CSE 564
Visualization & Visual Analytics

Medical & Scientific Visualization

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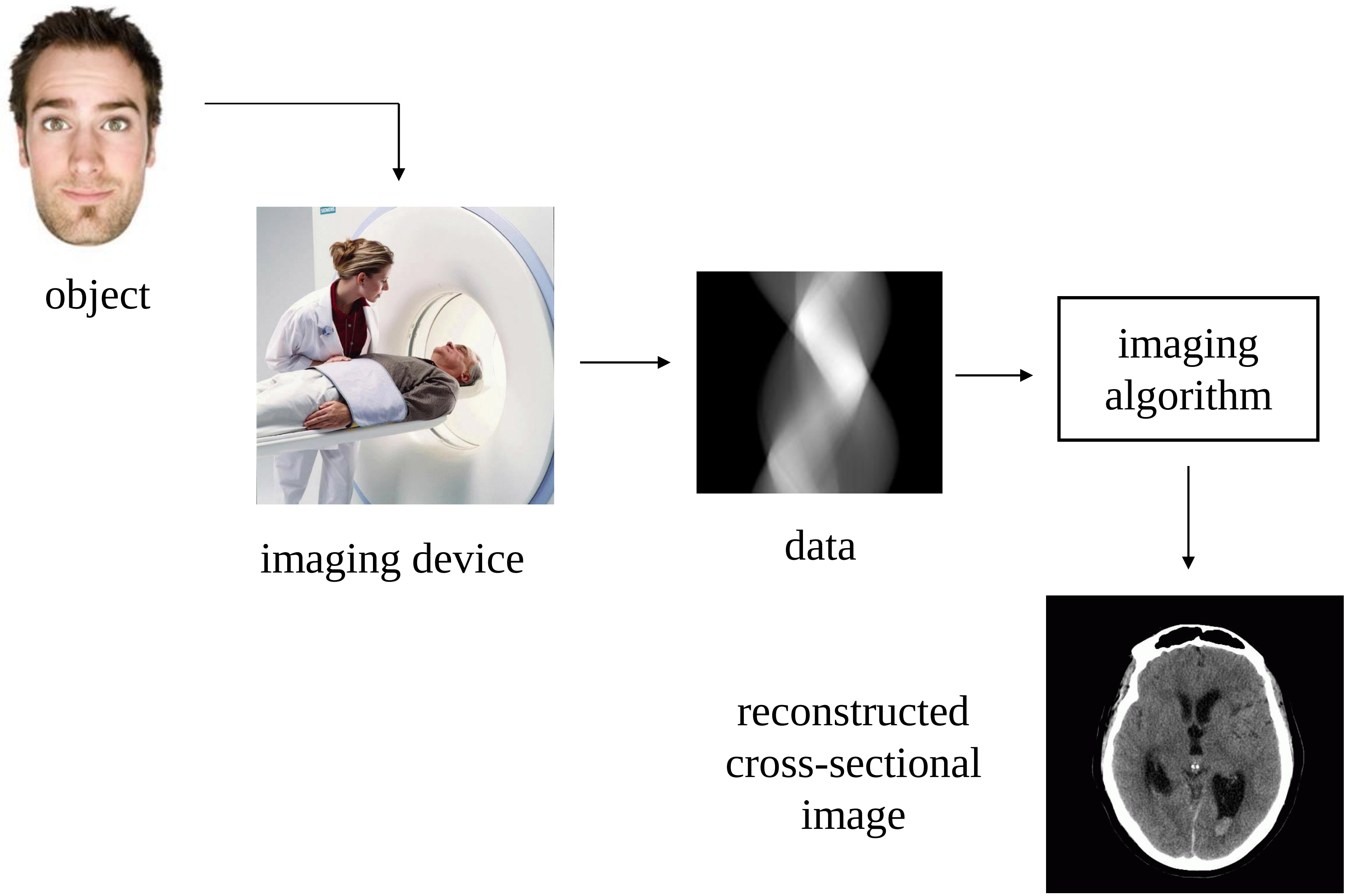
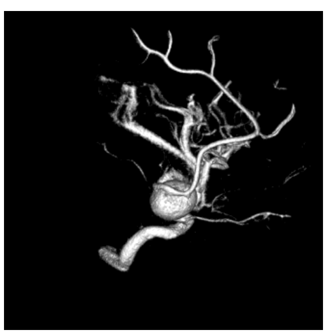
Lecture	Topic	Projects
1	Intro, schedule, and logistics	
2	Applications of visual analytics, basic tasks, data types	
3	Introduction to D3, basic vis techniques for non-spatial data	
4	Data assimilation and preparation	Project #1 out
5	Data assimilation and preparation	
6	Bias in visualization	
7	Data reduction and dimension reduction	
8	Visual perception	Project #2(a) out
9	Visual cognition	
10	Visual design and aesthetics	
11	Cluster analysis: numerical data	
12	Cluster analysis: categorical data	Project #2(b) out
13	High-dimensional data visualization	
14	Dimensionality reduction and embedding methods	
15	Principles of interaction	
16	Midterm #1	
17	Visual analytics	Final project proposal call out
18	The visual sense making process	
19	Maps	
20	Visualization of hierarchies	Final project proposal due
21	Visualization of time-varying and time-series data	
22	Foundations of scientific and medical visualization	
23	Volume rendering	Project 3 out
24	Scientific and medical visualization	Final Project preliminary report due
25	Visual analytics system design and evaluation	
26	Memorable visualization and embellishments	
27	Infographics design	
28	Midterm #2	

