CSE 564
Visualization & Visual Analytics

Medical & Scientific Visualization

Klaus Mueller

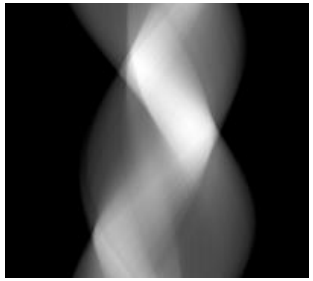
Computer Science Department
Stony Brook University

Lecture	Topic	Projects
1	Intro, schedule, and logistics	
2	Applications of visual analytics, basic tasks, data types	
3	Introduction to D3, basic vis techniques for non-spatial data	Project #1 out
4	Data assimilation and preparation	
5	Bias in visualization	
6	Data reduction and dimension reduction	
7	Visual perception and cognition	Project #1 due
8	Visual design and aesthetics	Project #2 out
9	Python/Flask hands-on	
10	Cluster analysis: numerical data	
11	Cluster analysis: categorical data	
12	Foundations of scientific and medical visualization	
13	Computer graphics and volume rendering	Project #2 due
14	Scientific and medical visualization	Project #3 out
15	High-dimensional data, dimensionality reduction	
16	Big data: data reduction, summarization	
17	Correlation and causal modeling	Project #3 due
18	Principles of interaction	
19	Midterm #1	
20	Visual analytics and the visual sense making process	Final project proposal due
21	Evaluation and user studies	
22	Visualization of time-varying and time-series data	
23	Visualization of streaming data	
24	Visualization of graph data	Final Project preliminary report due
25	Visualization of text data	
26	Midterm #2	
27	Data journalism	
	Final project presentations	Final Project slides and final report due

Medical Imaging: Overall Concept

human (in pain)

