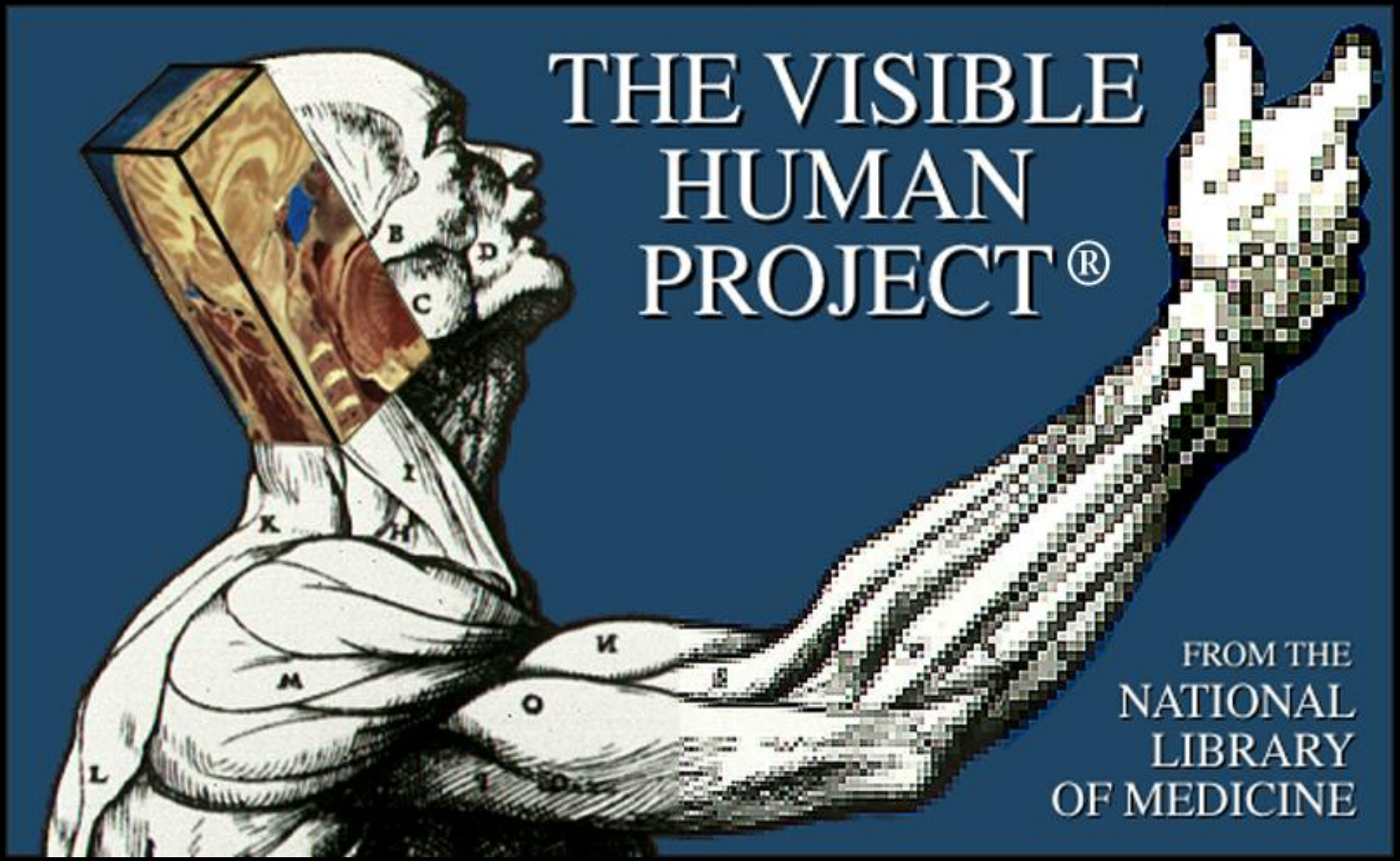



# Imaging Informatics

# Background

- Knowledge in pictures
- Digital technologies
  - Fast computers
  - Higher resolution displays
  - High density storage media
  - Ubiquitous high speed networks
- Pictures may be as practical as text

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# Types of Images

- Black and white picture
  - X-ray
- Color picture
  - Pathology
- Motion
  - Angiogram
  - Sonogram
- 3-dimensional
  - Hologram

# Uses of Imaging

- Specialties:
  - Radiology
  - Pathology
  - Dermatology
  - Neurology
  - Ophthalmology
  - Cardiology
  - Surgery
- Cross-specialty
  - Telemedicine
  - Multi-media medical records
  - Multi-media publication

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# The making of a digital image

- Bit map
  - a 2-dimensional array of numbers through which a digital image is encoded (digitized) and decoded (visualized)
- Pixel
  - a single numeric element in a bit map which describes the visual magnitude of that point in the picture
- Voxel
  - a single numeric element in a 3-dimensional array of numbers representing a volume

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# All pixels are not the same

- 8 bit (hundreds of colors)
  - magnitude of grayness from black (0) to white ($2^8 = 256$)
  - magnitude of color composition (3 bits [$2^3 = 8$] red, 3 bits [$2^3 = 8$] green, 2 bits [$2^2 = 4$] blue) from black (0) to white ($8x8x4 = 2^8 = 256$)
- 24 bit (millions of colors)
  - magnitude of color composition (8 bits [$2^8=256$] each for red, green, blue) from black (0) to white ($256x256x256 = 2^{24} = 16,777,216$)

# Image resolution

- Spatial
  - how much area does each pixel represent
- Contrast
  - minimum intensity difference
- Color
  - minimum color difference
- Temporal
  - minimum time between sequential images
  - maximum time to capture a single image

# Image dimensionality

- Space (3D)
  - XYZ: left-right, up-down, in-out
- Time (1D)
  - T: relative time
- Color (3D)
  - RGB: red, green, blue
  - YUV: luminance, hue, saturation
  - $YC_rC_b$: mathematical variation of YUV

# A Picture is Worth a Thousand Words

- Classic DOS Text:
  - 80 characters on 25 lines (`courier 12`)
  - 2,000 characters

    (1 character = 8 bits)
  - 16,000 bits

- Full Color Images:
  - 1024 dots by 768 dots
  - 786,432 dots (pixels) ~ .75 megapixel

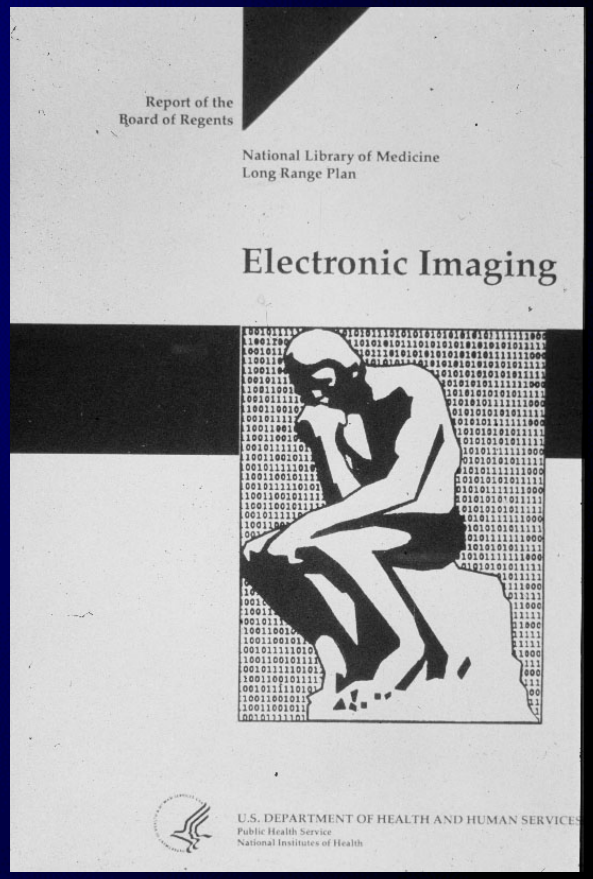
    (1 dot = 24 bits, i.e., millions of colors)
  - ~18,800,000 bits

# The NLM Board of Regents Recommended That the NLM Should:

" . . . thoroughly and systematically investigate the technical requirements for and feasibility of instituting a biomedical images library."

