

## Introduction

Compelling computer graphics will increasingly require realistic physics based modelling to allow us to simulate the virtual human characters in movies, computer games, education and medical simulation. The IUPS (International Union of Physiological Sciences) Physiome project is developing the framework and science required for simulating human anatomy and physiology.

## Anatomically and Biophysically Based Models

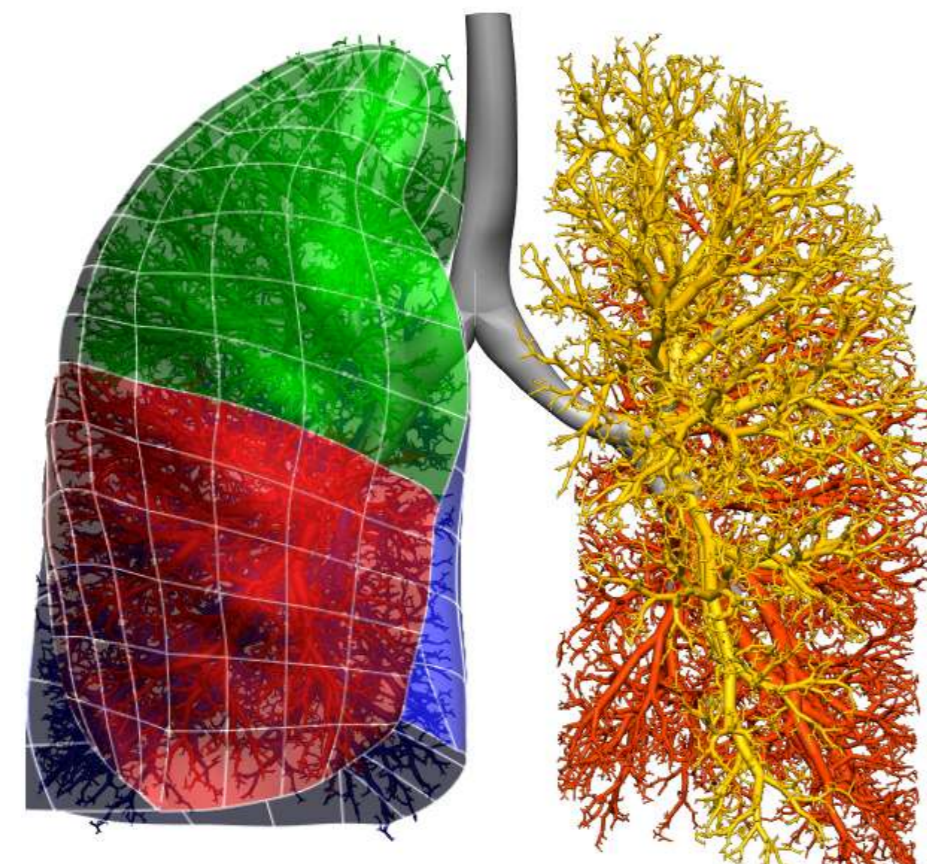
To simulate the complex processes within a human, models of the organs comprising a human are being developed. As well as accurate geometry, these models include physiology to represent chemical, electrical, mechanical and fluid based processes.

Some of the processes that are being modelled are heart myocyte activation, heart ventricular mechanics, heart tissue electrical activation, gut electromechanics, eye lens circulation, leg muscle mechanics, lung airways, lung mechanics and lung blood transport. The geometry of many of these models are shown in Figure 1. Methods are being developed to allow the coupling of related models across the range of spatial scales from proteins to whole organs.