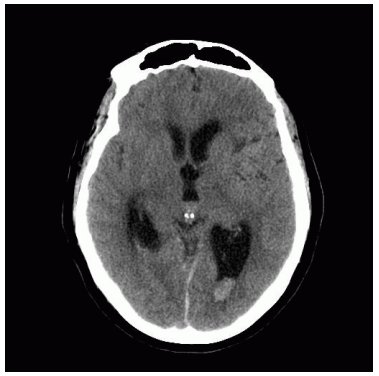
imaging device



data

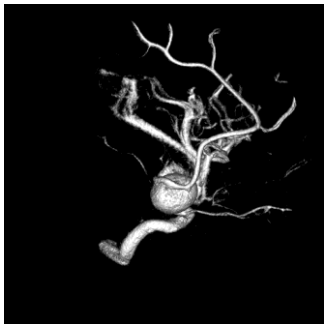
imaging algorithm

reconstructed cross-sectional image



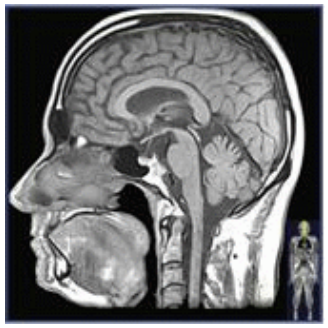
Imaging Modalities Overview

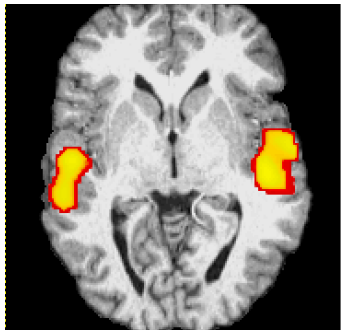
CT



X-ray

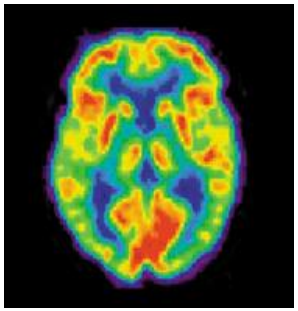
MRI / fMRI

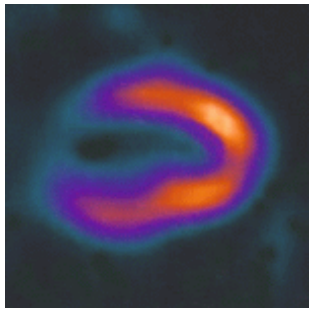




magnetic spin

Nuclear



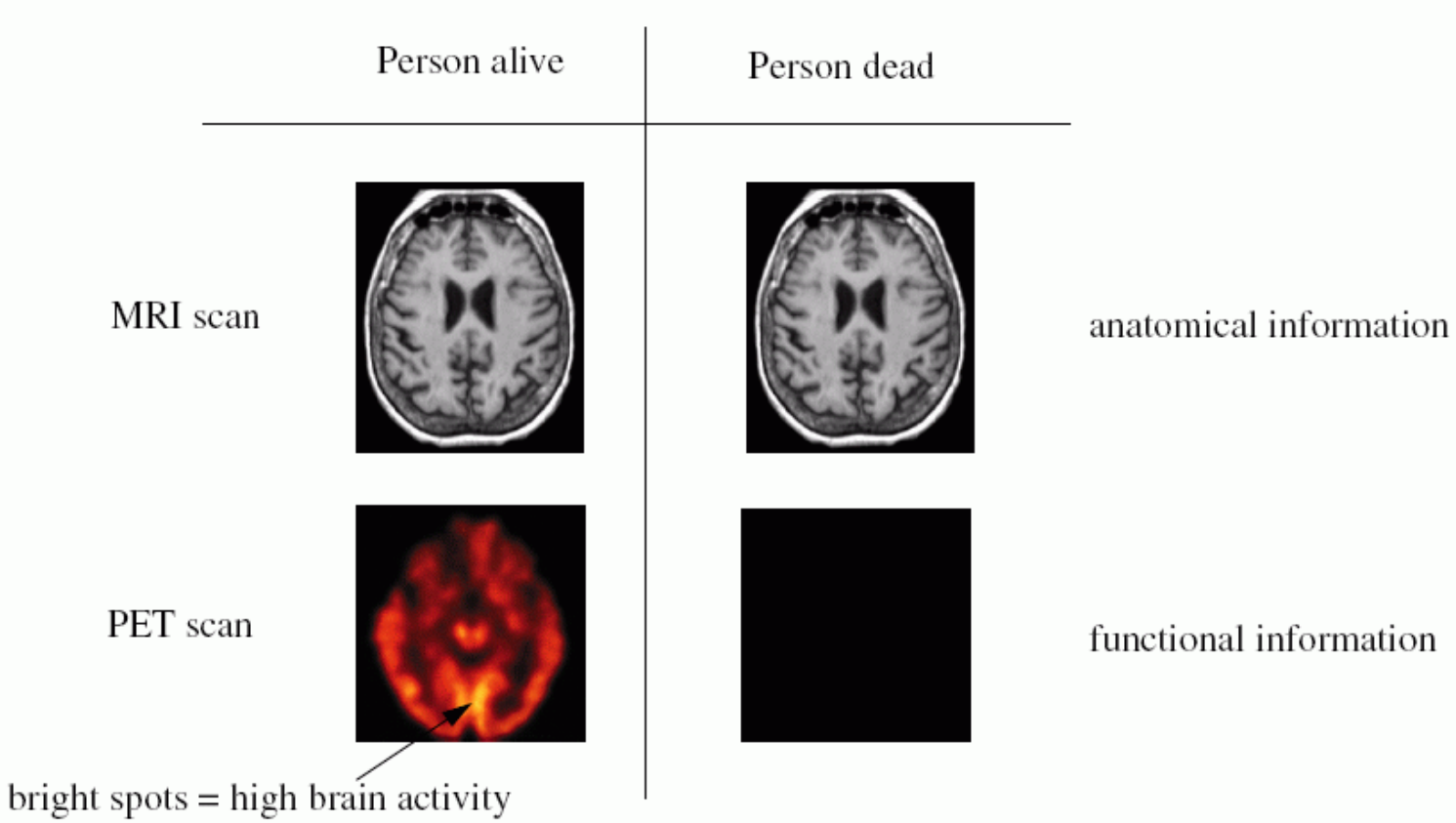


metabolic tracer X-ray emission

Ultrasound

sound waves

Anatomic vs Functional Imaging



An MRI scan shows you that you have a brain

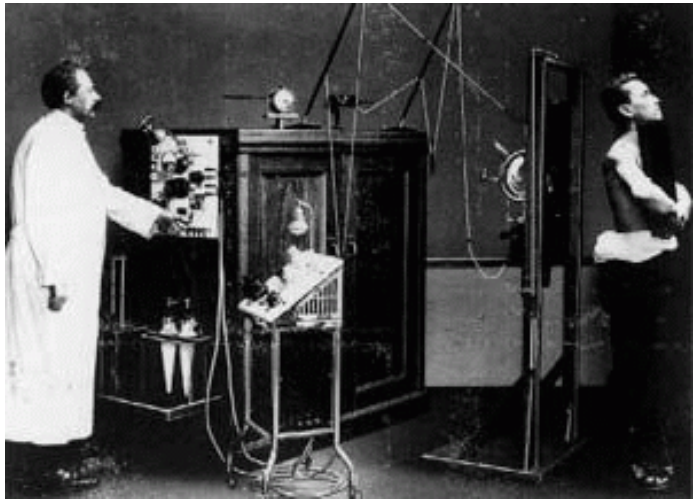
A PET scan shows that you use it

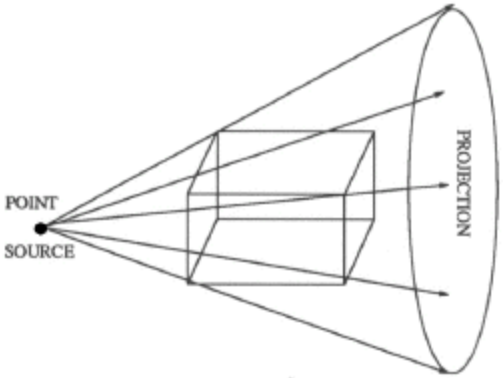
History: X-Rays

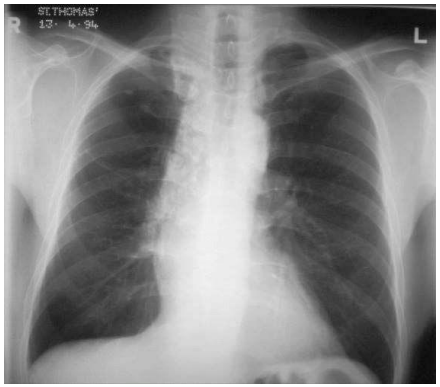
Wilhelm Conrad Röntgen

- 8 November 1895: discovers X-rays.
- 22 November 1895: X-rays Mrs. Röntgen's hand.
- 1901: receives first Nobel Prize in physics

An early X-ray imaging system:





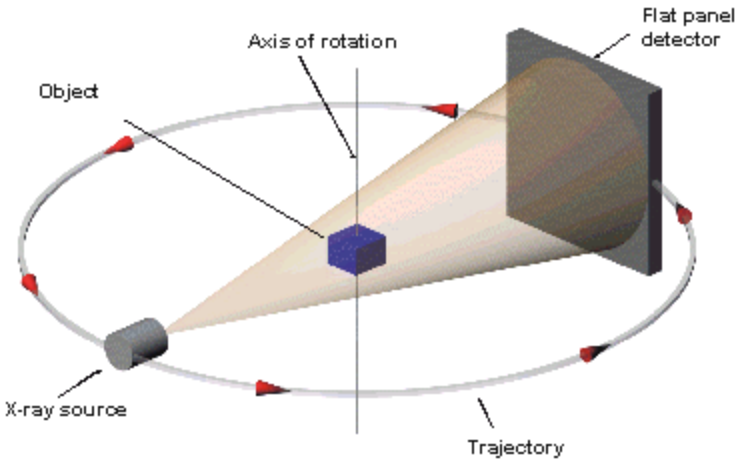


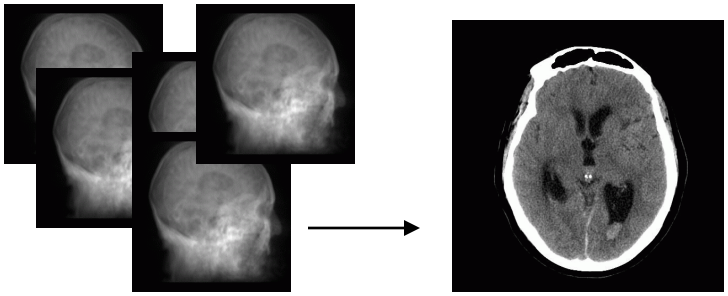
Note: so far all we can see is a projection across the patient:

History: Computed Tomography

The breakthrough:

- acquiring many projections around the object enables the reconstruction of the 3D object (or a cross-sectional 2D slice)

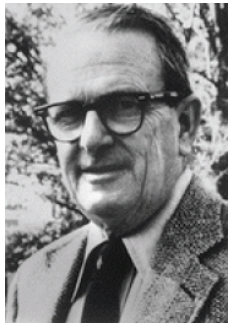




CT reconstruction pioneers:

- 1917: Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.
- 1963: Allan Cormack publishes mathematical analysis of tomographic image reconstruction, unaware of Radon's work.
- 1972: Godfrey Hounsfield develops first CT system, unaware of either Radon or Cormack's work, develops his own reconstruction method.
- 1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.