1986 Long Range Plan

“The NLM should undertake a first project, building a digital image library of volumetric data representing a complete normal adult human male and female. This Visible Human Project would include digitized photographic images from cryosectioning, digital images derived from computerized tomography, and digital magnetic resonance images of cadavers.”




1989 Board of Regents
Planning Panel on Electronic Imaging

# Habeas Corpus

*Seeking subjects to be a digital Adam and Eve*

Scientific American
January, 1993

Scientific American, January, 1993, pp. 146-7

*HEAD RECONSTRUCTION was created by combining 352 digitized photographs of tissue sections. The University of Colorado will now do the same for a whole body.*

## Habeas Corpus

*Seeking subjects to be a digital Adam and Eve*

A good man is hard to find. So, too, a good woman. Unlike the Marine Corps, the National Library of Medicine (NLM) does not need a few good specimens. Just one of each sex will do. The ideal candidates should be between the ages of 20 and 60 years, of medium height, not too thin, not too plump. Race or ethnic background is not an issue. But a prospect must meet more problematic criteria: he or she must have expired and been put into a cooler within the last 12 hours in preparation for being cut up by a team of medical specialists into more than 1,000 thin slices.

The NLM has embarked on an 18-month search for contestants to become the ideal male and female cadavers. Those chosen may become known as Adam and Eve. This search may mark the beginning of an era in which computers may rival cadavers as primary sources of information on anatomy.

By the end of 1993 the NLM wants to enter into a computer every millimeter of a male and a female cadaver via computed tomography (CT), magnetic resonance imaging (MRI) and standard photography. The result of this effort—the Visible Human Project—will be the most comprehensive digital record of an entire human body. "Before this, one university was doing the right knee while another was doing the left ear," says NLM director Donald A. B. Lindberg.

The main use for this computer-age *Gray's Anatomy* will, of course, be the study of anatomy. For the first time, a medical student will be able to "reverse dissect" a cadaver, reassembling it after having cut it apart on the screen. A researcher might also inject a mathematical model of abnormal cell growth into a computerized liver to grow a tumor. The data base may be used in designing prostheses or in assisting a surgeon to plan an operation better. A patient's CT image can be compared with Adam's and Eve's standard images for a "normal" human.

Before proceeding, NLM officials and outside experts debated for years the exact definition of normal but failed to achieve any consensus. Their loose classification now encompasses a male and a female of any race between the ages of 20 and 60 years, less than six feet in height and of average weight. "We decided that nothing can be considered average or normal, but we had to start somewhere," says Michael Ackerman, the NLM's associate director for specialized information services, which oversees the project. But even within this open definition, it has been difficult to find a body that has remained unscathed through the travails of daily living. "People die for a reason," Ackerman says.

The University of Colorado Health Sciences Center in Denver received the more than $700,000 contract (a word that is used advisedly among the project's staff) to find several male and female bodies. An NLM committee will choose one Adam and one Eve from the candidates the center screens.

Cutting was to have begun last July. But so far only five cadavers have been found, three males and two females. All but two of them still have shortcomings. "We've got two good males, but we're still not really happy with the females we have now," says Victor M. Spitzer, a professor of cellular and structural biology who is supervising the project at the university. The digital preservation of one of the two frozen males could begin within a few months, after the NLM review panel makes a choice. Spitzer is still searching in other states and explaining the purpose of the project at technical conferences.

A good candidate may be one who has died of a drug overdose, carbon monoxide poisoning or some other nondisfiguring cause of mortality and, of course, has agreed to donate his or her body to science. Colorado's Anatomical Visualization Laboratory will employ a milling machine that operates as if it were an automated carpenter's plane, shaving off a millimeter-thick slice from a section of the body. As each slice is removed, the newly exposed surface is photographed. The digitized photographs will be stored in a computer with MRI and CT images that are made before the cutting process is begun. Afterward, the real work will begin. Another contractor will finish the job by identifying and indexing each of the digital slices, a project that will take years more and will cost an estimated $10 million.

The final data base may consist of 50 gigabytes of digital information, enough, if left uncompressed, to fill more than 80 data-storing compact discs. Instead of distributing data on discs, the NLM may have the option to transfer the information over a proposed government-financed network that could accommodate transmission at the lightning speed of a gigabit per second, a project proposed by Vice President-elect Al Gore.

At some future date, Adam and Eve may have progeny, perhaps parents as well. The NLM would like to add imaged cadavers of children, the elderly and the sick to its storehouse. Meanwhile the search continues for a select few men and women who will be the recipients

# Rest In Pieces

LIGHT ELEMENTS

## Rest in Pieces

BY JEFFREY KLUGER

THERE ARE A LOT OF REASONS I'M NOT A DOCTOR today. For one thing, I'm just the tiniest bit squeamish. The sight of anything even remotely illness-related—needles, bandages, rice pudding with raisins—makes me instantly weak-kneed. For another thing, some of the routine parts of a doctor's job have always struck me as rather unattractive. I'm pretty sure I could go through my entire life without ever speaking the words, "Turn your head and cough," or, "Now, let's have a look at that polyp, shall we?" • More important, however, the science of anatomy has always left me baffled. From grammar school on, I've had only the roughest idea of how the human body is put together, even when that body is my own. I'm pretty certain I've got the standard heart, lungs, and kidneys; pretty sure I don't have a crop, gizzard, or brood pouch; and as for my gallbladder, pineal gland, and jejunum, I'll take it as an article of faith that they're where they ought to be, but I couldn't find them with a copy of *Gray's Anatomy* and a sextant.

In fairness, my anatomical illiteracy is not entirely my fault. My first exposure to the mysteries of the human innards was an "educational toy" (translation: no batteries, decals, or suction-cup darts) I acquired in childhood, called The Visible Man. The Visible Man was a tiny model of a human being with snap-in and snap-out organs that was supposed to show you precisely how the average person is put together. By and large, the little model did a pretty good job—provided, of course, that the average person is 11 inches tall, completely transparent, and able to accept an organ donation from a Lego set. In my house, The Visible Man lasted only a week or so before becoming The Visible Man Minus Key Organs, and it was eventually taken away from my brothers and me altogether after tiny plastic glands started turning up in the Chex mix.