Medical Imaging: Overall Concept



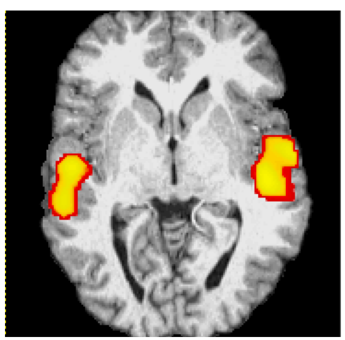
Imaging Modalities Overview

CT



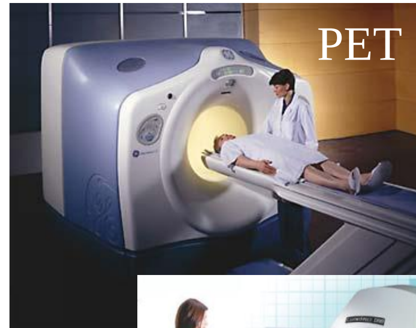
X-ray

MRI / fMRI



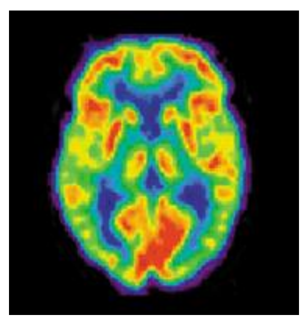
magnetic spin

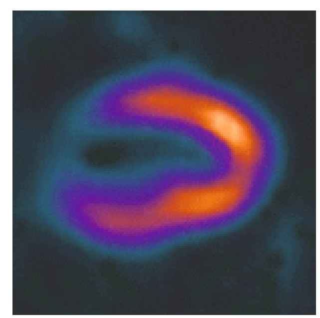
Nuclear



PET

SPECT



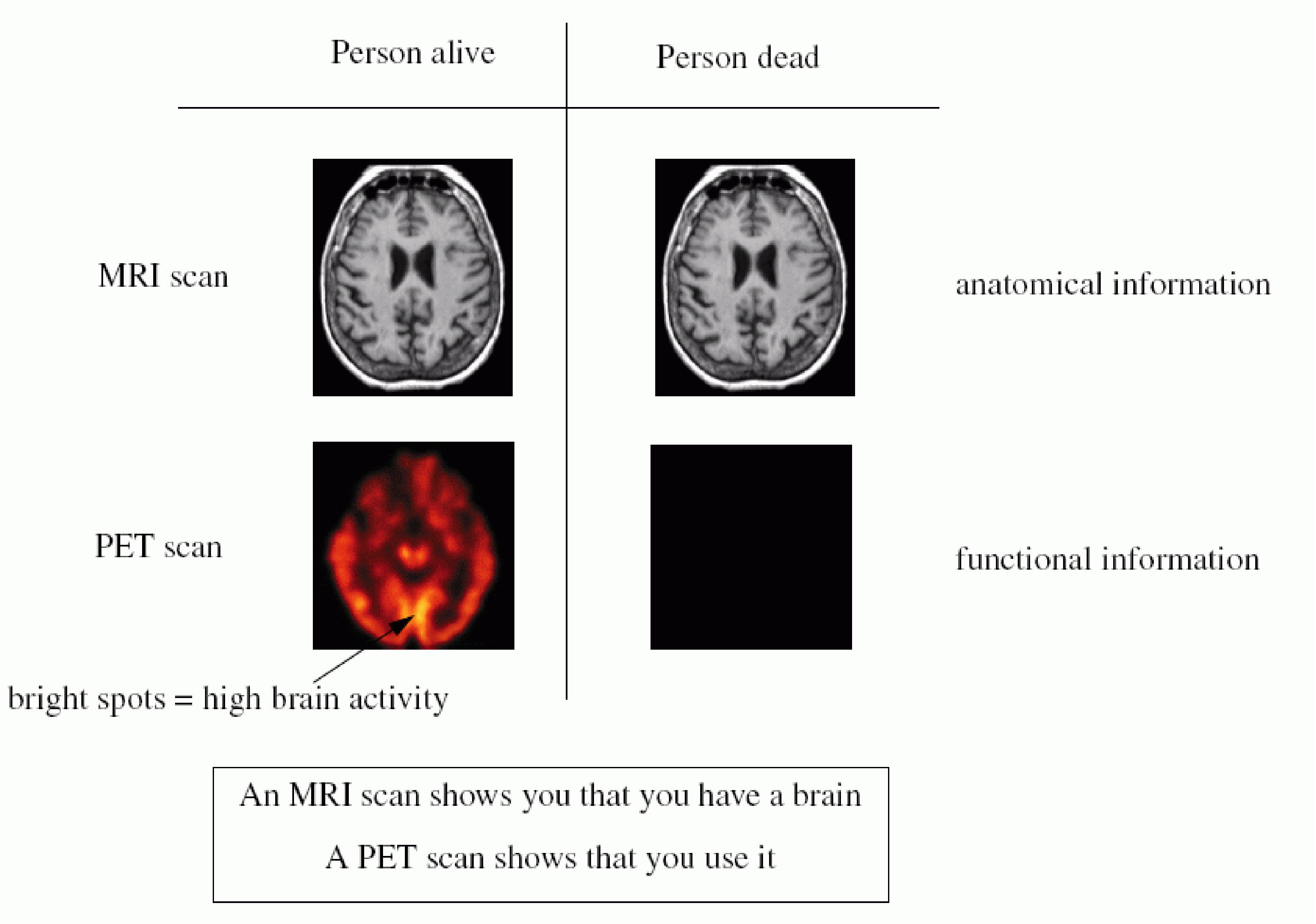


metabolic tracer X-ray emission

Ultrasound

sound waves

Anatomic vs Functional Imaging

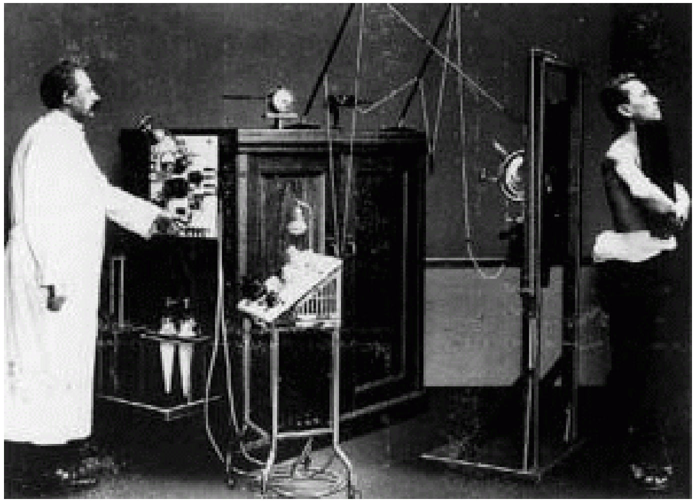


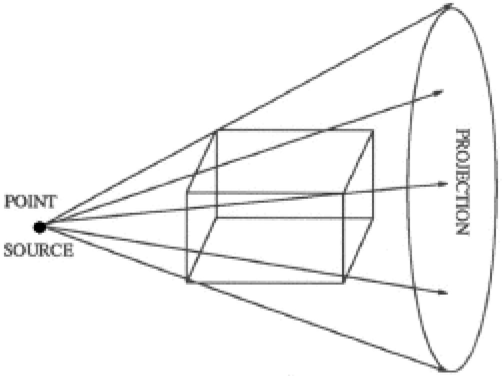
History: X-Rays

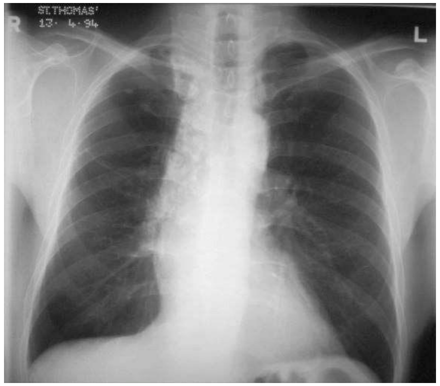
Wilhelm Conrad Röntgen

- 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:





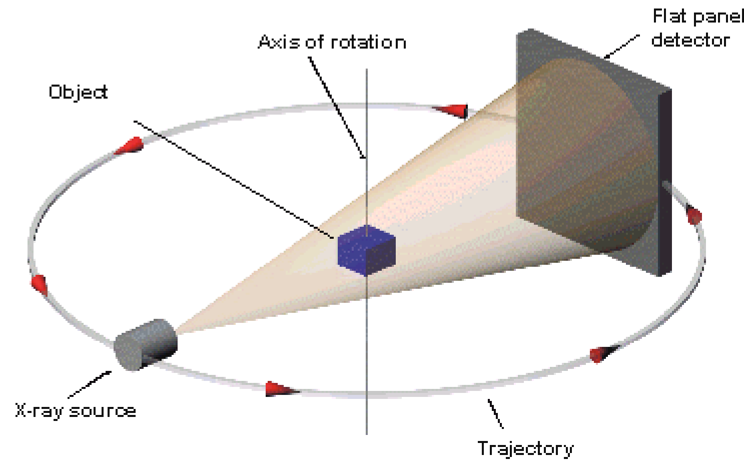


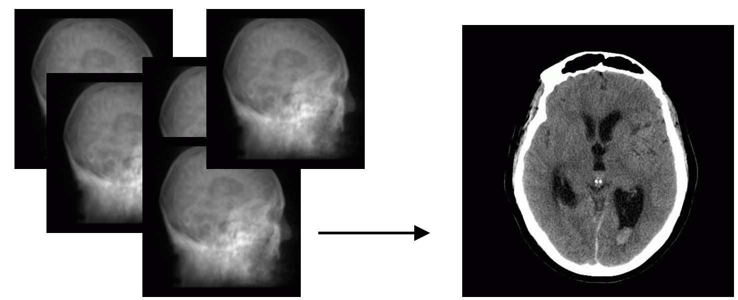
Note: so far all we can see is a projection across the patient:

History: Computed Tomography

The breakthrough:

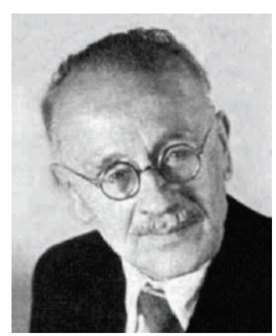
- acquiring many projections around the object enables the reconstruction of the 3D object (or a cross-sectional 2D slice)



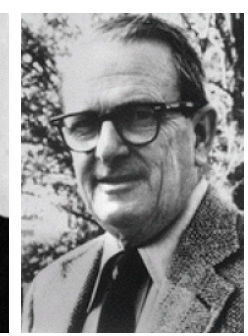


CT reconstruction pioneers:

- 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.