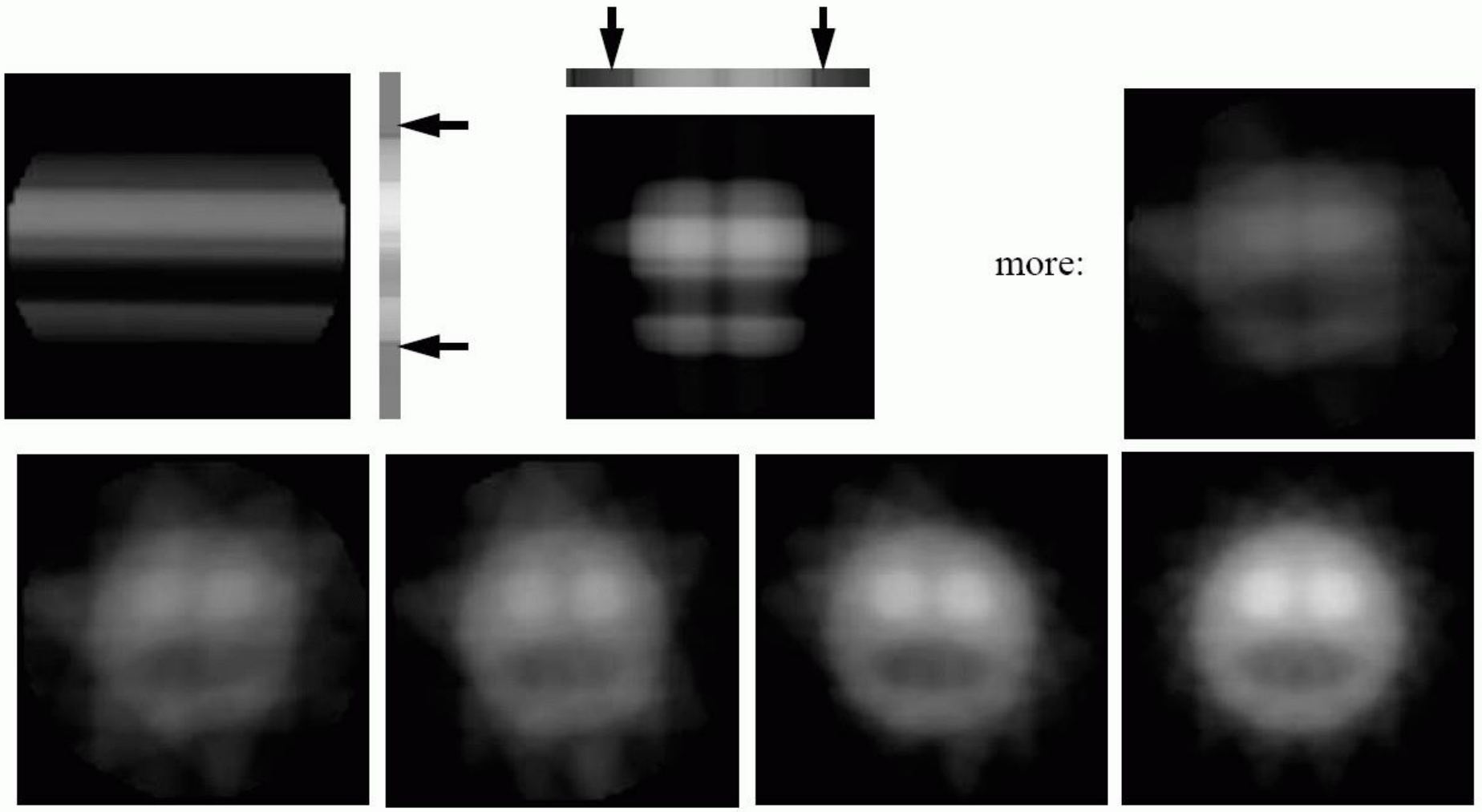
Radon



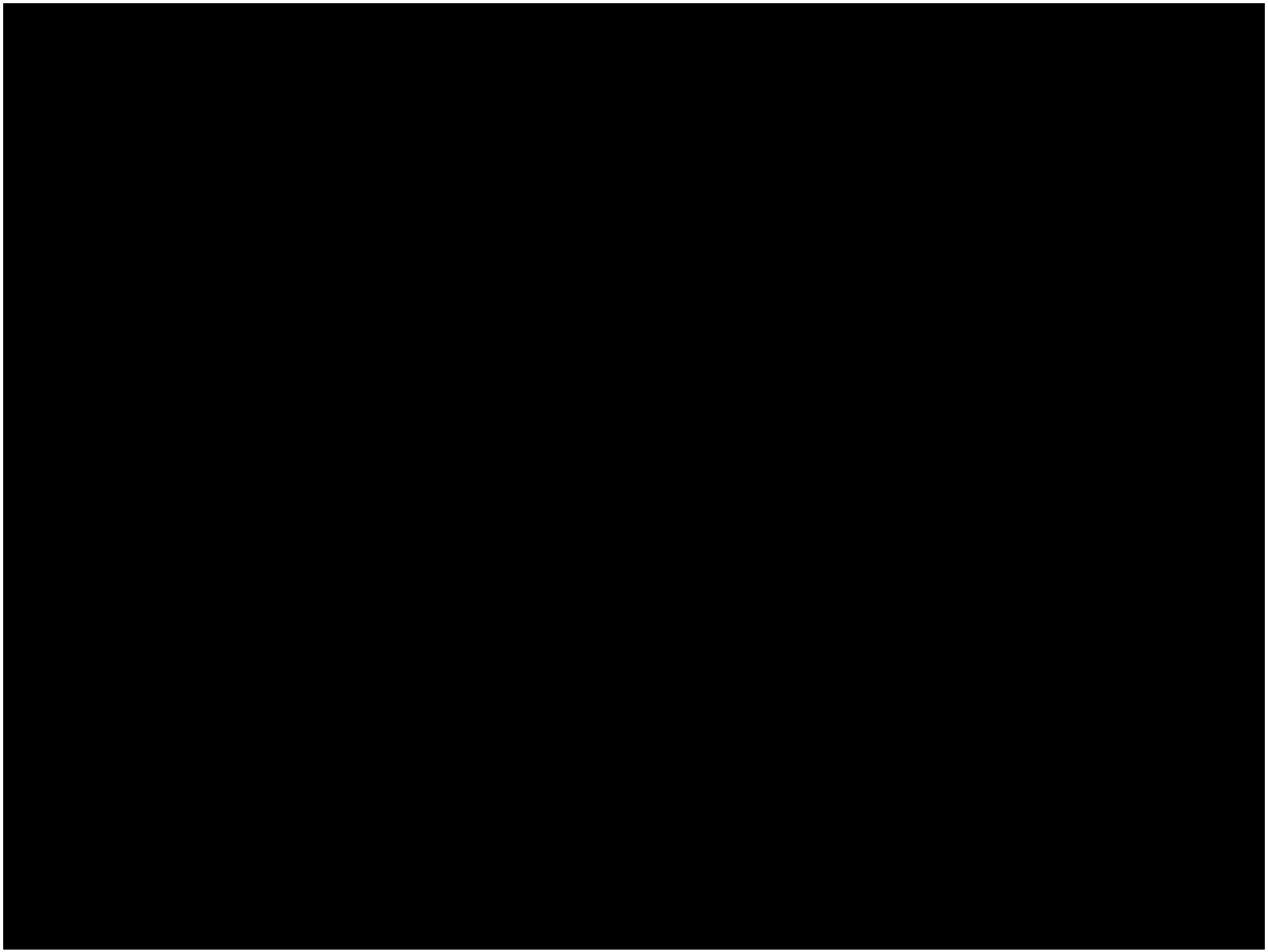
Cormack

Hounsfield

Computed Tomography: Concept



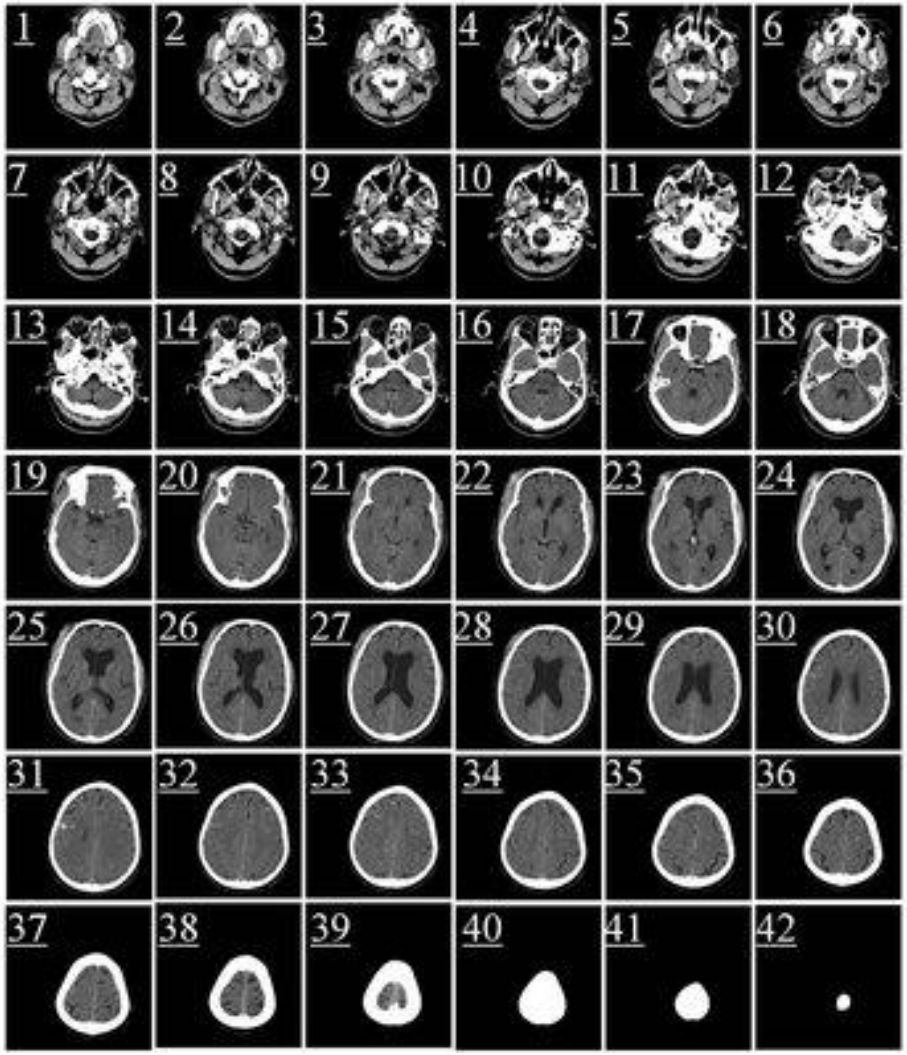
Slice Viewer

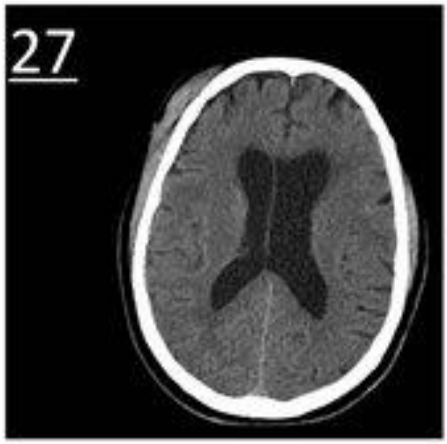


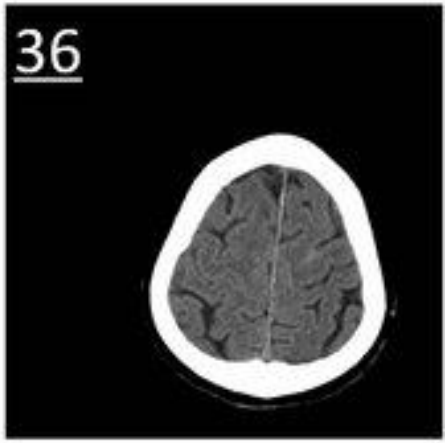
Reviewing Radiographs

Would 3D visualization help?

Slice Matrix







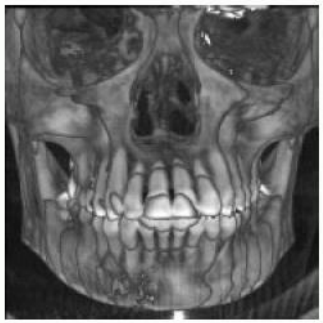
Would 3D visualization help?