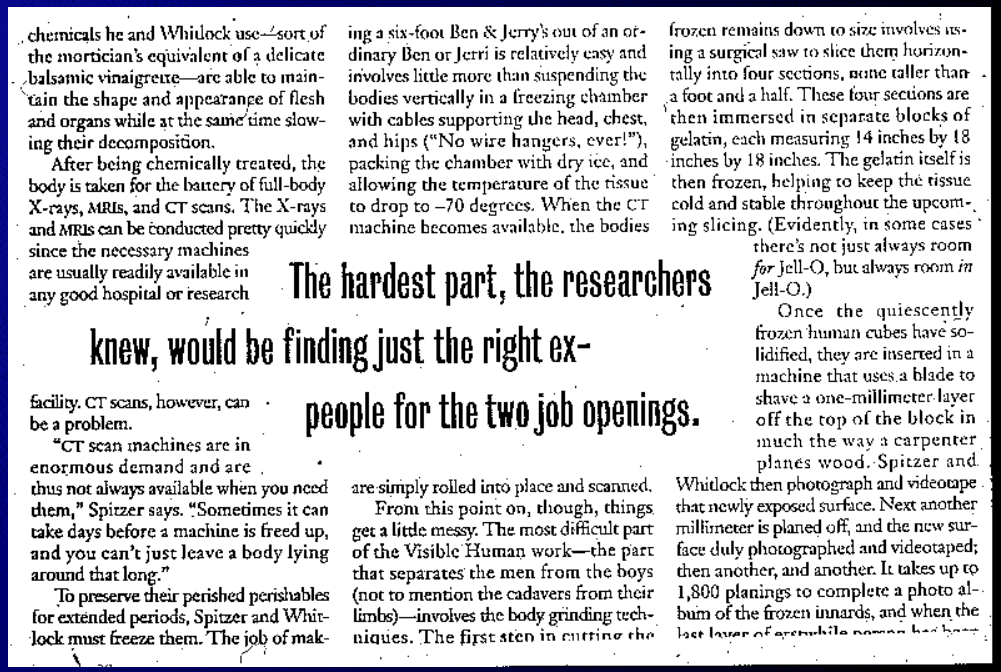
For even the most anatomically unschooled, however, all this confusion may soon come to an end. Recently the U.S. Department of Health and Human Services went The Visible Man of my childhood one better, announcing the creation of the intriguingly named—and now gender-neutral—Visible Human Project, a government program designed to simplify and standardize the study of human anatomy once and for all. The Visible Human Project is sort of the medical equivalent of the Miss America contest, in which one man and one woman will be selected from the general population to serve as science's archetypes of the human form. These two perfect specimens will be scanned, photographed, and data-based and then used as anatomy models in classrooms and laboratories across the country.

For anyone looking for a line of work that doesn't exactly require four years of graduate school, the two openings sound promising. But before typing up a résumé and submitting Polaroids of your pancreas, be aware of the fine print in the employment contract: The perfect pair chosen for the project will be X-rayed from head to toe, spend hours lying still in a magnetic resonance imaging machine for soft-tissue pictures, and later spend at least half a day submitting to a series of full-body CT scans. Finally (and here's the part that some fussier applicants might object to), both lucky winners will be steadily ground to dust by a planing machine and photographed as different parts of their bodies are exposed. Not

**At the National Institutes of Health, organ donors meet organ grinders.**

ILLUSTRATIONS BY MICHAEL WITTE

DISCOVER 86 OCTOBER 1993



chemicals he and Whitlock use—sort of the mortician's equivalent of a delicate balsamic vinaigrette—are able to maintain the shape and appearance of flesh and organs while at the same time slowing their decomposition.

After being chemically treated, the body is taken for the battery of full-body X-rays, MRIs, and CT scans. The X-rays and MRIs can be conducted pretty quickly since the necessary machines are usually readily available in any good hospital or research facility. CT scans, however, can be a problem.

"CT scan machines are in enormous demand and are thus not always available when you need them," Spitzer says. "Sometimes it can take days before a machine is freed up, and you can't just leave a body lying around that long."

To preserve their perished perishables for extended periods, Spitzer and Whitlock must freeze them. The job of making a six-foot Ben & Jerry's out of an ordinary Ben or Jerri is relatively easy and involves little more than suspending the bodies vertically in a freezing chamber with cables supporting the head, chest, and hips ("No wire hangers, ever!"), packing the chamber with dry ice, and allowing the temperature of the tissue to drop to –70 degrees. When the CT machine becomes available, the bodies are simply rolled into place and scanned.

From this point on, though, things get a little messy. The most difficult part of the Visible Human work—the part that separates the men from the boys (not to mention the cadavers from their limbs)—involves the body grinding techniques. The first step in cutting the frozen remains down to size involves using a surgical saw to slice them horizontally into four sections, none taller than a foot and a half. These four sections are then immersed in separate blocks of gelatin, each measuring 14 inches by 18 inches by 18 inches. The gelatin itself is then frozen, helping to keep the tissue cold and stable throughout the upcoming slicing. (Evidently, in some cases there's not just always room *for* Jell-O, but always room *in* Jell-O.)

Once the quiescently frozen human cubes have solidified, they are inserted in a machine that uses a blade to shave a one-millimeter layer off the top of the block in much the way a carpenter planes wood. Spitzer and Whitlock then photograph and videotape that newly exposed surface. Next another millimeter is planed off, and the new surface duly photographed and videotaped; then another, and another. It takes up to 1,800 planings to complete a photo album of the frozen innards, and when the last layer of erstwhile person has been

**The hardest part, the researchers knew, would be finding just the right ex-people for the two job openings.**

"The hardest part, the researchers knew, would be finding just the right ex-people for the two job openings."