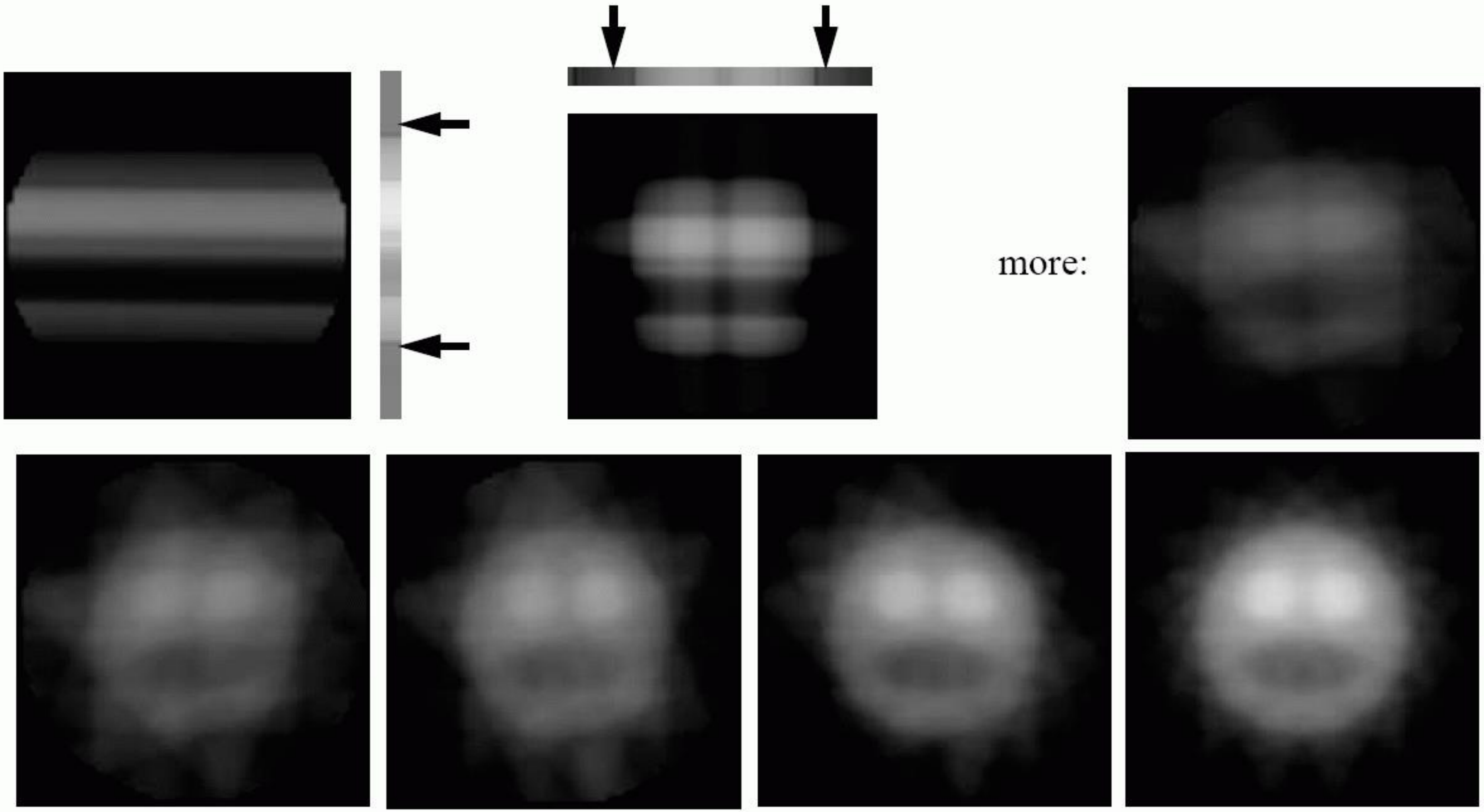
Radon



Cormack

Hounsfield

Computed Tomography: Concept

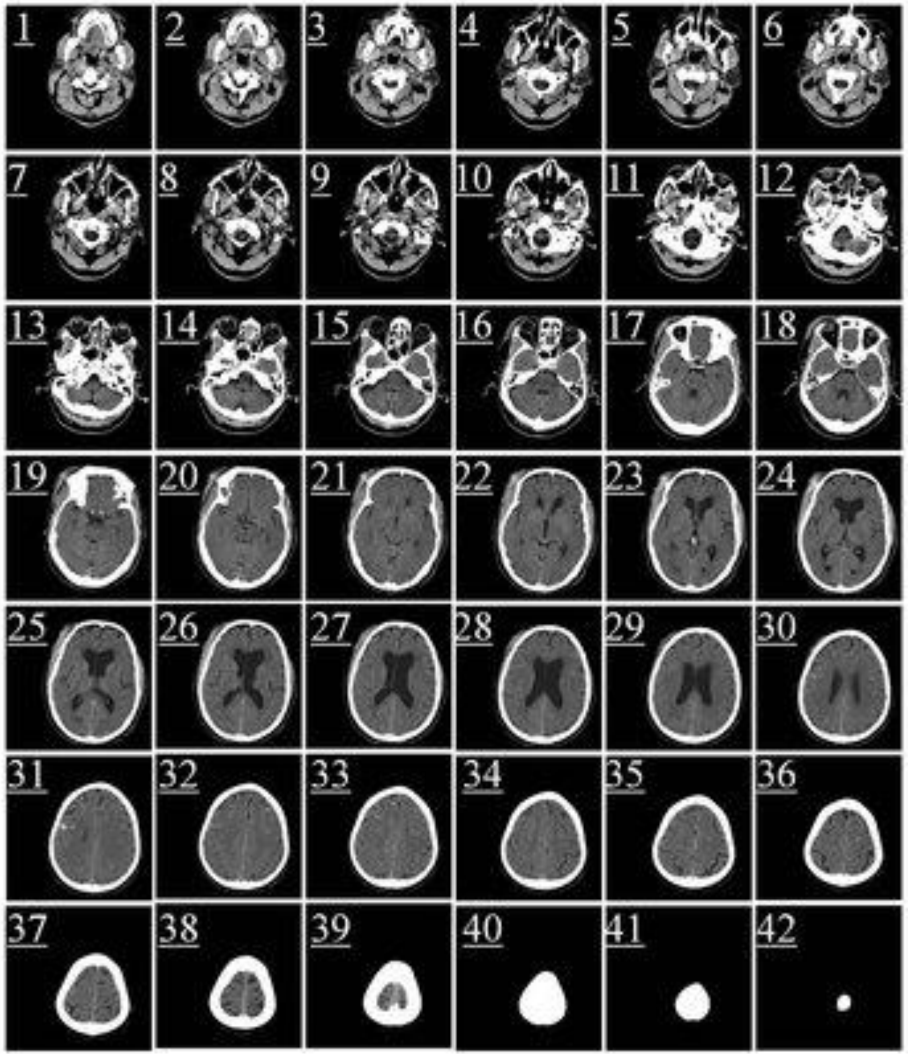


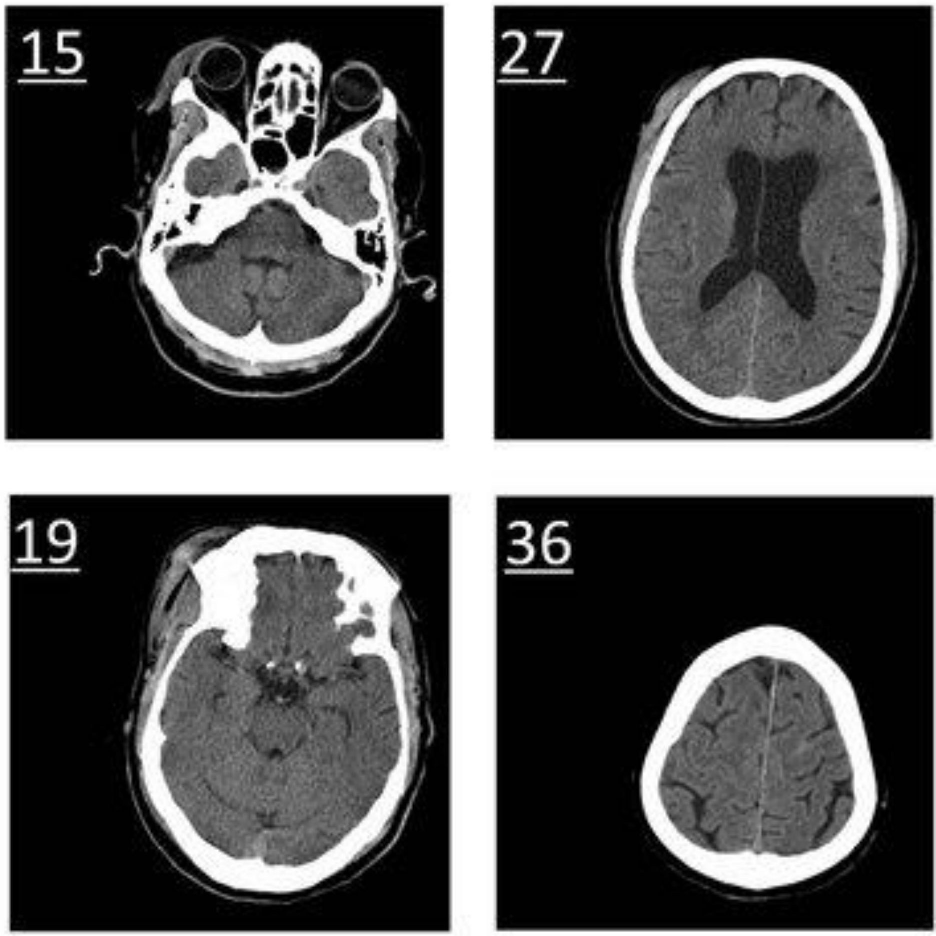
Slice Viewer

Reviewing Radiographs

Would 3D visualization help?