3D Visualization via Volume Rendering

Reconstructed object enables:

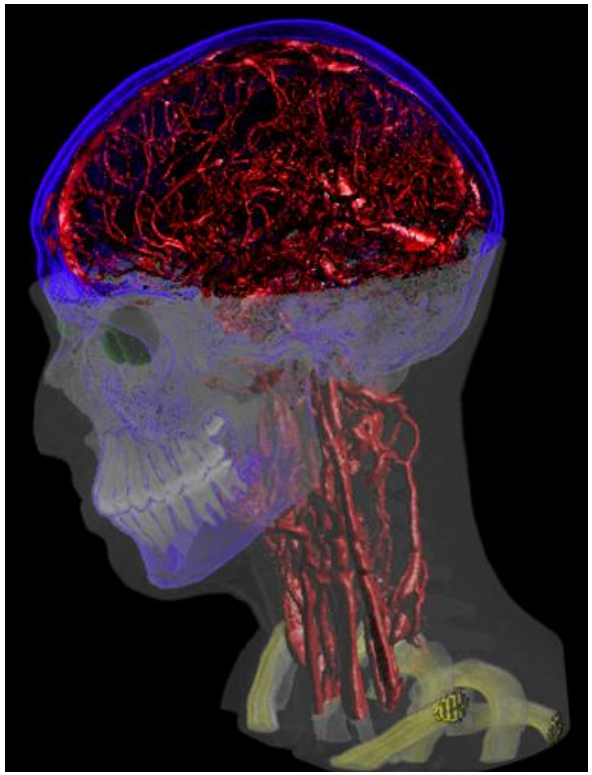
- Enhanced X-ray visualization from novel views:


- Maximum Intensity (MIP) visualization:

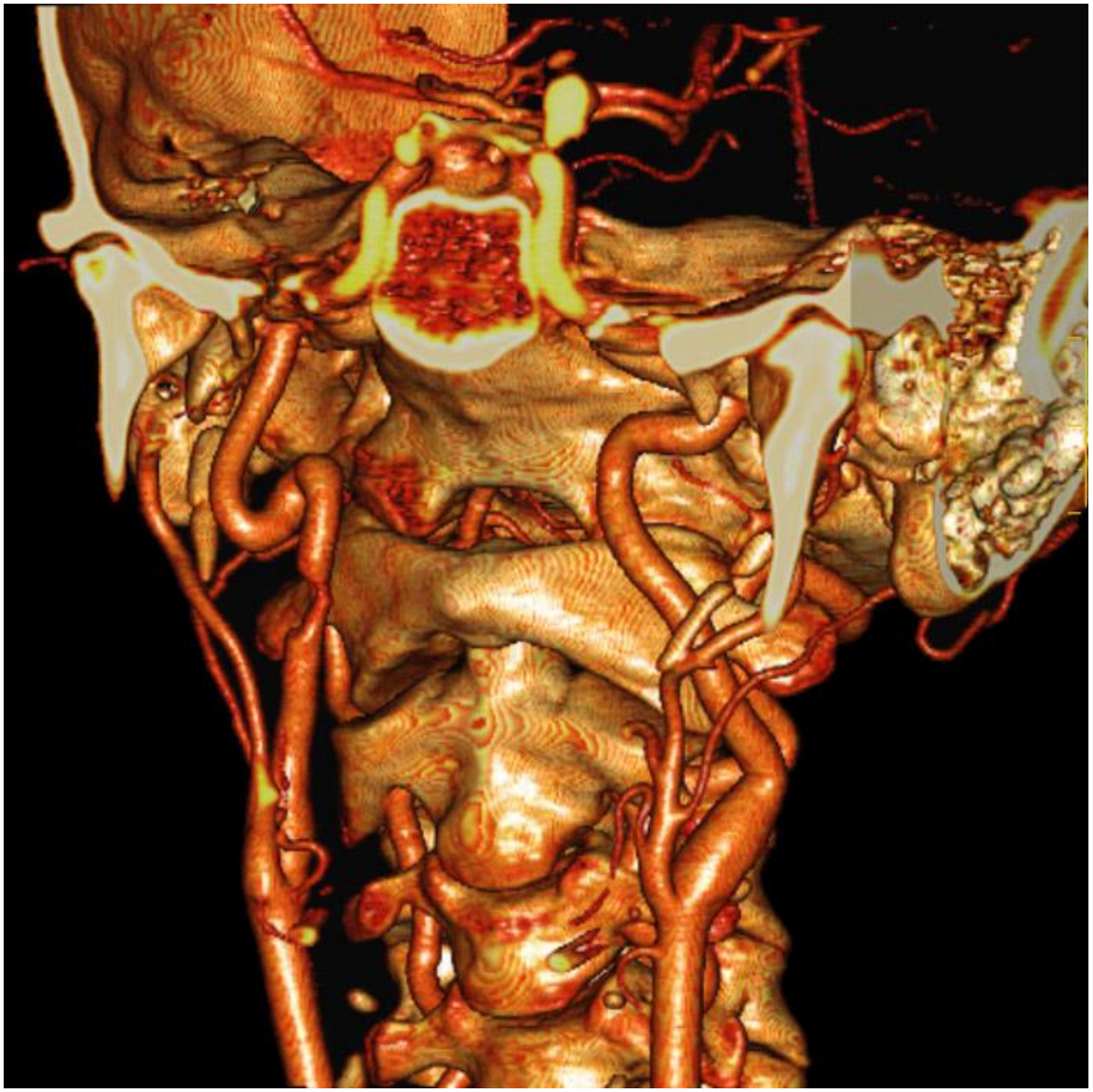

- Shaded object display:



Aortic Stent and Arterial Vessels

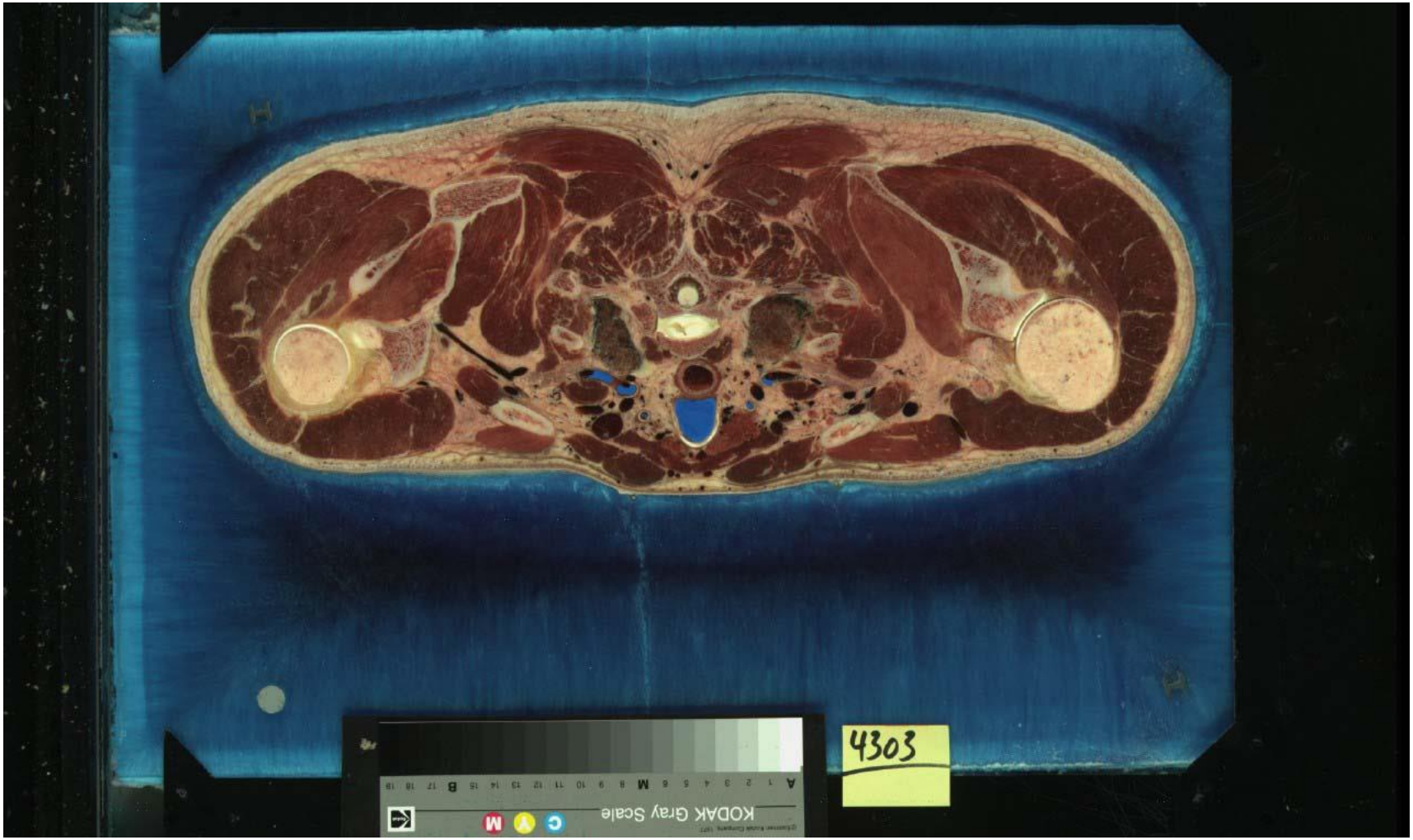
Cartotid Stenosis



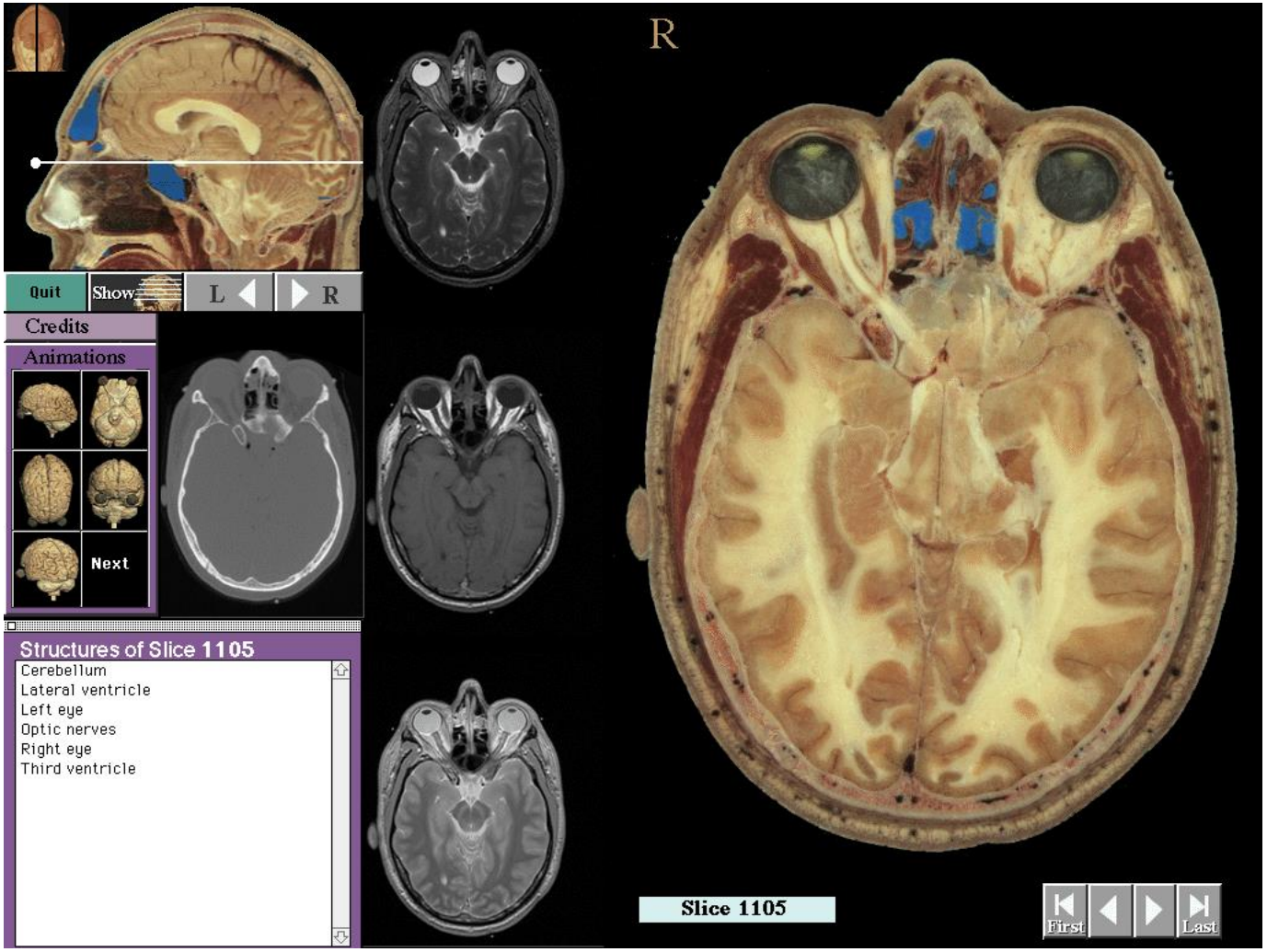
Virtual Colonoscopy

Virtual endoscopy, arthroscopy, etc.