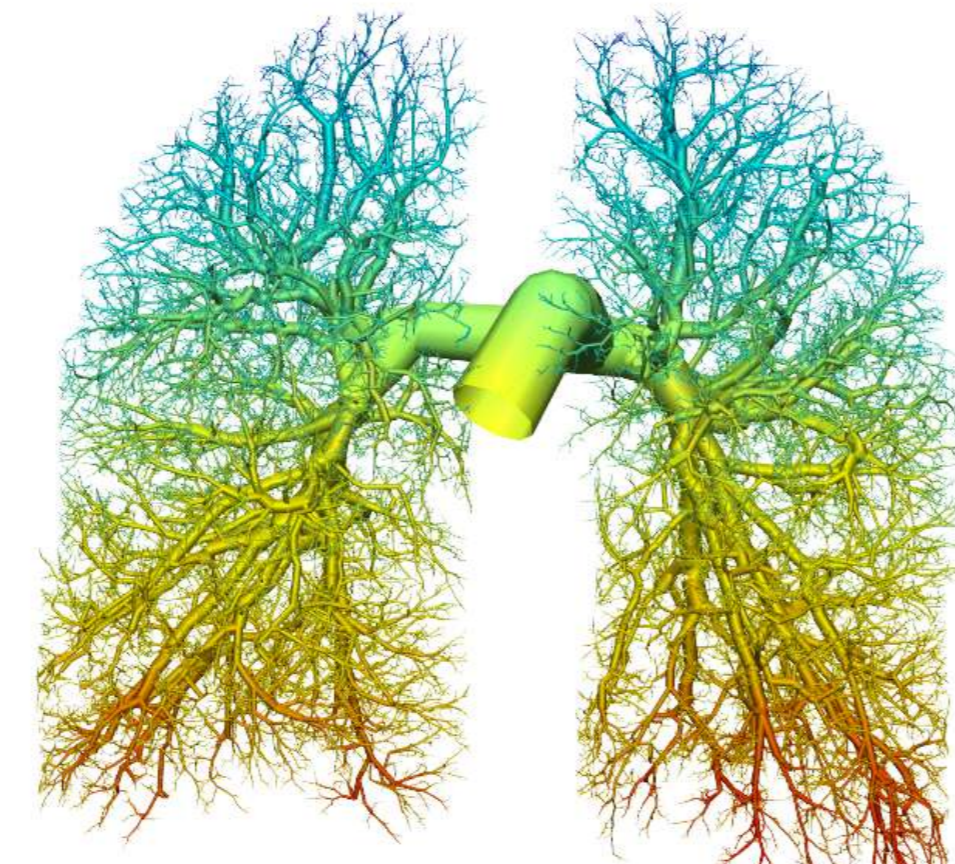
The development of these models starts with imaging data. In the case of this lung model this data is Computed Tomography, one slice of data is shown in Figure 2. These images are segmented with a combination of manual and automated techniques to form geometrical models such as in Figure 3. Additionally where details such as the smallest generations of the airways are not resolved from the imaging, these are added algorithmically. Once the geometrical model has been created, models of the fundamental physics are solved to simulate function. Figure 4 shows instantaneous velocities of arterial blood flow in the lungs.



**Figure 2.** Computed Tomography image of the lung.



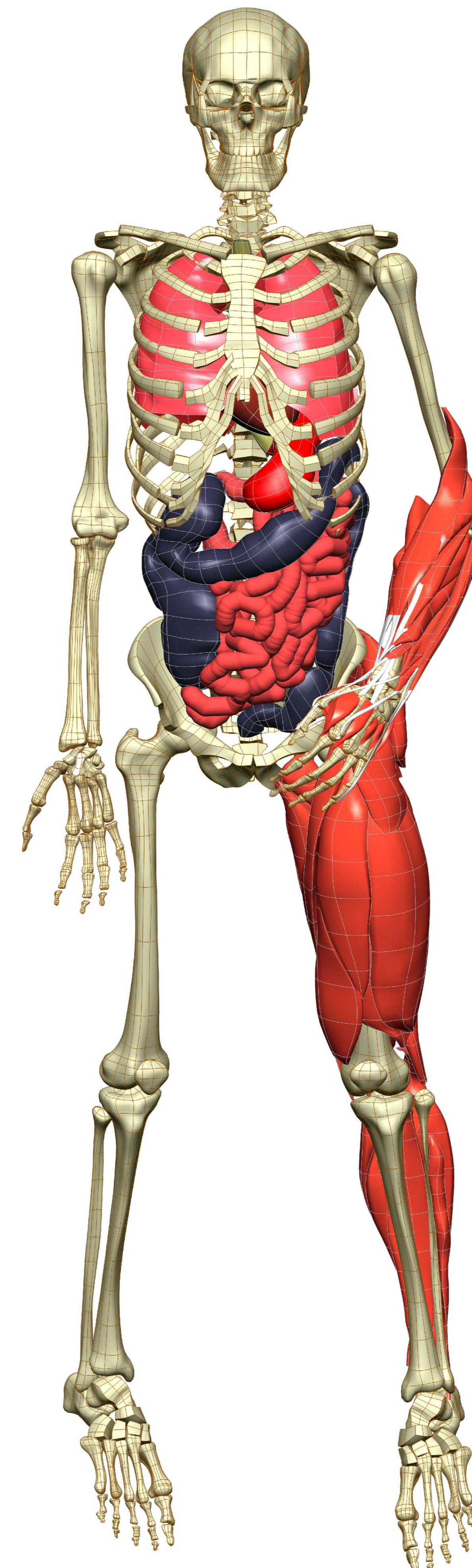
**Figure 3.** Geometry of the human lung. Colours show the separate lobes.