Slice Matrix





Would 3D visualization help?

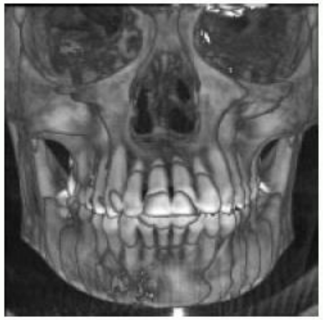
VR?

3D Visualization via Volume Rendering

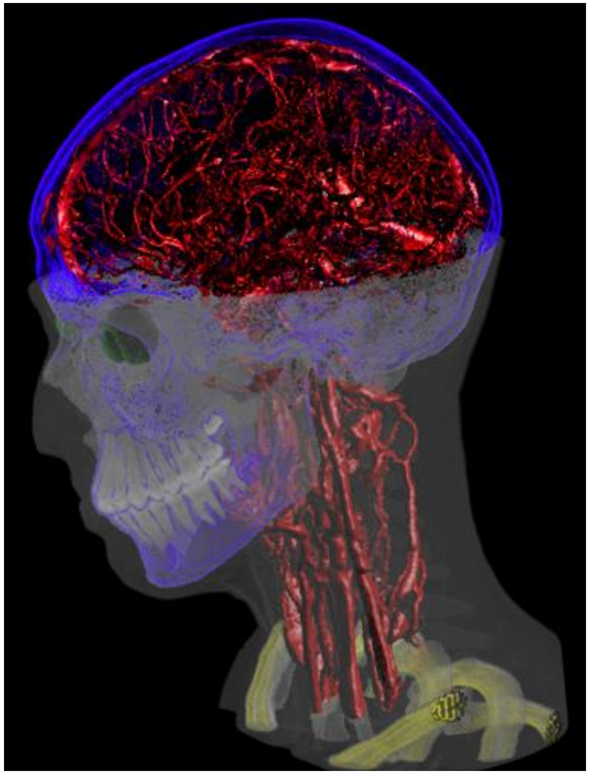
Reconstructed object enables:

- Enhanced X-ray visualization from novel views:


- Maximum Intensity (MIP) visualization:

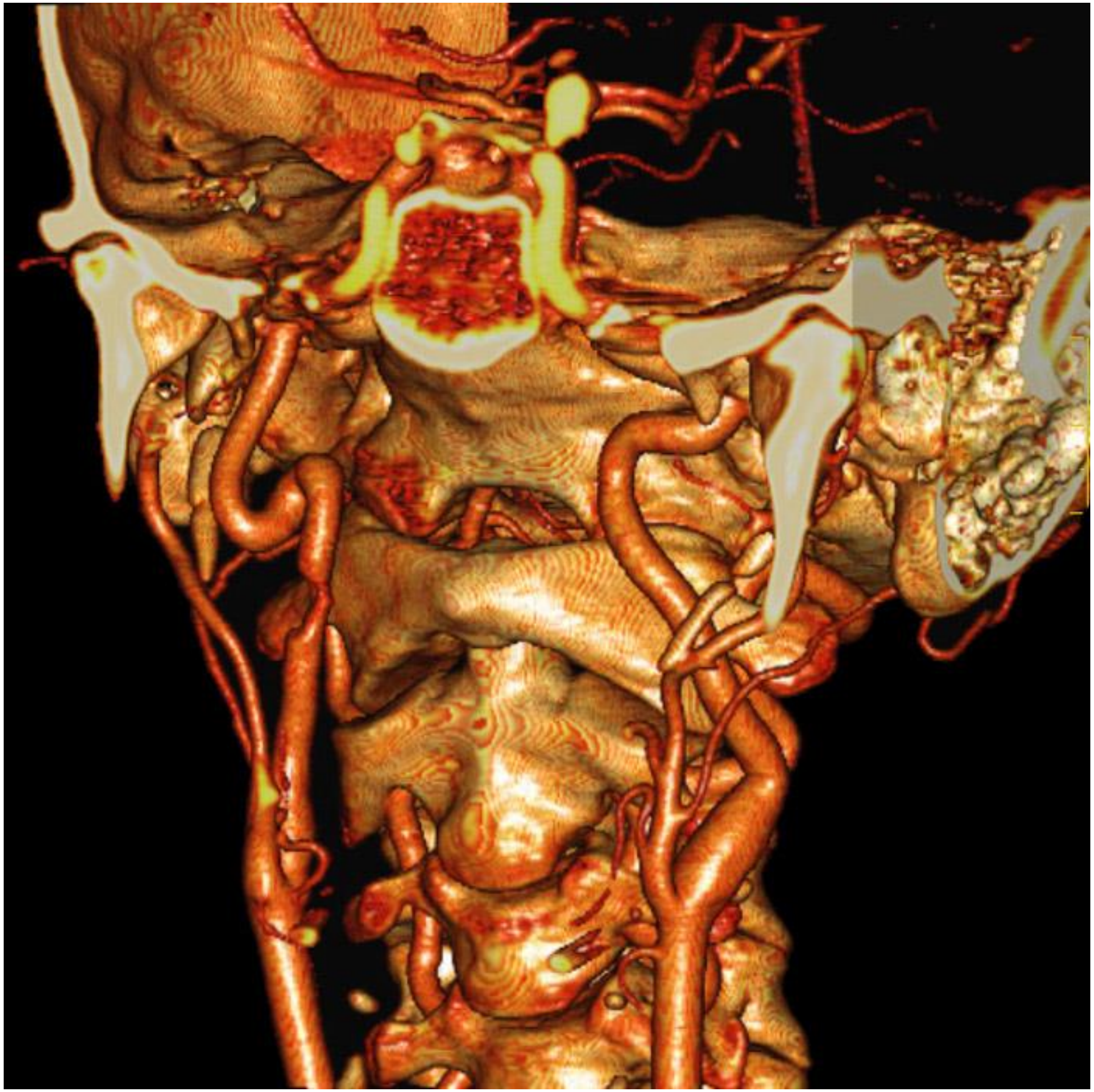




- Shaded object display:




Aortic Stent and Arterial Vessels

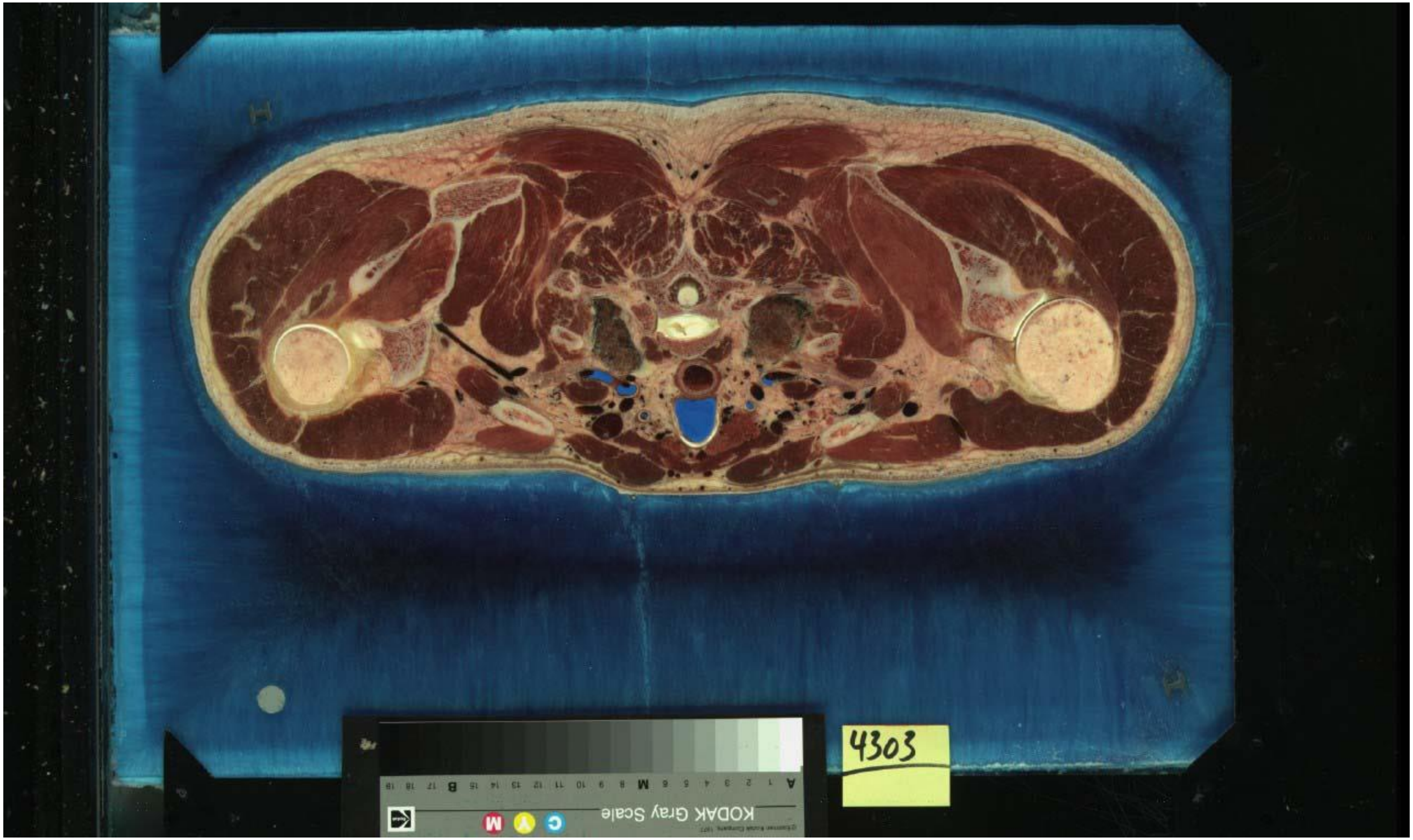
Cartotid Stenosis



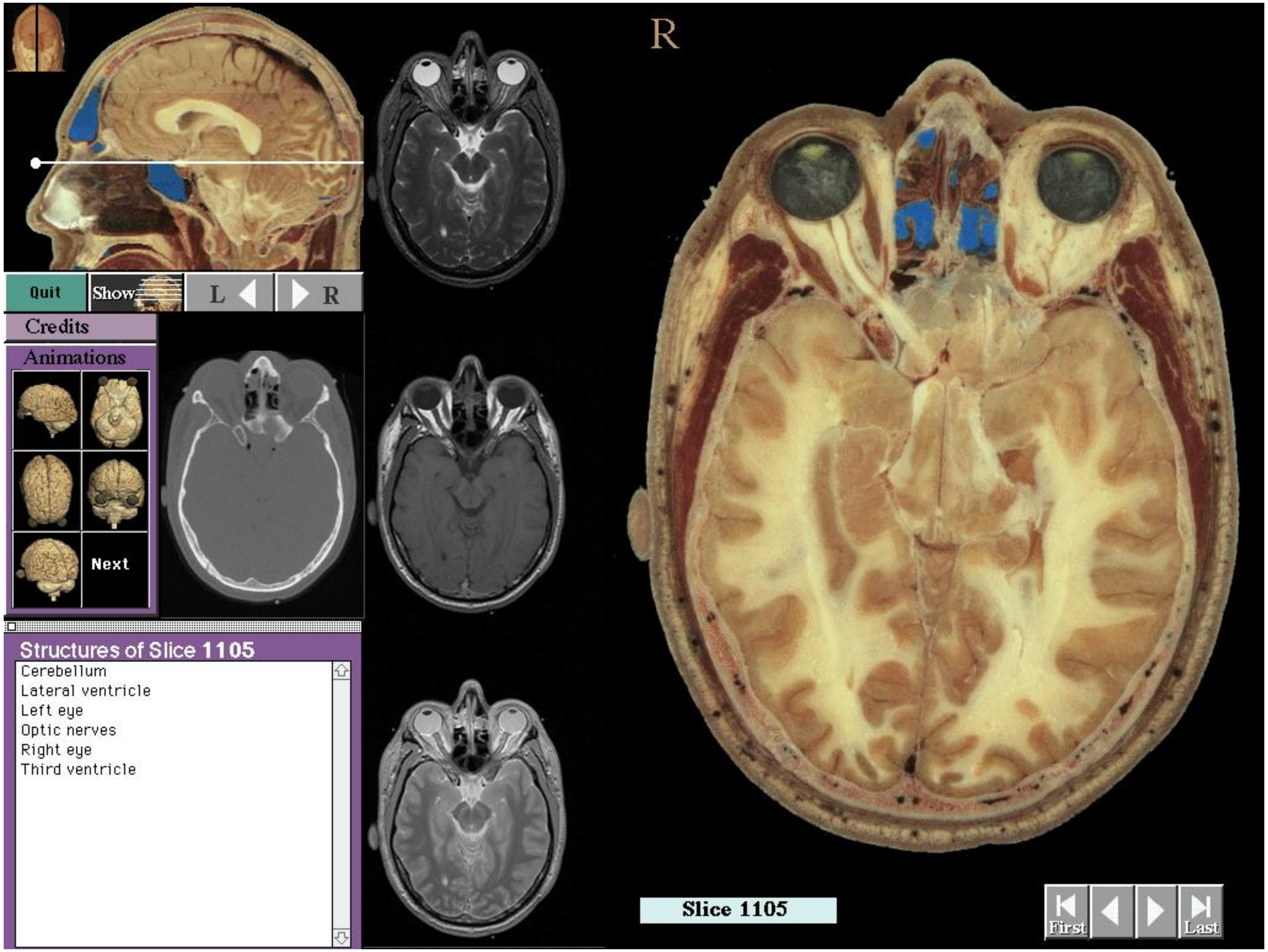
Virtual Colonoscopy

Virtual endoscopy, arthroscopy, etc.