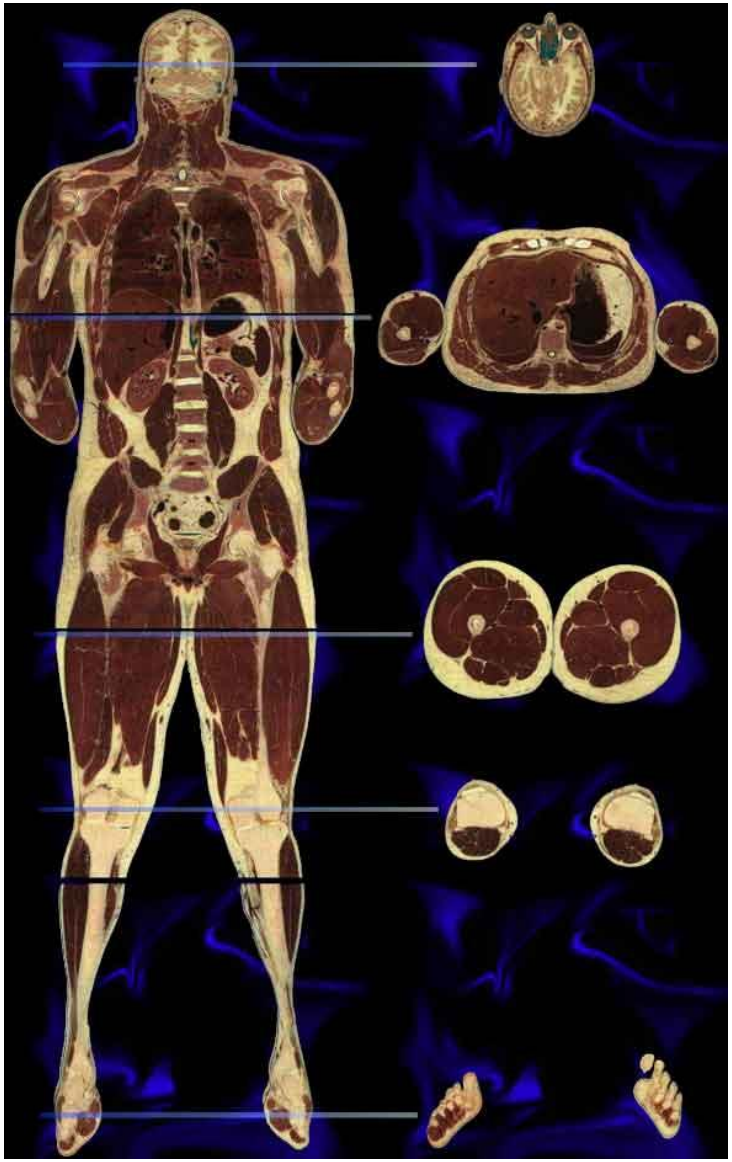
Dataset

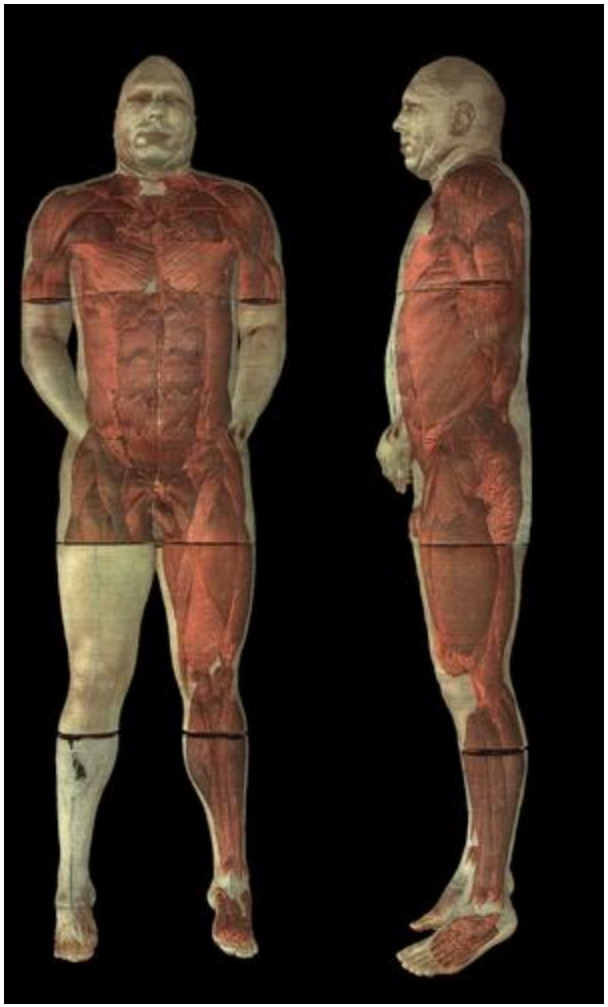


Renderings

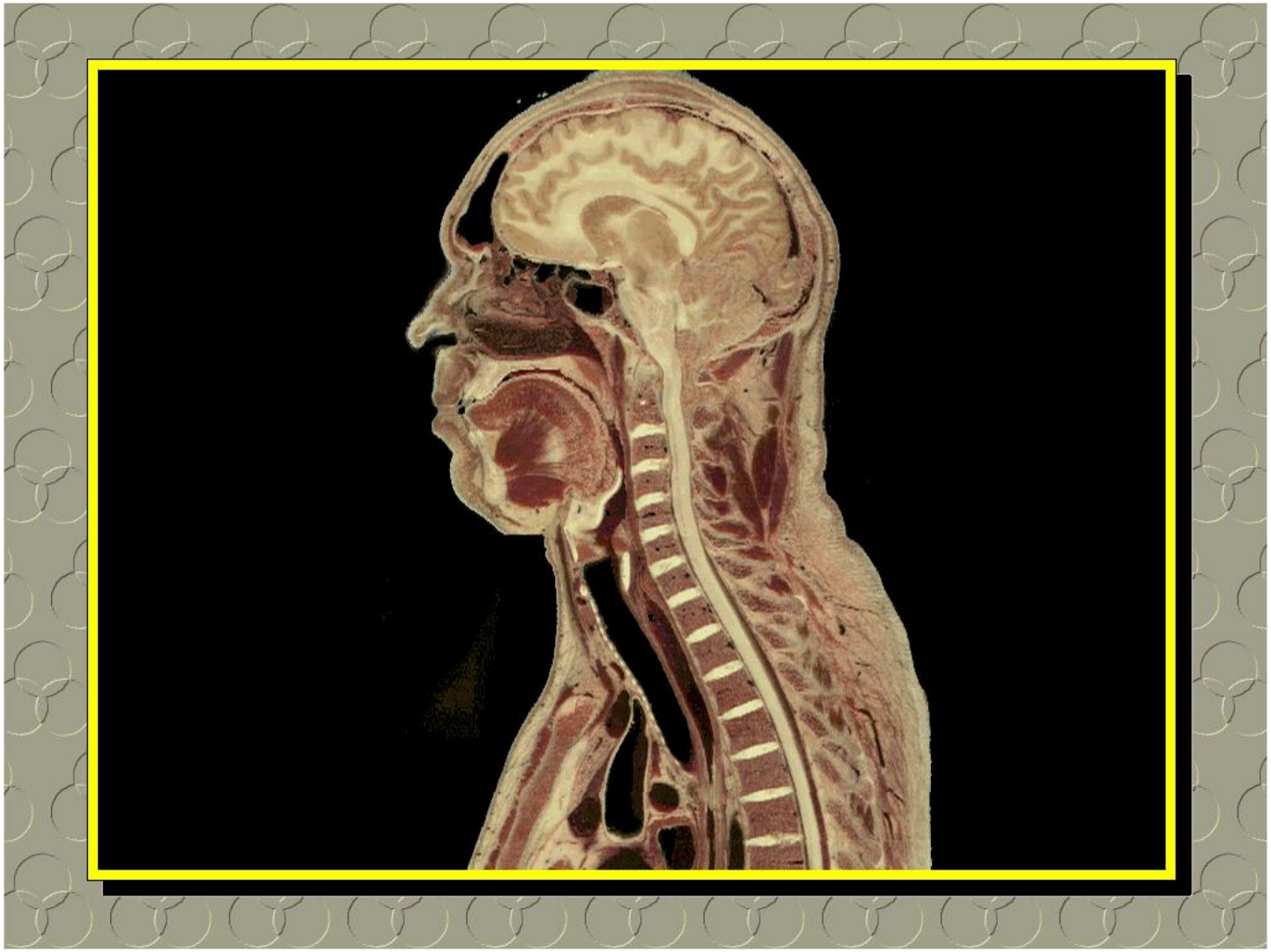

Quit
Show
L
R
Credits
Animations
Next
Structures of Slice 1105
Cerebellum
Lateral ventricle
Left eye
Optic nerves
Right eye
Third ventricle
R
Slice 1105
First
Last

Renderings





Renderings

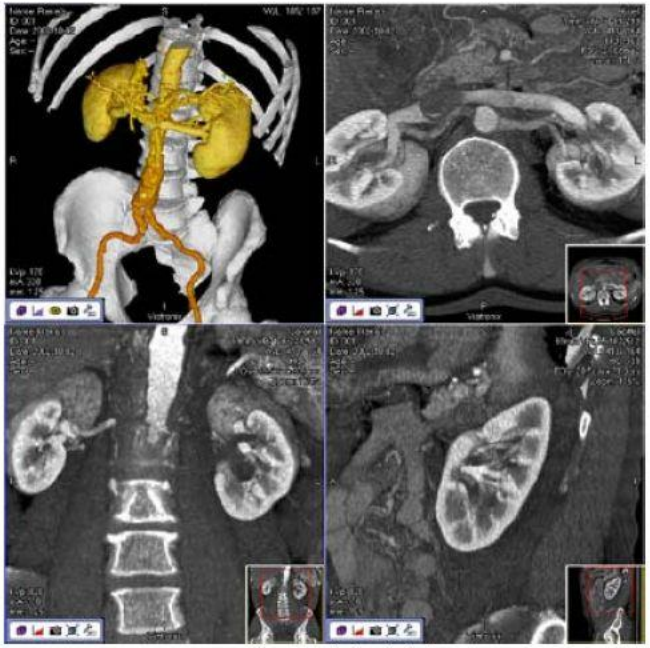


Renderings

- Data scanned with medical scanners (MRI, CT, PET, SPECT, etc.)

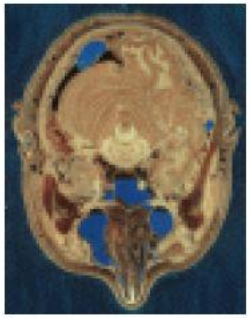
aortic aneurism

heart

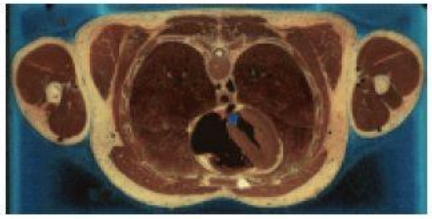


renals (with kidneys)

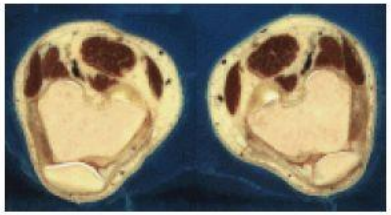
- Data photographed from histological slices (NIH-NLM *Visible Human*)



