Alternative Design 3
Intro/Purpose
The third alternative design takes into account the effect of gravity on lymphatic flow in the human arm. A piston system will be implemented on a track to allow vertical movement of the arm while a hinge joint at the elbow will allow limited flexion and extension of the arm, as seen in Figure 3. While the arm structure will be similar to Alternative Design 1’s Figure (ii), the bones of the arm will be composed of two cylinders with a hinge where the elbow is located. The hinge will have to account for the movement of two cylinders against each other. A method similar to an accordion-like hinge has been proposed. This will decrease the chance of the skin being damaged as a result of flexion of the arm. At the wrist, the elbow, and the beginning and the end of the upper arm, a hook or ring will be placed to attach a track. The track will be a beam that connects the movement of the piston system to the arm. The piston will have a roller inside of the track that allows the piston to exert force along the track and, therefore, along different points in the arm as the arm is lifted. A track was considered rather than positioning the piston in a definite location on the arm due in part to the arch that the arm makes as it lifts up and away from the base line. Two piston and tracks systems must be created for raising of the lower and upper arm. The set of pistons will allow two different types of movement. One movement will allow the forearm to bend up at the elbow to a ninety-degree angle and be brought back down. In this movement, the elbow hinge will be implemented while the upper arm is stabilized. The other movement will bring the upper arm and forearm up in line with each other to about a forty-five to sixty-five degree angle and then brought back down. In this movement, the forearm piston will be used until the piston’s roller rolls off the track or the upper arm will only support both parts of the arm.

Figure 3: Third Alternative Design Model where (a) is the piston, (b) is the track that will connect the piston to the arm to raise and lower the arm, (c) is the roller that allows the piston to move along the track, (d) is the connection between the track and arm.

The two movements will be implemented using a microcontroller and a compressor. The piston will run off the same compressor used to fill the air muscle. The microcontroller will program the
piston to work in correlation with the increase and or steady pressure applied to the air muscle. In other words, as particular muscle is contracting or relaxing in simulation of a particular everyday movement of the arm, the pistons will act to simulate the change in height experienced by the arm in those same everyday activities.

When modeling lymphatic system, the procedure to input dye and view circulation of the lymphatic fluid will be similar to Alternative Design 1 where the skin will be transparent or translucent, the compression sleeve will be removed after for viewing through the arm, and the dye is input through a syringe at the wrist.

A positive aspect of this movable system is allowing the force of gravity to produce an effect on lymphatic flow in the arm. In real life, a woman with lymphedema will be mobile, as will her arm. Swelling in any body part can be alleviated by elevation, as can swelling caused by blocked lymph flow. Therefore this model allows the user to test different heights and positions of the arm, and to demonstrate the effect gravity has on the fluid flow. The hinge at the elbow also allows movement that the previous designs were missing. Flexion and extension of the elbow in correlation with the change in the muscle will allow a simulation more similar to a real life environment. Testing can be conducted in multiple ways giving freedom to the user to demonstrate how gravity will affect the arm in whatever way is deemed important.

Since this is a movable system however, it will be harder to demonstrate the lymphatic/interstitial space layer than the previous opening hinge system in Alternative Design 2. Therefore, the skin of this system must be transparent enough to show the underlying gel layer, like in Alternative Design 2, but must be pliable enough to stretch with movement accordingly. The lymphatic layer may also have to compensate for the movement at the elbow. The layer must have enough elasticity so that it will not break or leak during movement. Caution will have to be taken to make sure each system works in harmony with the movement, and that damage is kept to a minimum.

Movement of the arm can be performed with the compression sleeve on, but removal of the sleeve must only be conducted while the arm is in a straight position. This may negate some of the effects movement caused on the lymphatic flow when in a vertical or bent position.

The application of two pneumatic systems (the air muscle system and piston system) in this design also requires special parameters. At certain testing points of the design, the piston system used to represent gravity must be in sync with the muscle pump system to simulate certain real life movements of the arm. The ability to parametrize the two systems at the same time will be challenging due to the requirement to have the compressor output to two different systems at once. Also the maximum weight that the piston track system can accommodate while still operating optimally must be taken into account when ordering a piston system.