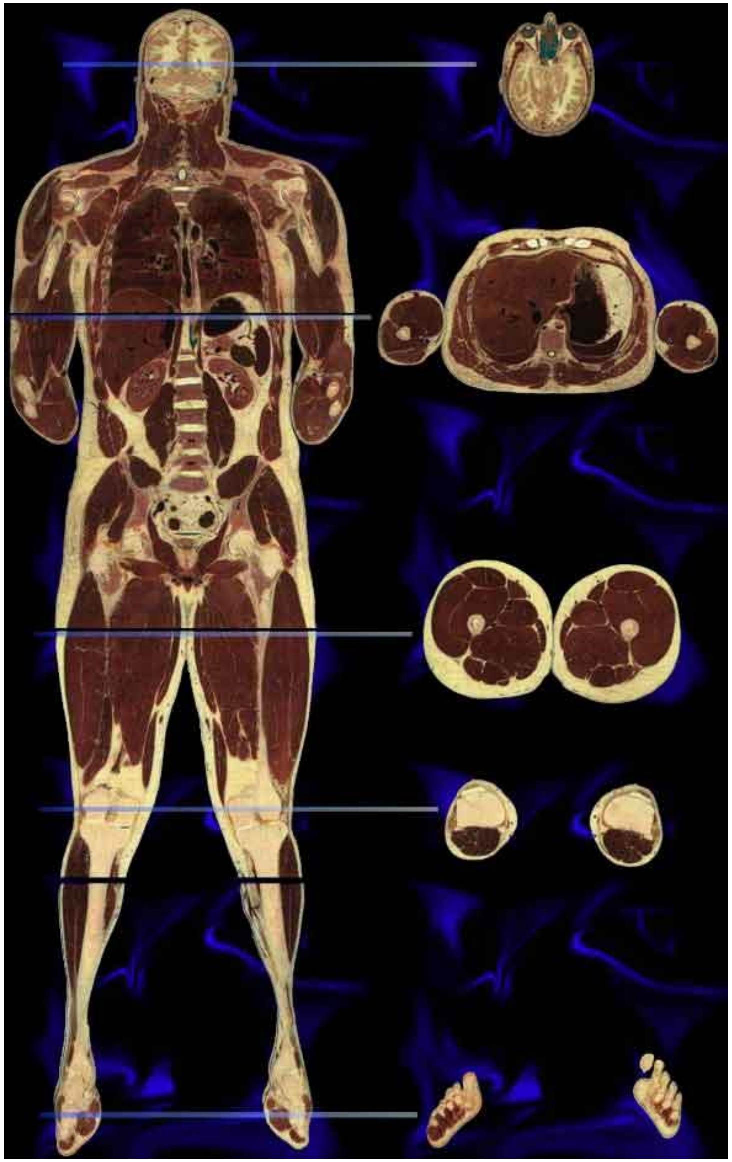
Dataset

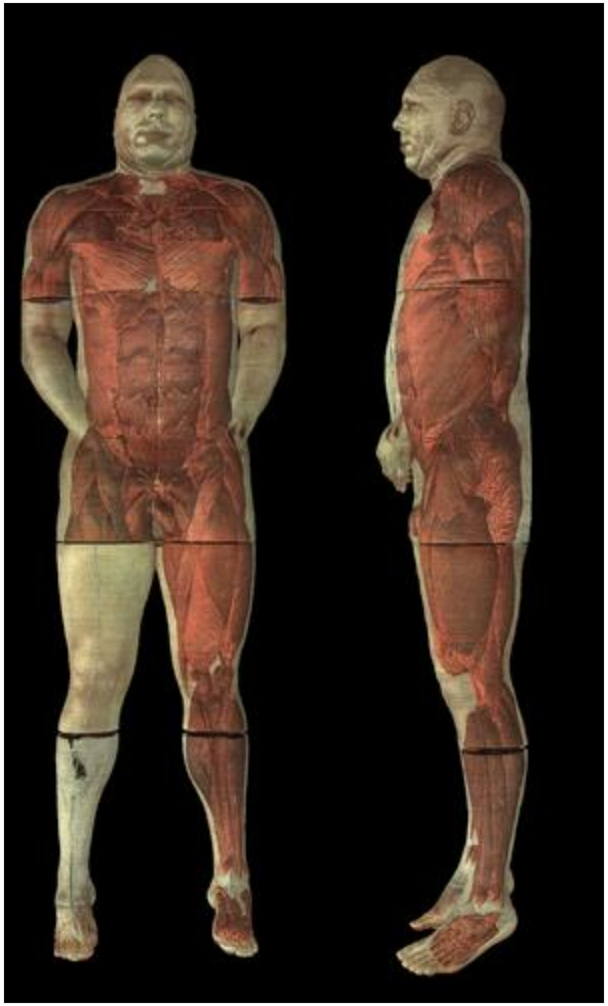


Renderings

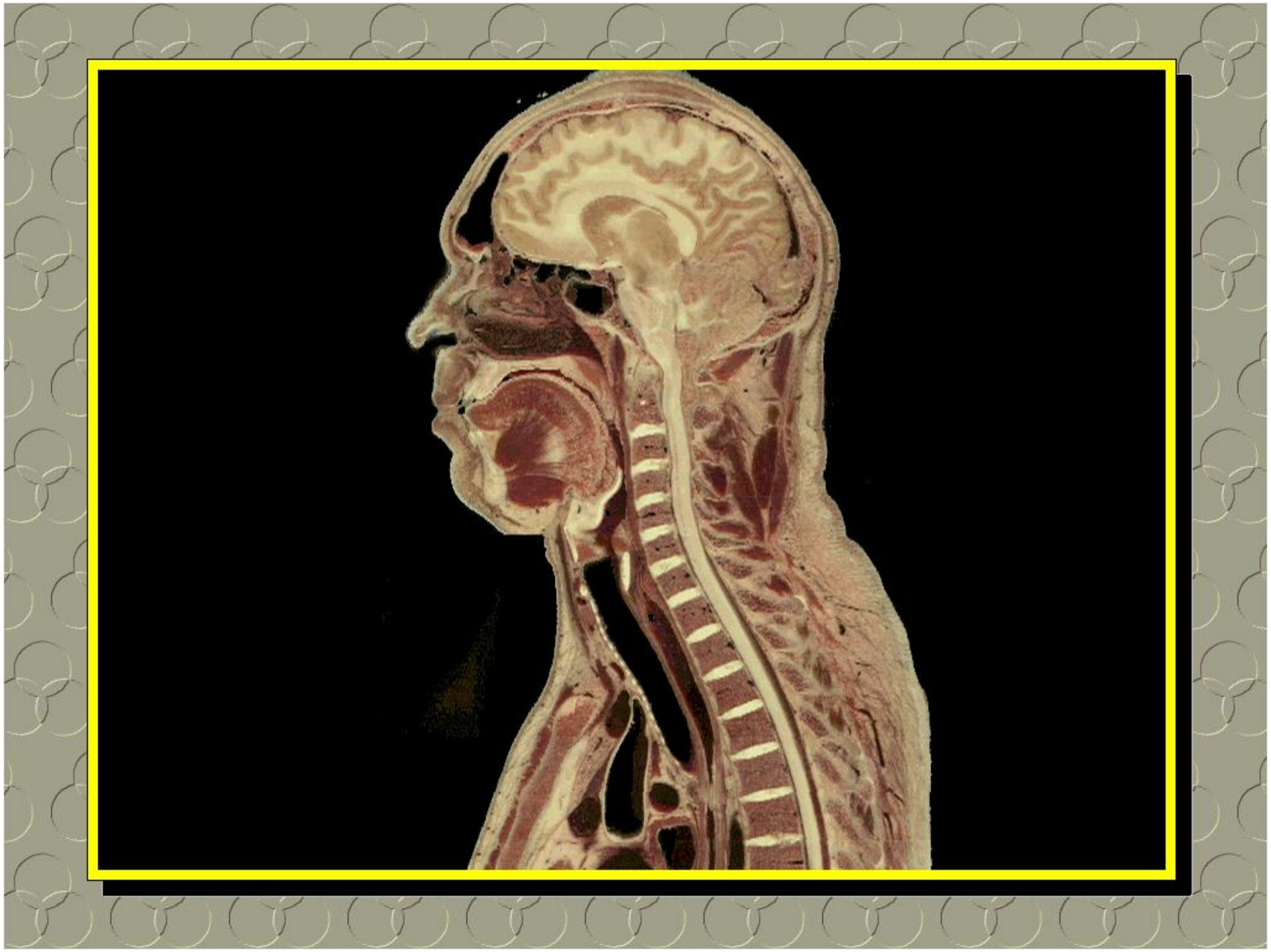

R
Quit
Show
L
R
Credits
Animations
Next
Structures of Slice 1105
Cerebellum
Lateral ventricle
Left eye
Optic nerves
Right eye
Third ventricle
Slice 1105
First
Last

Renderings



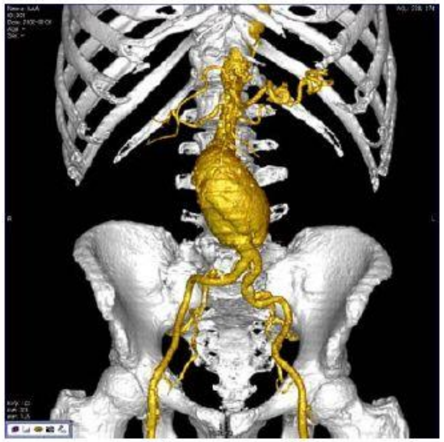


Renderings

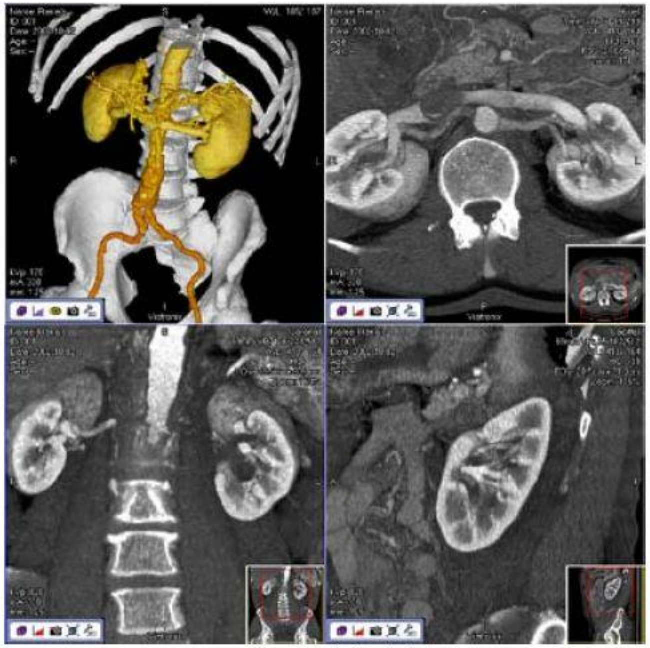


Renderings

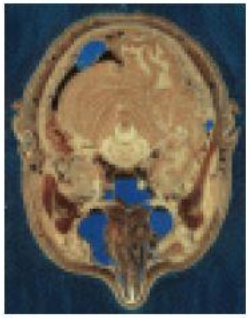
- Data scanned with medical scanners (MRI, CT, PET, SPECT, etc.)