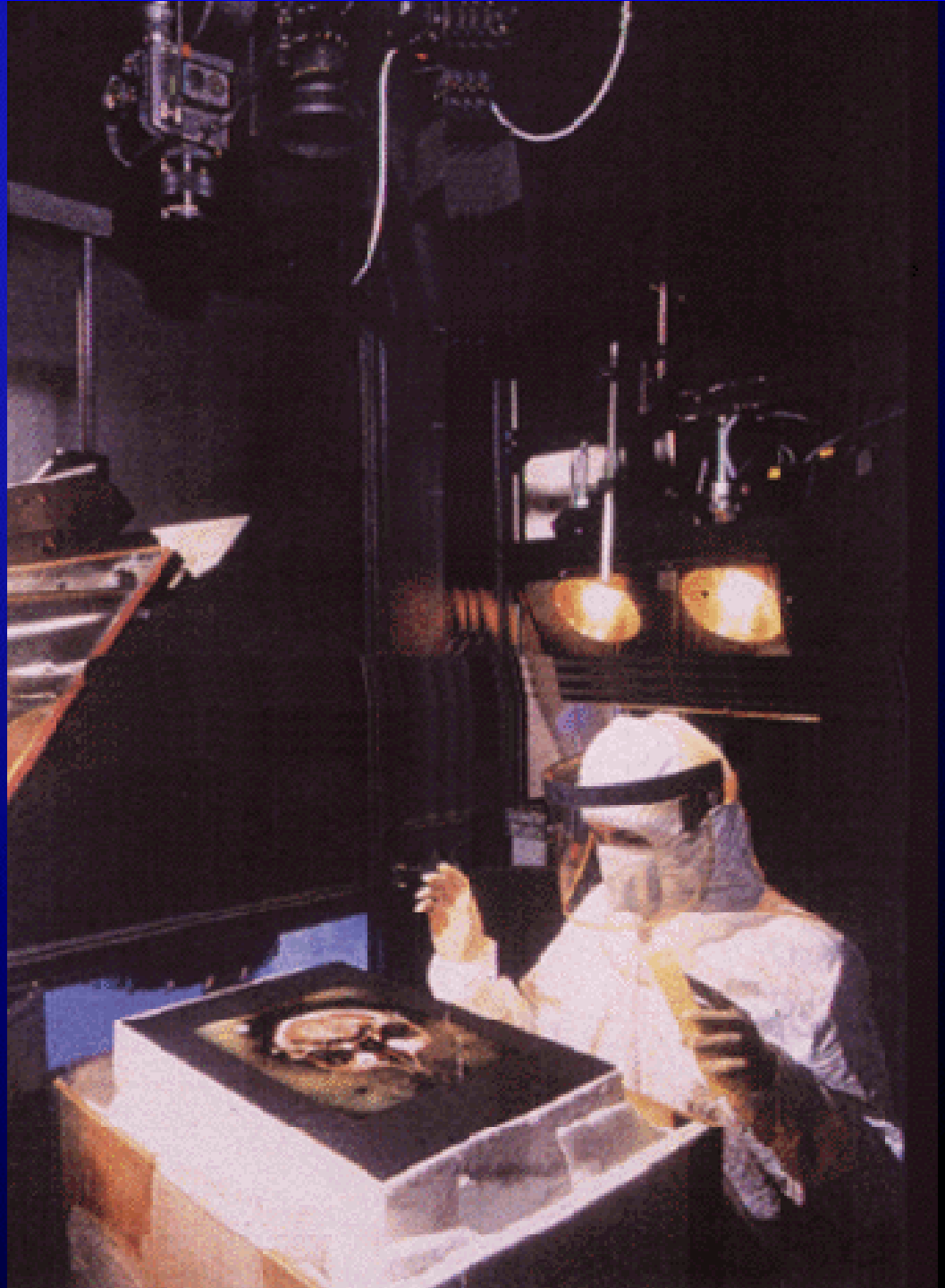
Discover Magazine

October 1993

"At the NIH, organ donors meet organ grinders"

NATIONAL LIBRARY OF MEDICINE

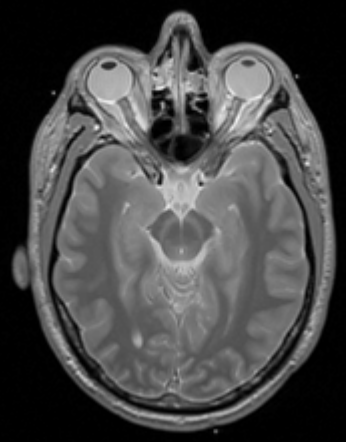
THE VISIBLE HUMAN PROJECT



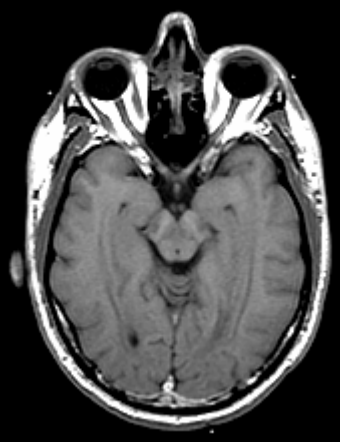
NATIONAL LIBRARY OF MEDICINE

THE VISIBLE HUMAN PROJECT

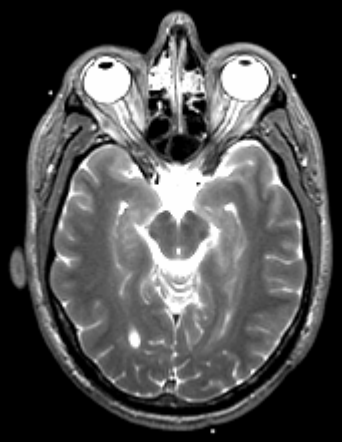
3117
NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT



MRI - Proton Density

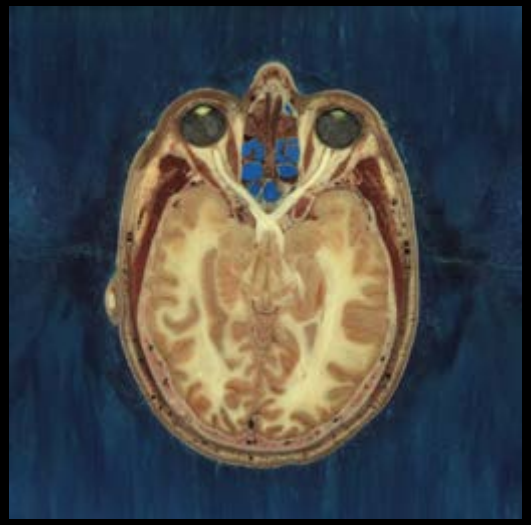


MRI - T1



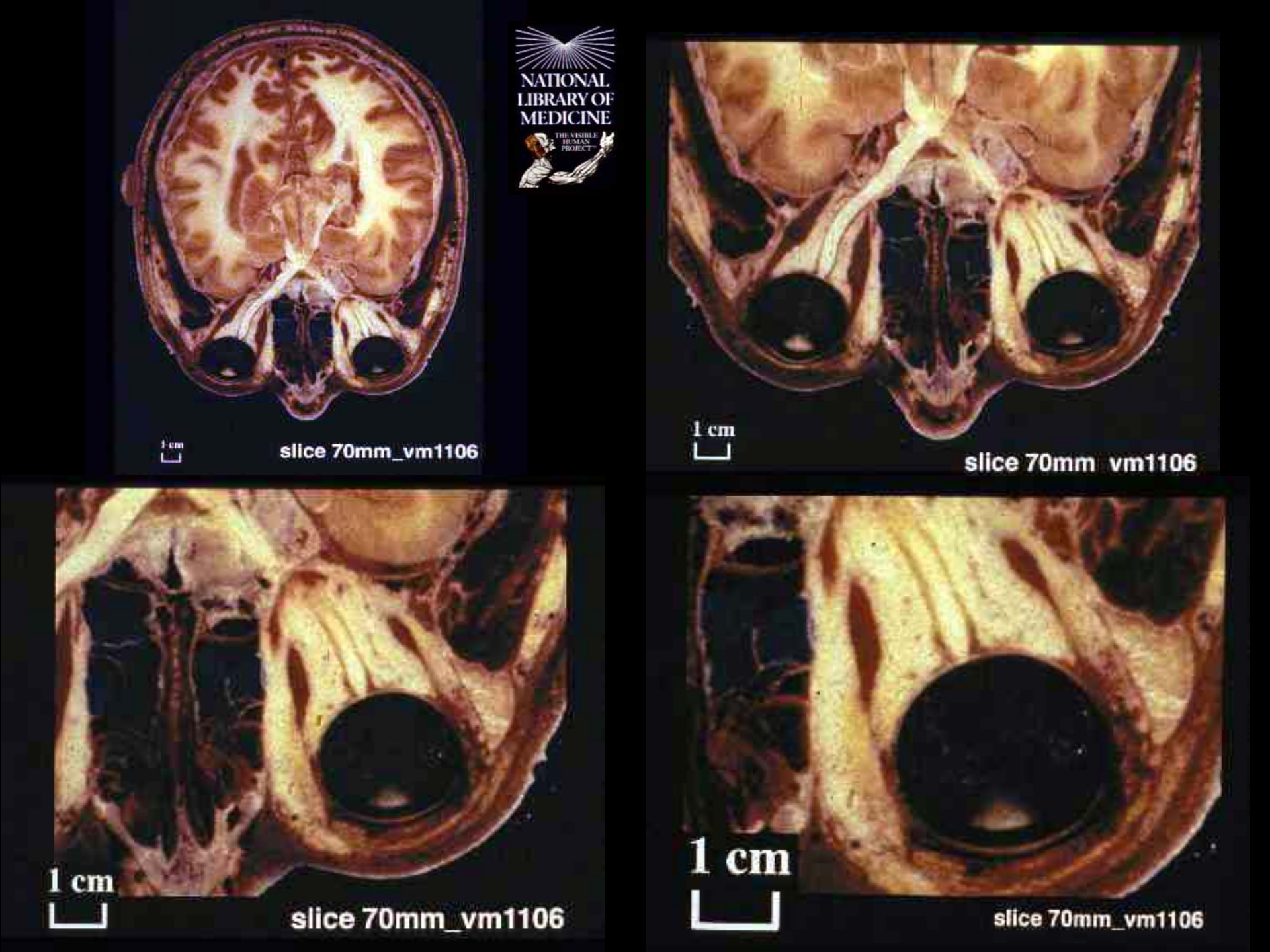
MRI - T2

CT

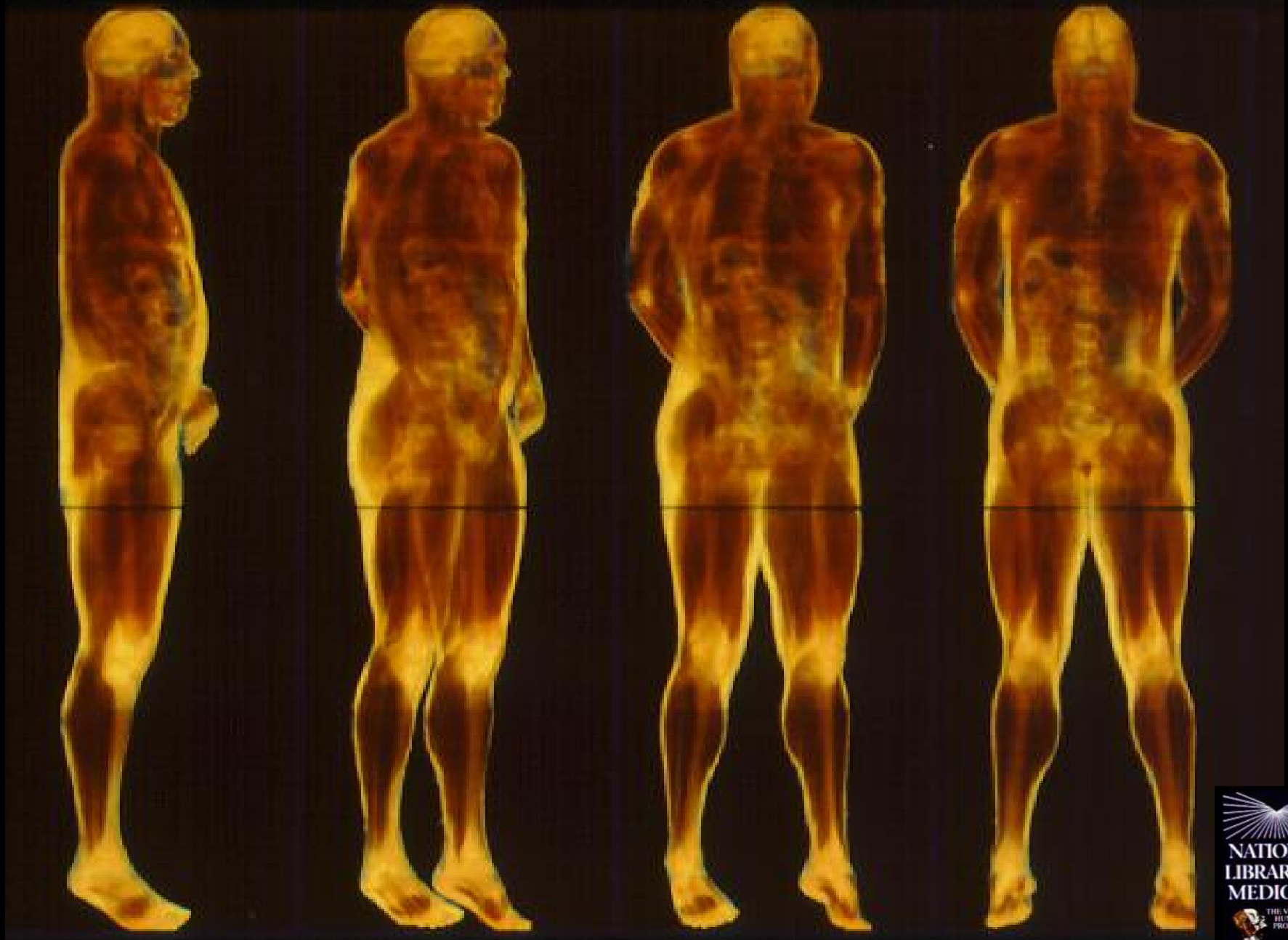


Cryosection

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT


NATIONAL
LIBRARY OF
MEDICINE
THE VISIBLE
HUMAN
PROJECT
1 cm
slice 70mm_vm1106
1 cm
slice 70mm vm1106
1 cm
slice 70mm_vm1106
1 cm
slice 70mm_vm1106

NATIONAL
LIBRARY OF
MEDICINE
THE VISIBLE
HUMAN
PROJECT


NATIONAL
LIBRARY OF
MEDICINE
THE VISIBLE
HUMAN
PROJECT

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

Male: 1.00mm data

Female: 0.33mm data

NATIONAL LIBRARY OF MEDICINE

THE VISIBLE HUMAN PROJECT™

Projects Based on the Visible Human Data Set

Applications for viewing images

Sources of images and animations

Products

Mirror Sites

Tools

Media Productions

Related Projects

Funding Sources

# The Visible Human Project®

## Overview

The Visible Human Project® is an outgrowth of the NLM's 1986 Long-Range Plan. It is the creation of complete, anatomically detailed, three-dimensional representations of the normal male and female human bodies. Acquisition of transverse CT, MR and cryosection images of representative male and female cadavers has been completed. The male was sectioned at one millimeter intervals, the female at one-third of a millimeter intervals.

The long-term goal of the Visible Human Project® is to produce a system of knowledge structures that will transparently link visual knowledge forms to symbolic knowledge formats such as the names of body parts.