head

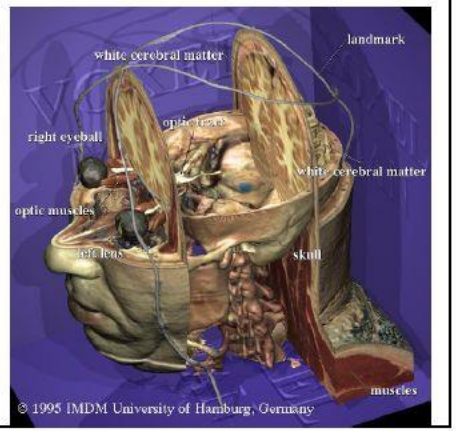


thorax

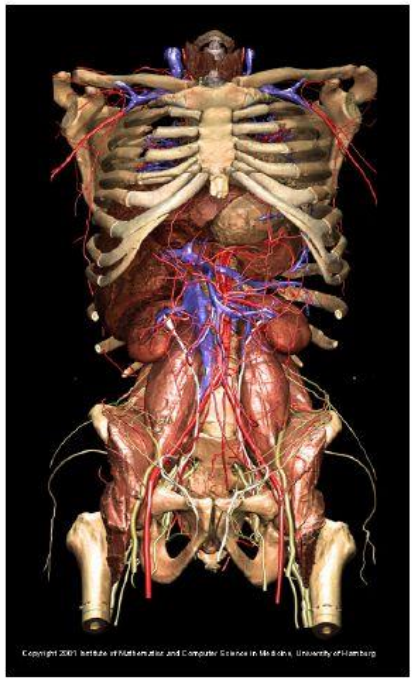


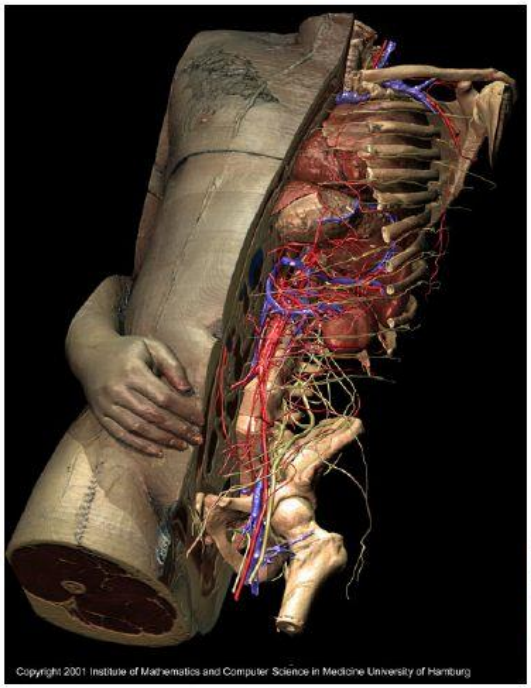
feet

atlas created from ~1700 1/3 mm slices

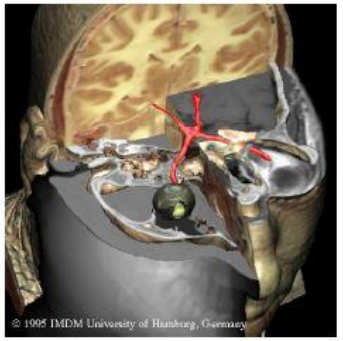


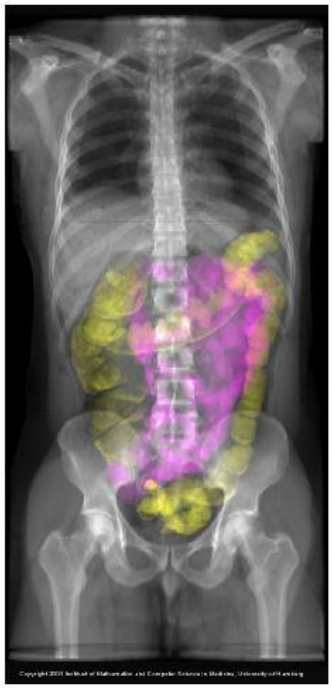
Renderings

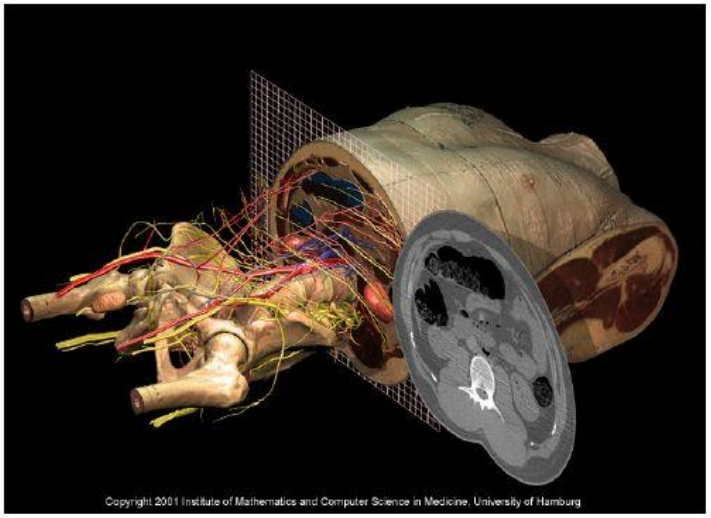

Copyright 2001 Institute of Mathematics and Computer Science in Medicine, University of Hamburg

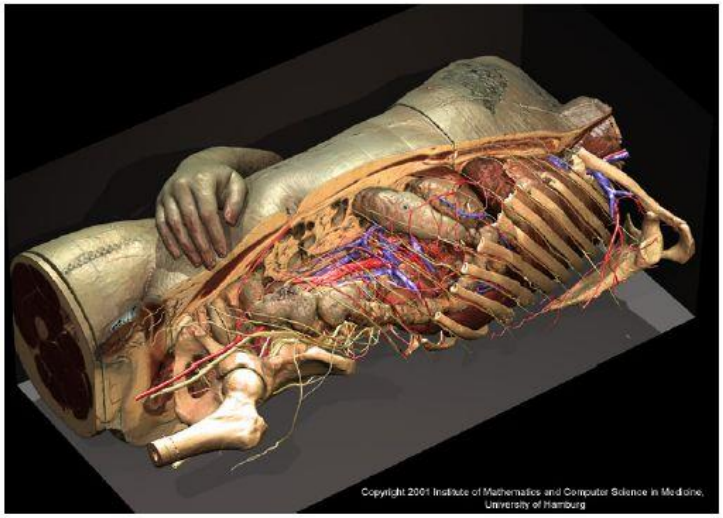

Copyright 2001 Institute of Mathematics and Computer Science in Medicine University of Hamburg


© 1995 IMDM University of Hamburg, Germany

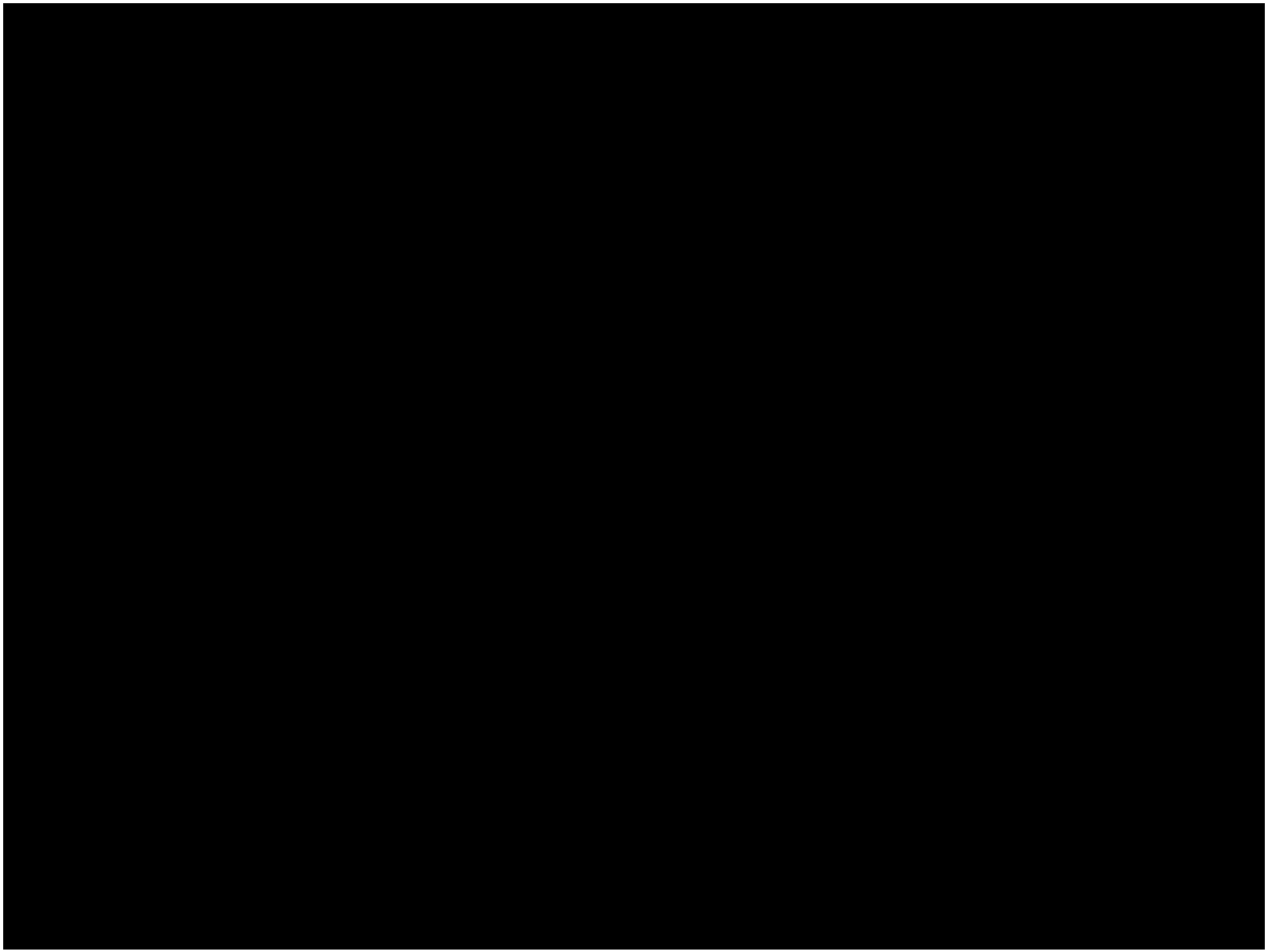

© 1995 IMDM University of Hamburg, Germany



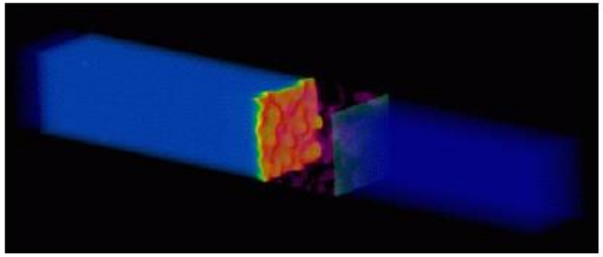

Copyright 2001 Institute of Mathematics and Computer Science in Medicine, University of Hamburg


Copyright 2001 Institute of Mathematics and Computer Science in Medicine, University of Hamburg