aortic aneurism

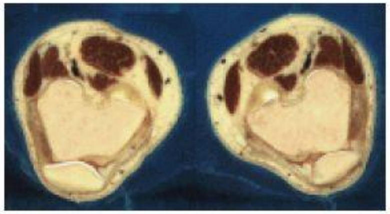

heart


renals (with kidneys)

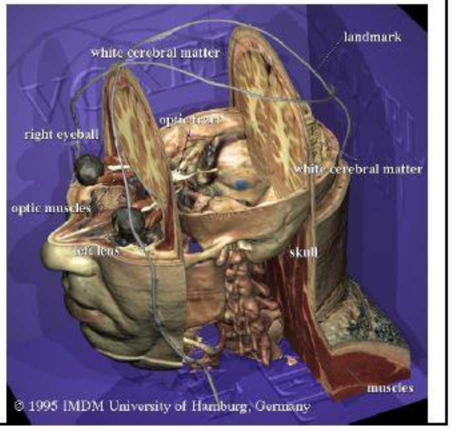
- Data photographed from histological slices (NIH-NLM *Visible Human*)


head

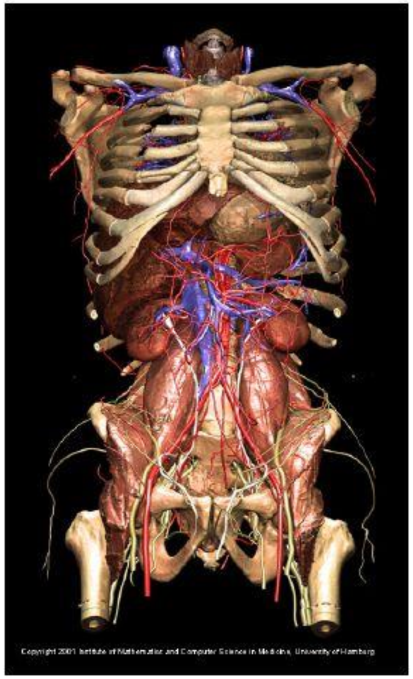

thorax

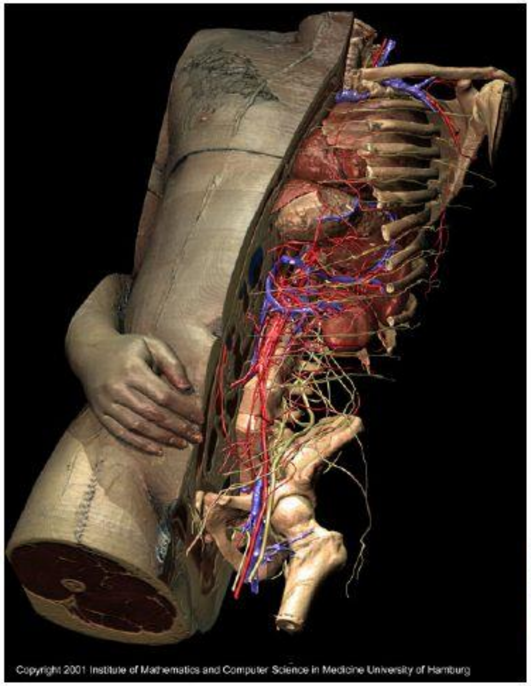

feet

atlas created from ~1700 1/3 mm slices



Renderings

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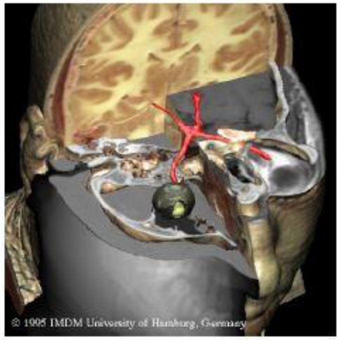
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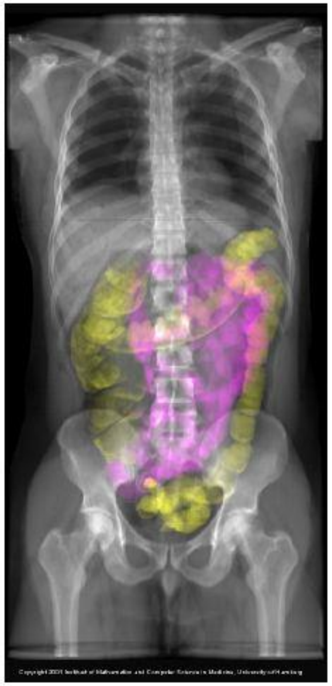

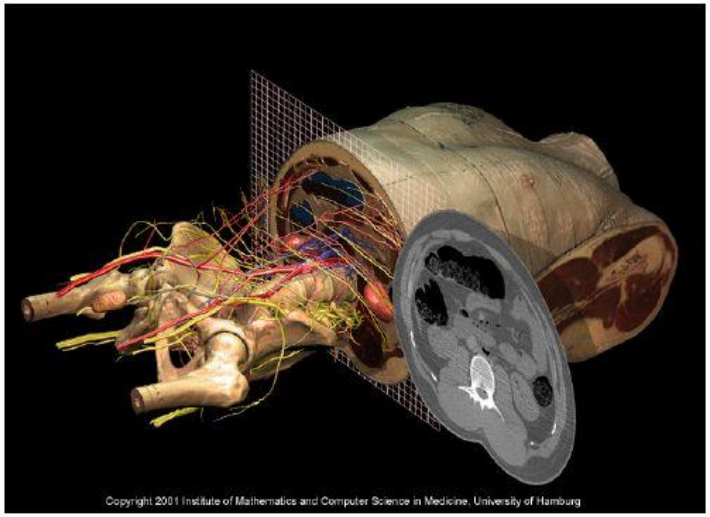
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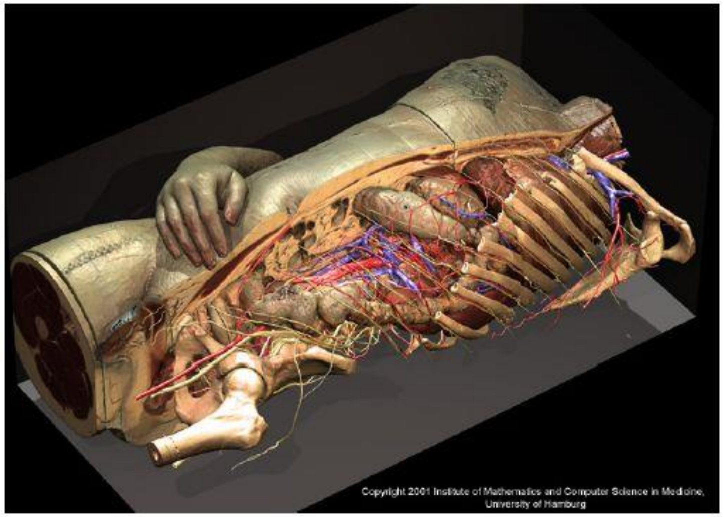
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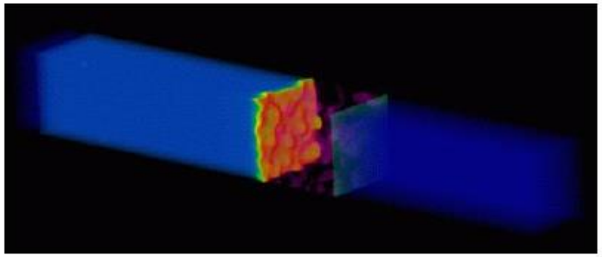
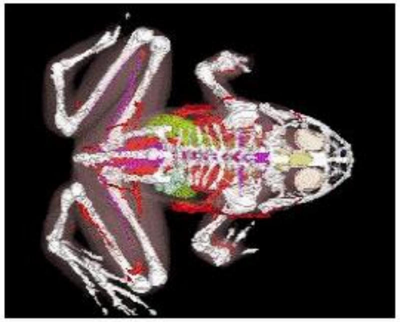
Comes Back to Life…