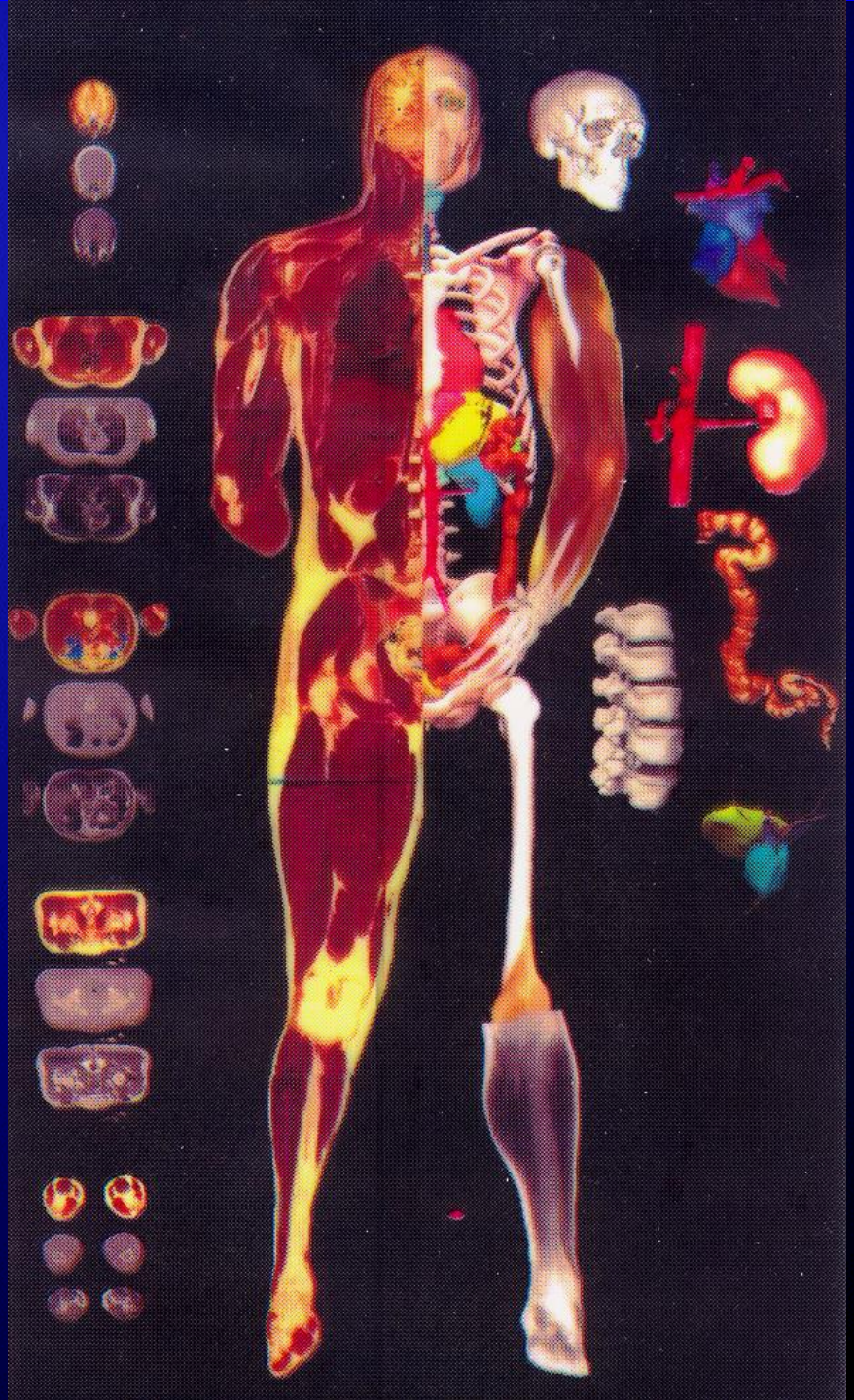
## Further Information

- **General Information**
  - A description of The Visible Human Project® image data and how to obtain it (includes license agreement documents).
  - The Visible Human Project® FactSheet.
  - A sampler of images and animations from the Project.
  - The Visible Human Project®: From Data to Knowledge: An update of ongoing National Library of Medicine VHP initiatives.
  - Digitally encoded videos - requires RealPlayer.
- **NLM Initiatives**
  - Cryosection, MRI and CT image data of the head of a 72 year old male. Cryosections done at 0.174mm intervals and photographed at a resolution of 1056 x 1528 pixels. Work done at Brigham and Women's Hospital, Harvard Medical School, under contract to NLM. Available only to VHP license holders. These images can be found in the directory BWH_Harvard when logged on to the NLM image server.
  - AnatLine: a prototype system consisting of an anatomical image database and an online browser developed at the National Library of Medicine.
  - AnatQuest: the overall goal of the AnatQuest project is to explore and implement new visually and compelling ways to bring anatomic images from the Visible Human dataset to the general public. Includes 3D renderings and labeled views.
  - Insight Toolkit (ITK): an open-source software toolkit for performing registration and segmentation, developed by six principal organizations under contract to the NLM, three commercial (Kitware, GE Corporate R&D, and Insightful), and three academic (UNC Chapel Hill, University of Utah, and University of Pennsylvania).
  - The Visible Human Project ATLAS of Functional Human Anatomy, version 1.0 The Head and Neck, developed under contract to the NLM by the University of Colorado Center for Human Simulation.
- **Information from the contractors for the Project**
  - University of Colorado Health Sciences Center (primary)
  - National Center for Atmospheric Research
- **Proceedings from The Visible Human Project Conferences** - The information presented here is identical to that distributed on CD-ROM to conference attendees. Please refer to section "Disc Info" or "About This CD-ROM", for pertinent information.
  - The Visible Human Project® Conference, 1996
  - The Second Visible Human Project® Conference, 1998
  - The Third Visible Human Project® Conference, 2000

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

http://www.nlm.nih.gov/research/visible/visible_human.html

Cross Sectional Bit Maps



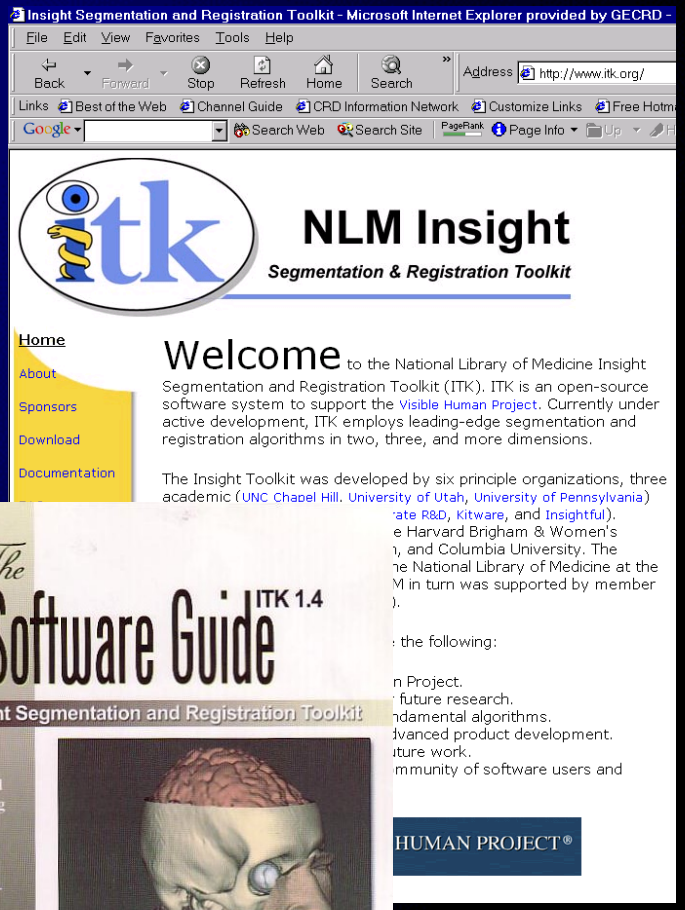
3 Dimensional Objects

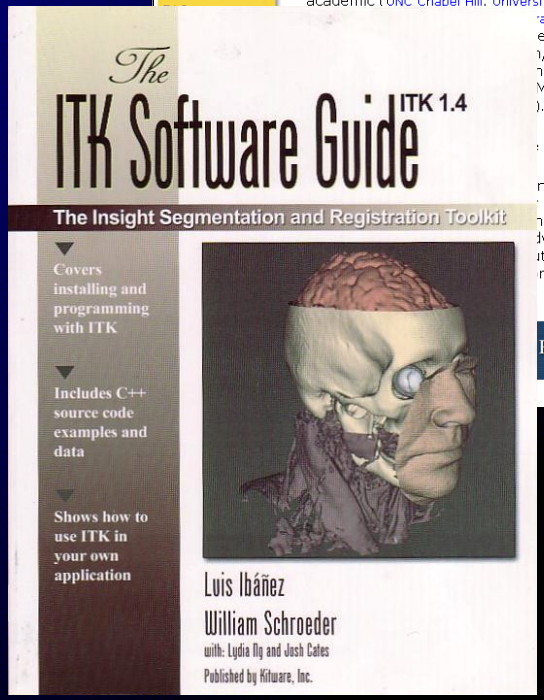
NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# Segmentation & Registration Tool Kit

