

The Digital Human

The Vision:

Advances in our understanding of the operation of the human body at all physical scales are matched by spectacular progress in information science. The purpose of this project is to revolutionize the way we view, study and interact with information about the human body and its complex and inter-related systems. We propose to build a complete, functioning library of interactive views and simulations of human anatomy, physiology, pathology, histology and genomics based on the most accurate computerized imaging and simulation techniques available — a complete *Digital Human*.

Medical research is leading to spectacular discoveries of the way the human body works and how diseases and disabilities can be overcome. The completion of human genome sequencing and the advent of proteomics promise an even greater flow of information. A vast library of knowledge is ready to be filled at a breathtaking pace with volumes of digital information about the human body. The breadth and quantity of emerging data has, however, made it difficult for researchers, students, teachers, patients, and clinicians to keep pace. The specter of an enormous library of knowledge with no card catalogue, no search engine, and no way to link new volumes of data is a very real concern. Fortunately, as our library of knowledge is filled with volumes of data about the human body, new computer tools are available to locate needed information and to grasp this information quickly by modeling how the complex systems of the body function and interact.

The *Digital Human* will link relevant research and clinical data, computer models of human biology and medicine and advanced display techniques to provide an unprecedented depth of insight into the functioning of the human body. It will be an important tool for medical research, and for education and training from high school through postgraduate professional school — including the continuing education and certification of healthcare professionals. The *Digital Human* aims to promote, unify, and disseminate digital information about the human body and its complex and inter-related systems. The immediate twin pathways are digital simulations of discrete systems in the human body and development of information technologies to facilitate management, access, linkages, and distribution of the data.

The ultimate goal is construction of a complete, functioning, accessible simulation of the human body – from the functioning of DNA and other molecules within individual cells to the operation of entire organ systems such as the heart, lungs, brain, and musculo-skeletal systems.

Potential Benefits:

The medical benefits of a digital human will be significant. A *Digital Human* will provide a test platform to speed the development of new drugs and therapies. Physicians will be able to practice on simulated humans, reducing medical error and reducing the need to practice on patients. As medical knowledge expands, the model will keep pace allowing the specific pathology and disease of an individual to be displayed and customized for very individualized

therapies. These may include surgery, drug interventions to modify physiological function, and tumor and cancer resections, with full knowledge of the exact spread of the problem and the margins of safe and effective therapy. Complex surgical procedures such as hip replacement, skull base surgery, complex liver surgery, could be rehearsed in the virtual environment using the patient's anatomy prior to the actual procedure.

As they are developed, portions of the *Digital Human* could be adapted for use in education from high school biology to the certification of healthcare personnel and practicing clinicians. They could be used to evaluate medical devices, drugs, and therapies before they are tested on animal or human subjects. The system could also be used to improve the safety of automobiles, aircraft, and other vehicles, and for a variety of other civilian and military purposes.

Key Information Technologies for the Digital Human

The *Digital Human* is far too ambitious for any group or individual to undertake. It must be built by a large community able to share and review each other's work. The challenge lies in the vast amounts highly complex information that already exists about the human body, the rate at which new information is being developed, and the fact that the information is currently stored in diverse forms in NIH, DoD, public domain databases, and research laboratories. Information is stored in multiple heterogeneous formats: molecular models, 3-D computer graphics databases, relational database tables, flat files, text stores, image repositories, and Web sources. They sit on different hardware platforms, under different operating systems and database management systems. Turning this vast universe of raw data into useful scientific insight and making that knowledge accessible, is one of the most difficult technological challenges facing the project. Modern software tools make this feasible.

The *Digital Human* project will (i) build a community of researchers working on simulating the human body (and its components) making it possible for them to share and reuse components without legal complexities (defining the terms for "open source" software), and (ii) develop a series of standards allowing components built by different groups and individuals to plug together and be reused. NIH and other agencies are already building models and simulations of the heart, lungs, cells and other systems. These investments will undoubtedly increase rapidly since experimental data capable of supporting complex simulations is now available and advances in information science make it possible to consider a major effort. Unfortunately most simulations today are built from scratch by independent groups – there is no ability to share components so that different pieces will fit together.

A functioning simulation of a body requires finding reliable ways to get software components developed by different groups to work seamlessly together. A simulated heart, for example, must be built from software components representing, blood vessels, cardiac muscle, nerves and other elements. The complete heart simulation must show how blood flows, chemical and electrical signals are passed, and other dynamic changes require complex interaction among components. The combined system must correctly represent the dynamic performance of the heart, it must provide an accurate 3-dimensional visualization of these functions, and it must react appropriately to interventions to show what happens if components are probed or cut as a part of surgery. And the system must be flexible enough so that

components can be replaced as new information is developed and replaced to reflect the heart of a particular class of individuals (a diseased heart valve could, for example, be inserted to help people understand the implications of this defect or help surgeons understand appropriate interventions). While such capabilities are possible, they greatly exceed the current state of the art and will require years of careful research to develop.

Technical Objectives

The *Digital Human* model will:

- ***Represent human biology at all relevant physical scales:*** The system would simulate the behavior of proteins, cells, tissues, organs, and larger systems.
- ***Allow access, collaborative, worldwide development and sharing by many individuals and teams:*** Experts from all over the world should be allowed to contribute content, models, and other materials to this borderless system.
- ***Be platform independent -- designed to be accessible over time, systems and software.*** The design should be based on science and not tied to any specific operating system or programming language.
- ***Be Peer Reviewed:*** Components should make it easy to check the authorship of components and the review process.

Potential Applications

Medical Practice:

- Predict impact of therapies on individual patients
- Allow surgeons and surgical teams to develop and practice procedures using data from individual patients
- Improve communication between healthcare providers and patients
- Support a new generation of computer assisted surgery, telesurgery

Health Sciences Education and Training:

- Education for basic biology courses in molecular and organismal biology (high school through graduate school) using simulation and advanced visualization
- Serve as curriculum for medical school and allied health training
- Train surgeons and others on new equipment and methods without risking patients and animals
- Certify surgeons, physicians and other healthcare workers using realistic tests

Medical Research:

- Build models linking vast amounts of information available from multiple sources (including genome project)
- Insight into complex processes that suggest new medical phenomena and treatments
- Test interventions

Military Research:

- Estimate utility of defensive measures (body armor, protection against chemical and biological attacks) to reduce development times
- Simulate impact of traumatic forces on the body

- Simulate non-lethal weapons

Space Exploration:

- Simulate impact of weightlessness on cells, tissues, organs
- Enhance design of suits and tools by simulating the operation of the body in space environments

Transportation:

- Improve design of collision resistant vehicles
- Improve ergonomics of controls and displays.