**Figure 4.** Calculated instantaneous arterial blood flow pressures.

To facilitate the communication of these models and the building of databases containing representations of them several XML file formats are being developed. CellML (refer to [www.cellml.org](http://www.cellml.org)) is able to specify the mathematics representing the physiology. Many cellular processes and some material constitutive laws have been coded in CellML. FieldML is being developed to allow the generalised description of interpolating fields. Ontological classification allows the models to be stored in an extensible database that is well connected with existing bioinformatic databases.

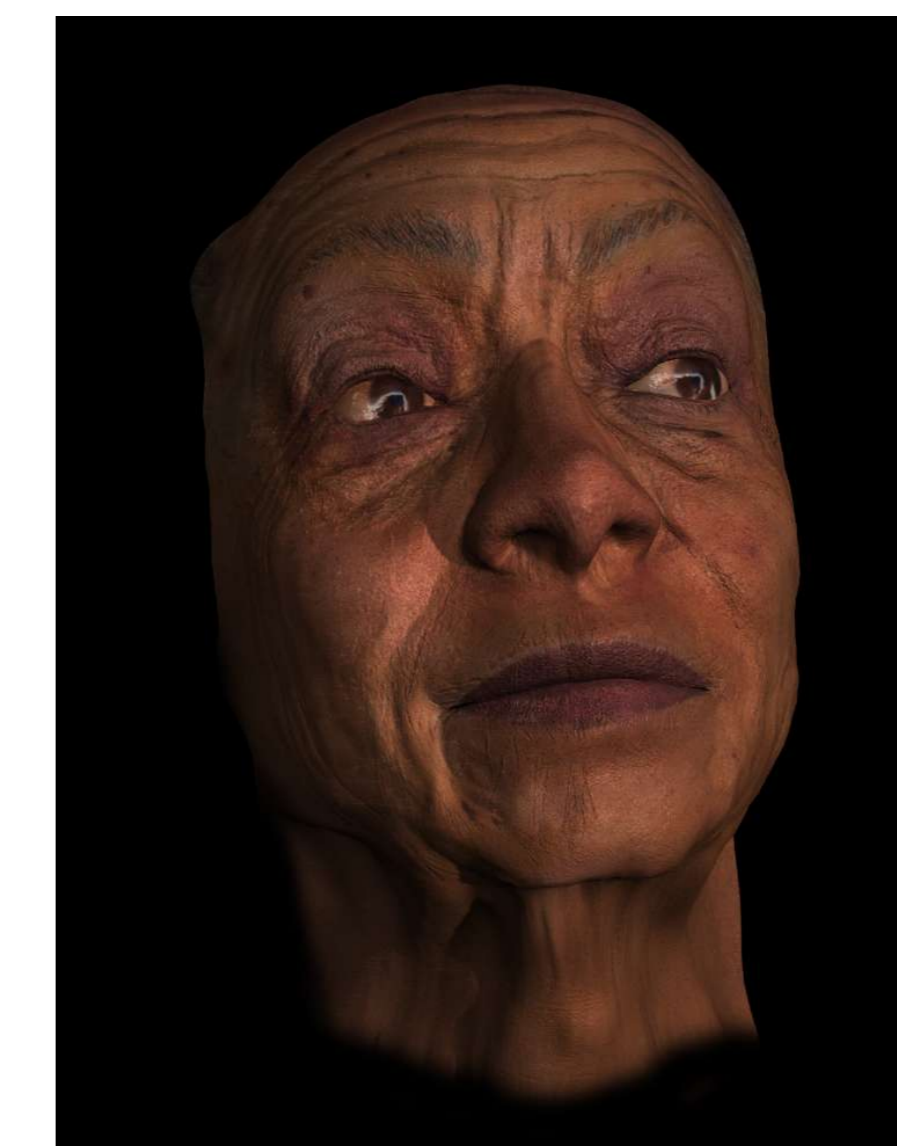
Free Form Deformation allows a customised model which matches measured characteristics of an individual to be generated from a generic model, retaining the complexity and topology of the original model.



**Figure 1.** Integrated geometrical meshes of skeleton, heart, lungs, stomach, intestine and muscles of the leg and hand.

## Facial Animation

This system of creating detailed, biophysically based generic models and then using Free Form Deformation to customise them to a particular individual has been successfully applied to facial animation. Using software and technology from the Bioengineering Institute, LifeFX Inc simulated the face of an old woman as shown in Figure 5. This face was composited into Young at Heart, Figure 6. (ACM SIGGRAPH Electronic Theatre 1999, 2000).