# - ITK -

- Open Source
- Image Segmentation
  - multivalued (multimodal) data
- Image Registration
  - rigid and deformable registration



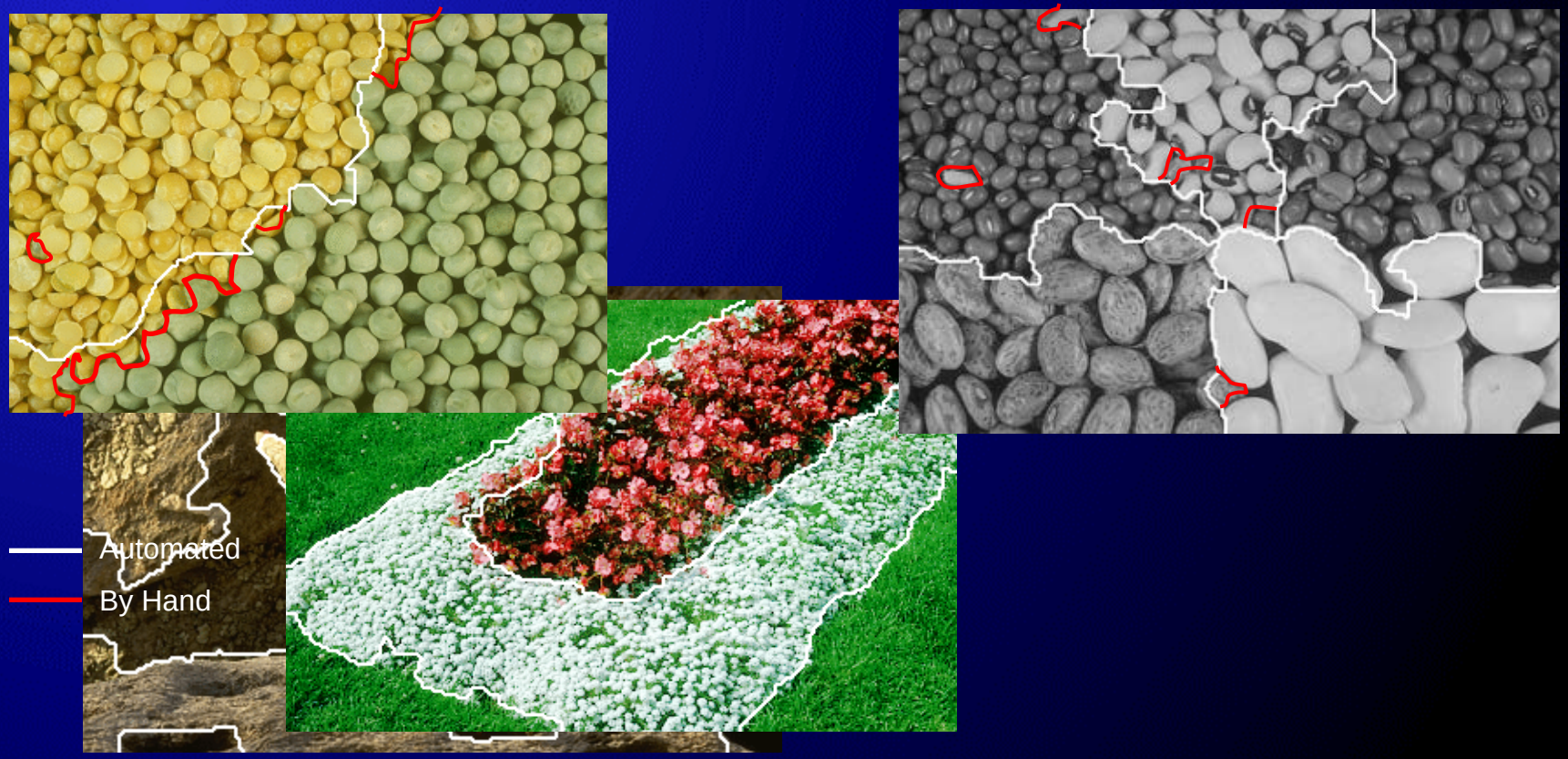




http://www.itk.org

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# Image Segmentation

The process of dividing images up into subsets that correspond to surfaces or objects



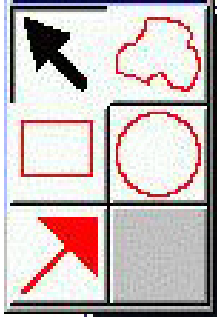

<u>Manual Segmentation</u>:

Pro: Often most accurate method available

Con: Labor-intensive and time-consuming; requires subject expertise; high intra and inter-observer variability

