live Tissue Processor for Muscle (Prof. Dennis)

Motivation: Muscle tissue engineering requires access to large numbers (many millions) living "muscle precursor" cells, called *satellite cells*, which are present in all skeletal muscles. These are the cells that snap into action after severe muscle injury to rebuild the damaged muscle fibers. These cells can be harvested from living muscle as long as the muscle has been removed from the animal not too long after death (within about 4 to 6 hours). So, it is possible to actually go to a meat market, buy freshly slaughtered meat (from cows, pigs, etc.), and grow the muscle cells. This source of cells is an excellent alternative to raising large animals in a research facility just to remove a few grams of muscle. The design challenge is to develop a simple system to quickly clean and thinly slice the meat without killing too many of the cells. The thin slices will then be processed further to remove the cells.

Solution: We will design and build several tissue processors and test whether or not they are effective at releasing cells from the tissues of large mammals.

Method: This is an open-ended design, so any reasonable approach can be considered.

#4: Implantable low-power micro-actuators (Prof. Dennis)

Motivation: The near-term success of tissue engineering may lie in the use of implantable bioreactor systems. There are many advantages to growing tissues within a living host rather than in an incubator. Plastic surgeons use tissue expanders which are saline-inflated balloons to create open spaces beneath the skin and stretch the skin for use in grafting. So, it is reasonable to consider the use of such open volumes beneath the skin for the engineering of other tissues (besides skin) for later use in the individual. To successfully engineer skeletal muscle tissue it is necessary to be able to provide controlled mechanical stimulation, so it will be necessary to develop implantable mechanical actuators for this purpose

Solution: We will be developing a series of components and subsystems for tissue engineering bioreactors. Traditional as well new microactuator technologies will be considered such as the use of shape memory alloys and electro-active polymers: http://ndeaa.jpl.nasa.gov/nasa-nde/lommas/eap/EAP-material-n-products.htm

Method: This is an open-ended design, so any reasonable approach can be considered.

#5: Implantable/immersible sensors: force, displacement, temp, pH (Prof. Dennis)

Motivation: Tissue engineering bioreactors will require the ability to implement feedback control to guide the tissue during development. To do this the system must have both sensors and effectors. For this project we will select one or more miniaturized sensors for development. The sensors must ultimately be easy to build and calibrate, inexpensive (essentially disposable) and cell culture compatible.

Solution: Students will study various sensor types and will determine which technologies will allow the design of sensors suitable for use in tissue engineering bioreactors.

Method: This is an open-ended design, so any reasonable approach can be considered.

#6: Process for mass producing implantable force transducers (Prof. Dennis)

Motivation: Force sensing is critical for the engineering of functional skeletal muscle tissues. The forces generated range from as low as 1 μN up to several mN, and perhaps higher. The design challenge is compounded by the fact that these sensors must be cell culture compatible, inexpensive, easy to build in large numbers (hundreds), and they must withstand immersion in salt water for long periods of time without functional degradation. Such a device does not exist commercially, so it is necessary to both design the transducer and the process for making many of them easily and cheaply. Due to the importance of this specific sensor (force), although it is a subset of project #5 (above) it is listed separately. It is the most important of the sensors for the success of the tissue engineering bioreactors.

Solution: Several possible technologies can be employed, perhaps the most promising is the use of thin film bonded-resistance strain gauges or the use of thin piezoelectric polymer films.

Method: This is an open-ended design, so any reasonable approach can be considered, but the design constraints are very strict so most potential solutions will be eliminated at the early concept phase.

#7: Implantable Tissue Bioreactor support systems (Prof. Dennis)

Motivation: If good progress is made on most of the above projects, then it will be possible to work on subsystem integration of the bioreactors themselves. This will include embedded microcontrollers and transcutaneous optical communication electronics.

Solution: System-level integration of the projects listed above.

Method: Use of surface-mount electronics and micro-power design techniques is required.