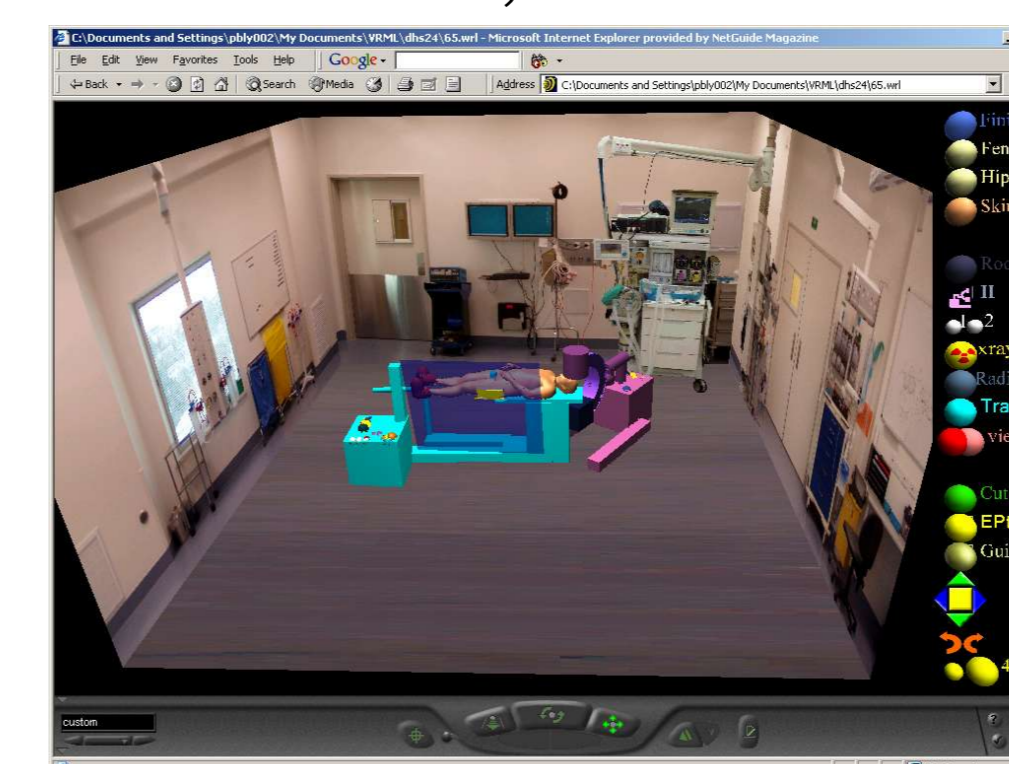
**Figure 5.** Simulated face of an old woman.



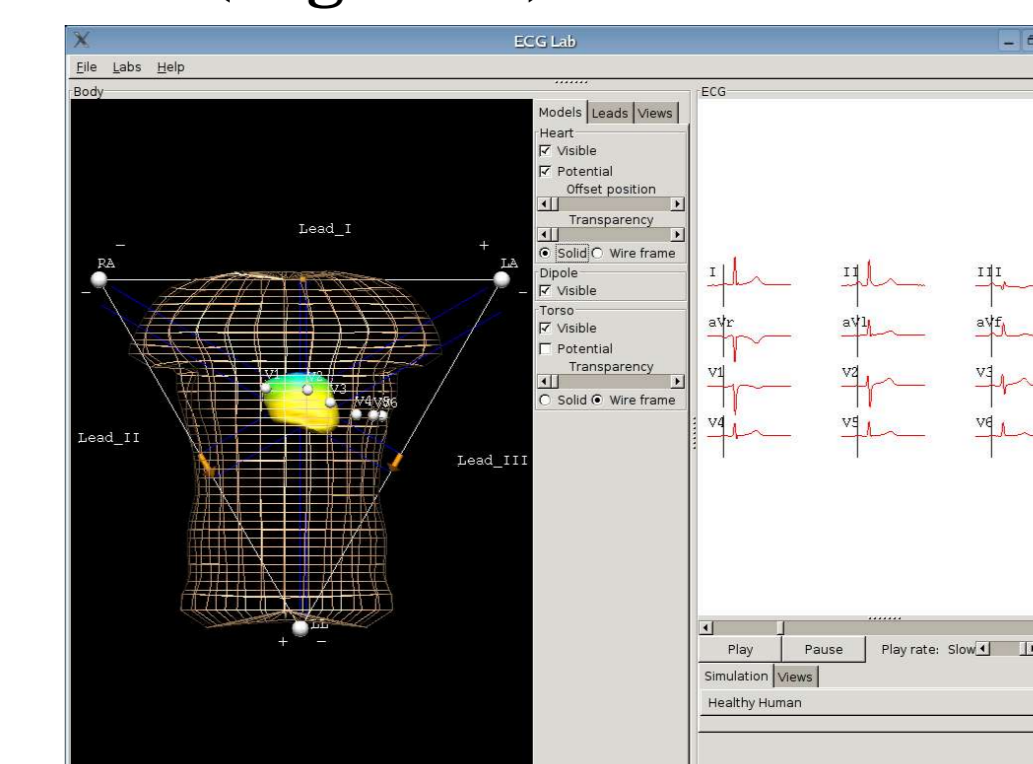
**Figure 6.** Simulated face of old woman composited into Young At Heart (ACM SIGGRAPH Electronic Theatre 2000).