New
Open
Save
Export HTML
Document Properties
About
Quit

Tools



**Document Title:** Lateral View

**Image Representa**

| Image Name | File path |
|---|---|
| default | file:/home/ge |

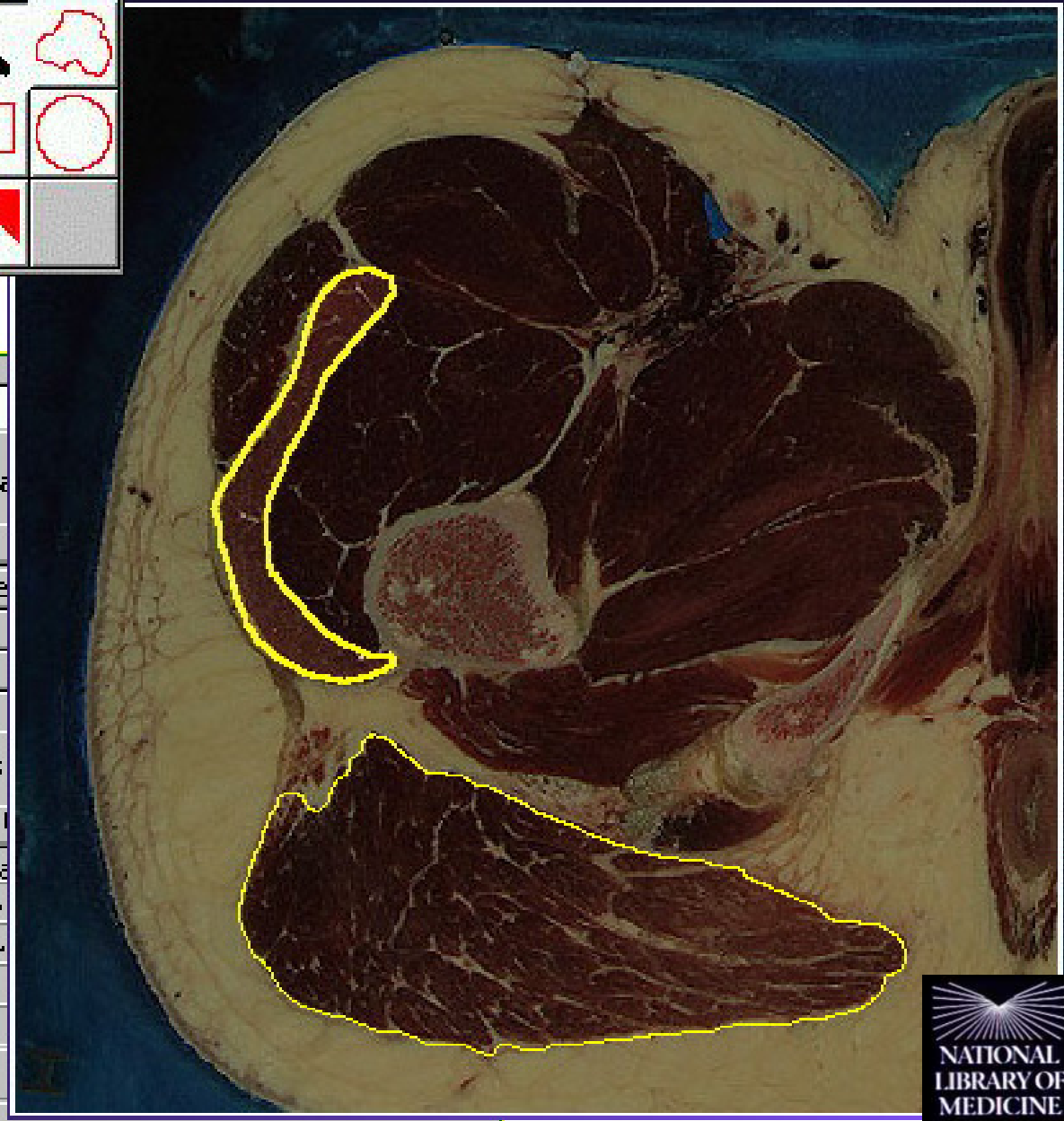
**Meta-Links**

| Link Name | Type | Destin |
|---|---|---|
| Medial | | media |
| Ventral | | ventr |
| Superior | | super |

**Default color:**

Cancel

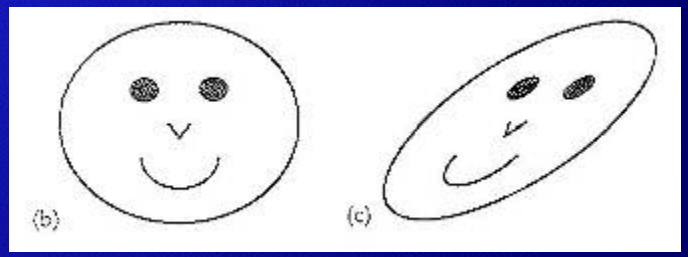
Ok



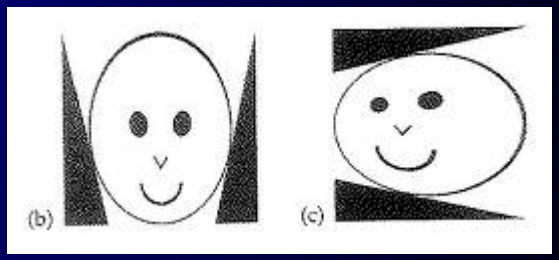
NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# Image Registration

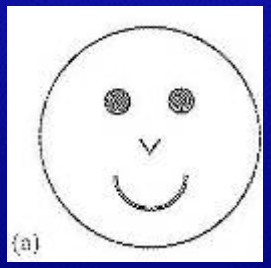
The process required to bring images into spatial alignment.



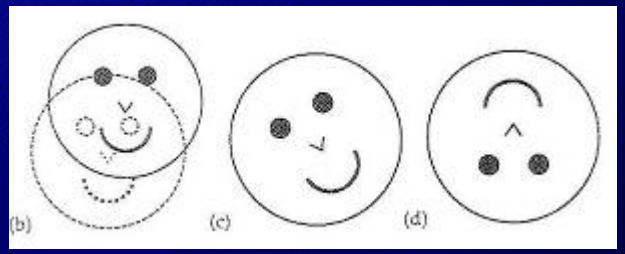

Scaling Shearing Transformation



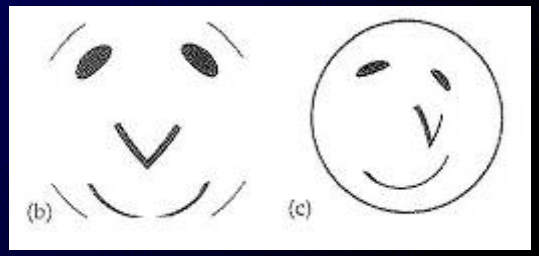

Projective Transformation




Original




Rigid Transformation




Curved Transformation

# Image Registration

Original

Shearing Transformation

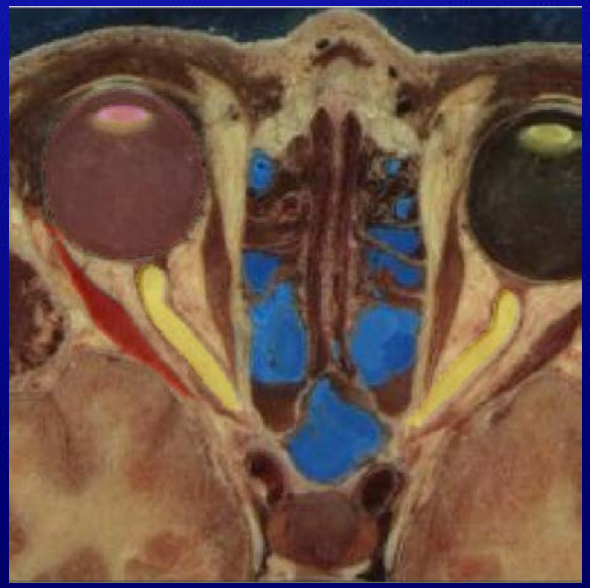
Projective Transformation

Rigid Transformation

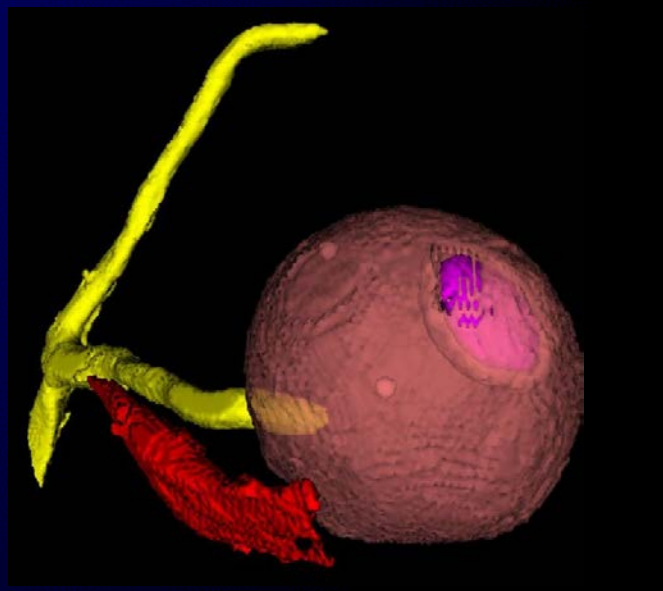
Curved Transformation

NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

# Visible Human Segmentation and Registration Using ITK



→ itk →



NATIONAL LIBRARY OF MEDICINE
THE VISIBLE HUMAN PROJECT

The only way to predict the future is to invent it.

*Lister Hill Center – National Library of Medicine*

www.nlm.nih.gov