Comes Back to Life…

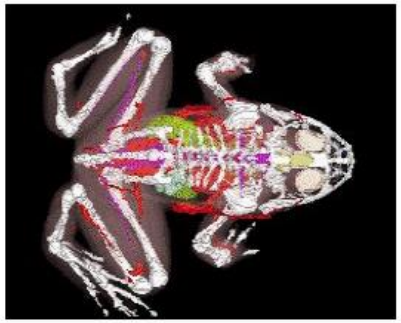


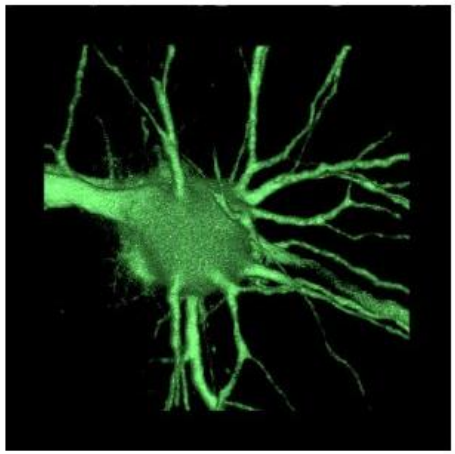
Scientific Visualization



shock wave

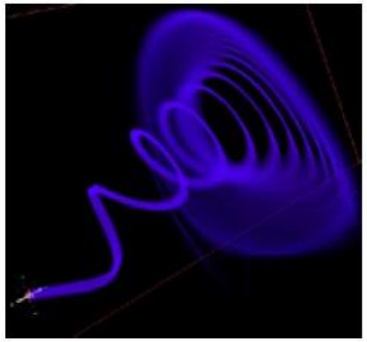
virtual frog

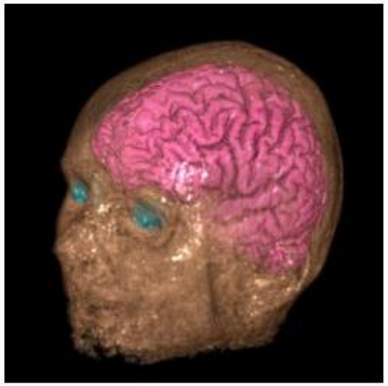




nerve cell

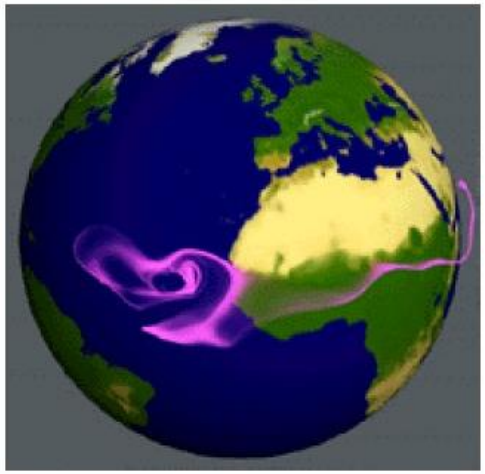
spiral flow





transparent MRI head

wind flow



MRI head

semi-transparent tomato

Simulations

Relativistic simulation of laser particle acceleration in an under-dense hydrogen plasma (800M particles)

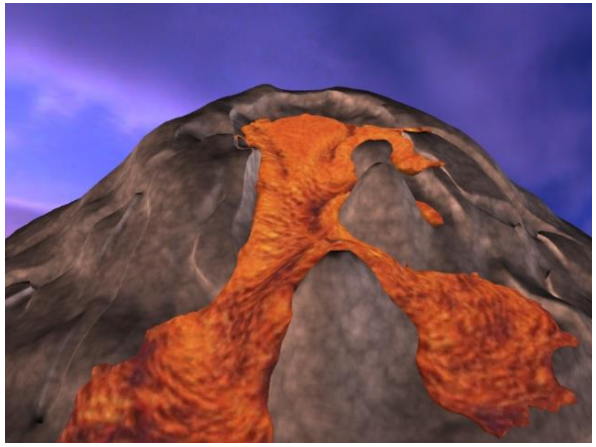
Fluid Dynamics Simulations

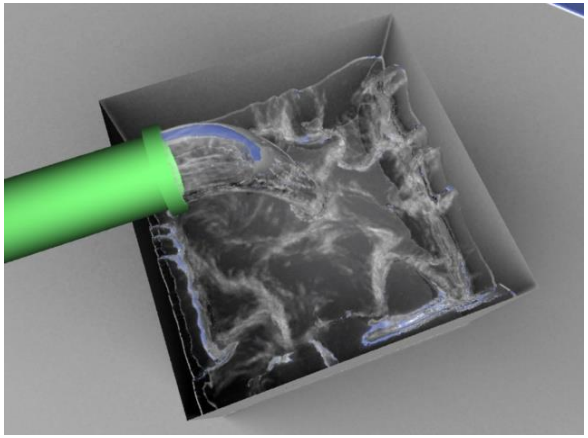
Navier-Stokes equations for viscous, incompressible liquids.

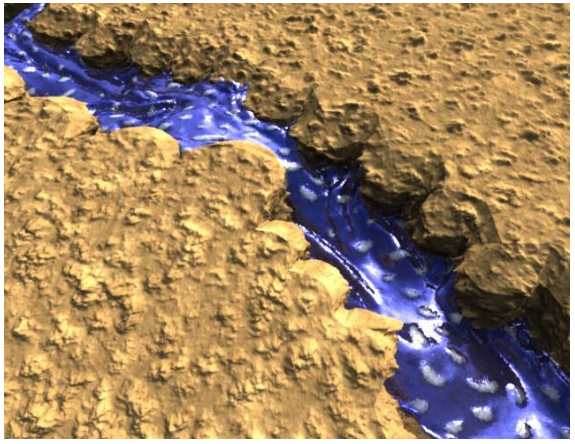
$$\nabla \cdot \mathbf{u} = 0$$ Conversation of mass

$$\mathbf{u}_t = -(\mathbf{u} \cdot \nabla)\mathbf{u} + \nu \nabla^2 \mathbf{u} - \frac{1}{\rho} \nabla p + \mathbf{f}$$

Advection Diffusion Pressure





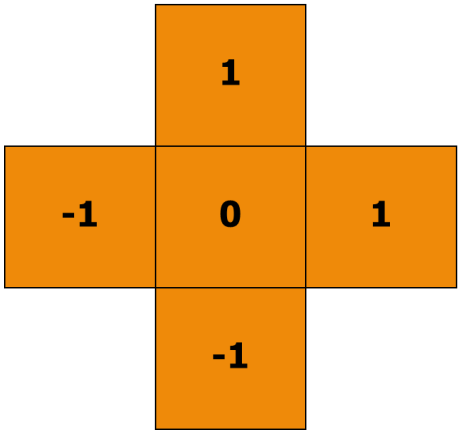


Navier-Stokes Solution

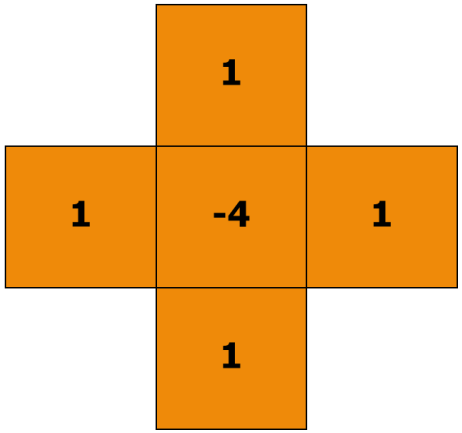
Via finite differencing

It all boils down to Ax=b.

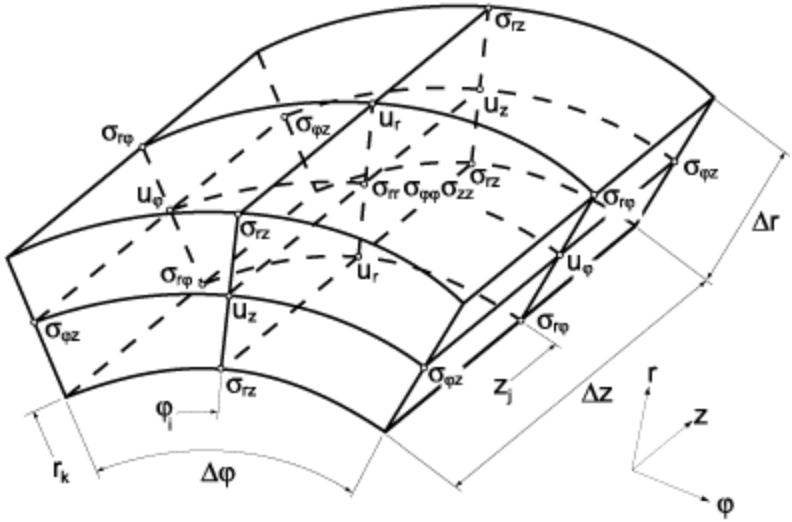
Divergence Operator



Laplacian Operator



$$\begin{bmatrix} ? & ? & \cdots & \cdots & ? \\ ? & ? & & & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & \vdots \\ ? & \cdots & \cdots & \cdots & ? \end{bmatrix}_{n^d x n^d} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ \vdots \\ x_{n^d} \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ \vdots \\ x_{n^d} \end{bmatrix}$$



Visualize via Volume Rendering