## Medical Education and Surgical Simulation

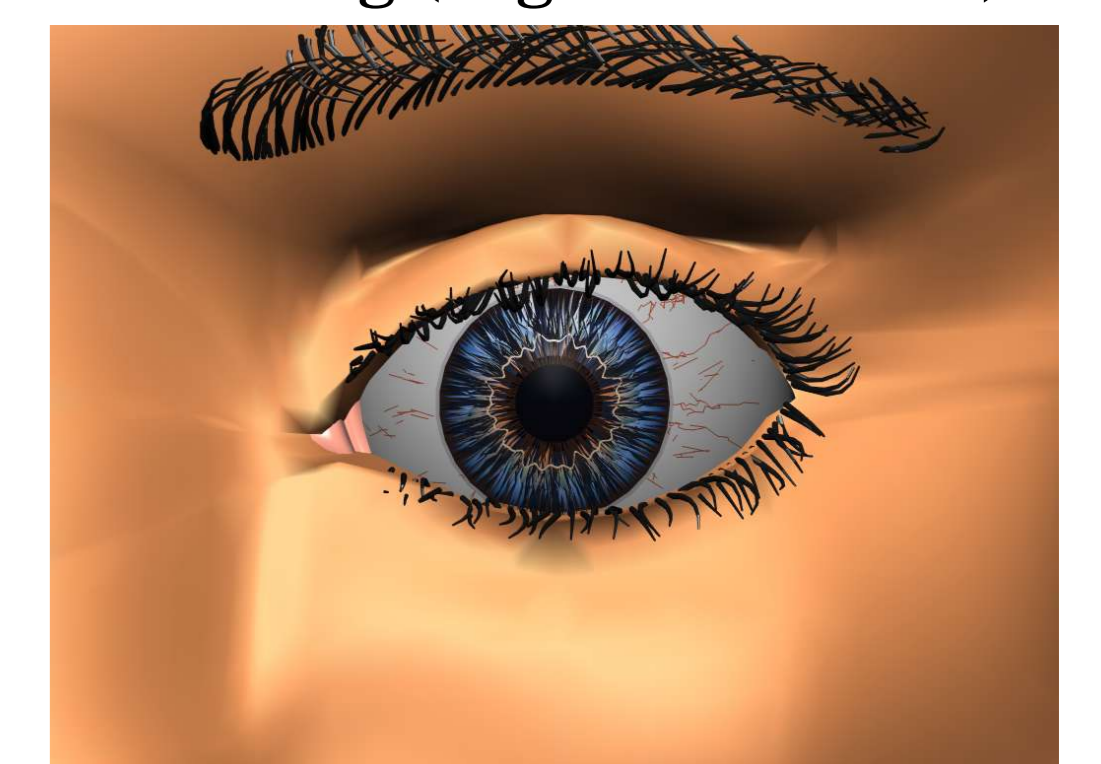
Creating these models requires an understanding of the fundamental processes that are occurring. Once a computer representation exists it can be used to investigate novel interventions, to facilitate education (Figure 8) or to allow surgical training (Figures 7 and 9).



**Figure 7.** Simulated dynamic hip screw surgery.



**Figure 8.** Educational application for teaching electrocardiography.



**Figure 9.** Virtual eye surgery environment.

## Conclusion

As the capabilities of computer rendering systems and graphics cards continue to advance it will be possible to incorporate more and more physics based simulation into movies and computer games. These advances will allow computer simulation of processes such as the response to disease, exercise or injury. The IUPS Physiome Project is advancing the science that will enable this to happen.