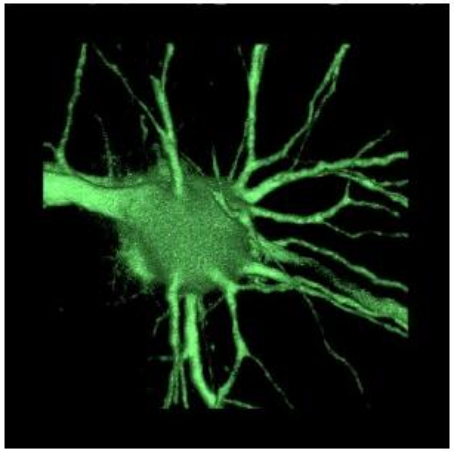
Scientific Visualization



shock wave

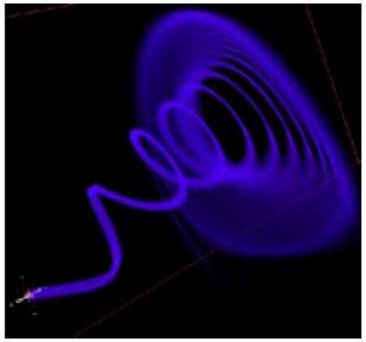
virtual frog

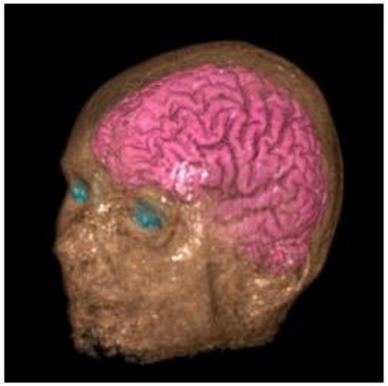




nerve cell

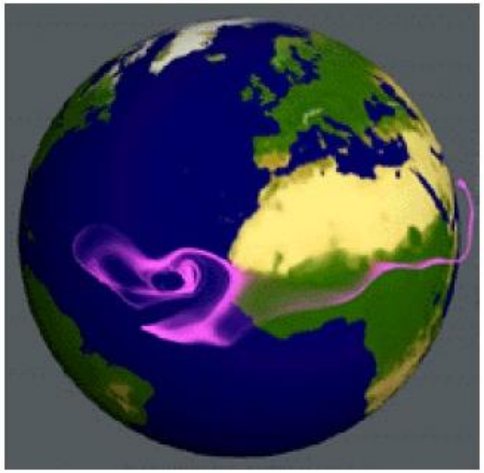
spiral flow





transparent MRI head

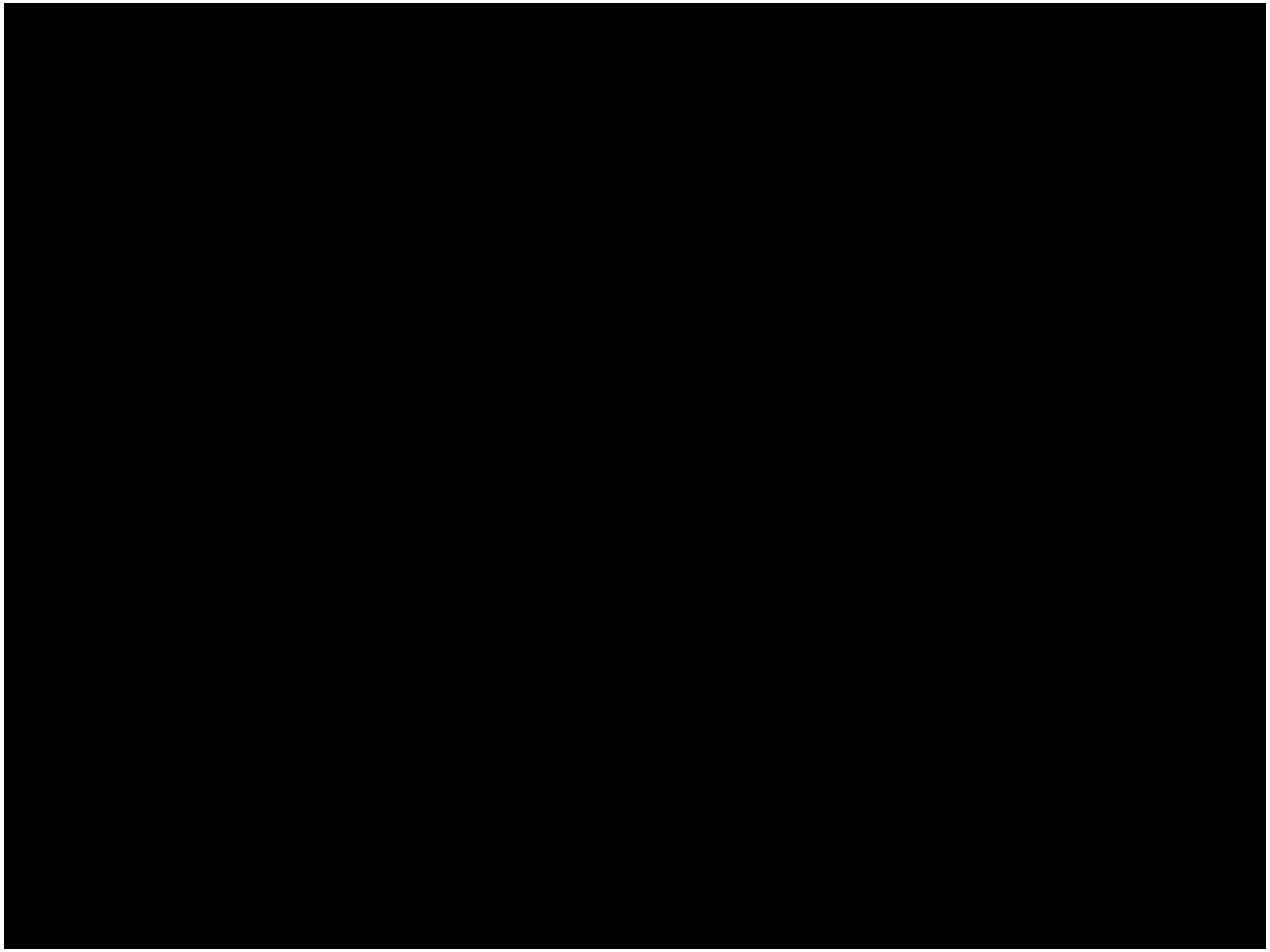
wind flow



MRI head

semi-transparent
tomato

Simulations



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

Fluid Dynamics Simulations

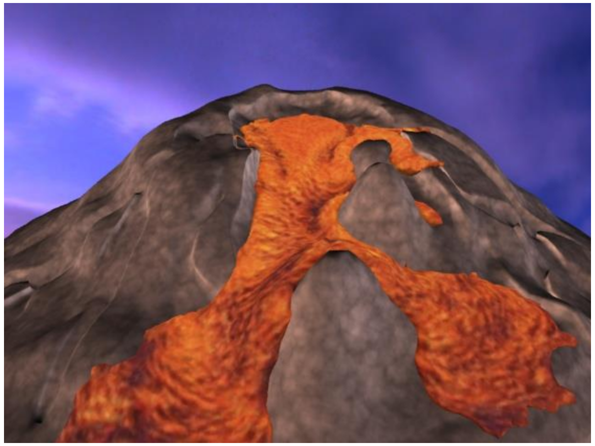
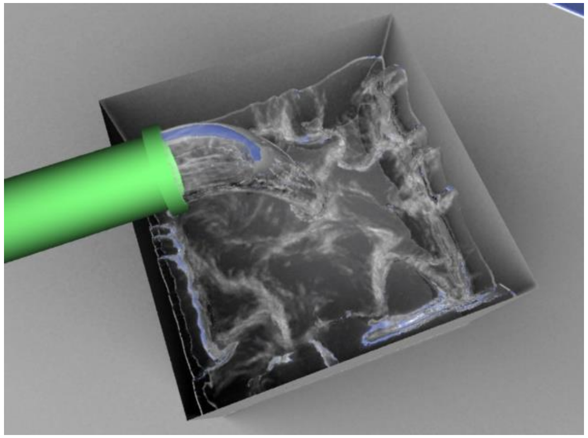
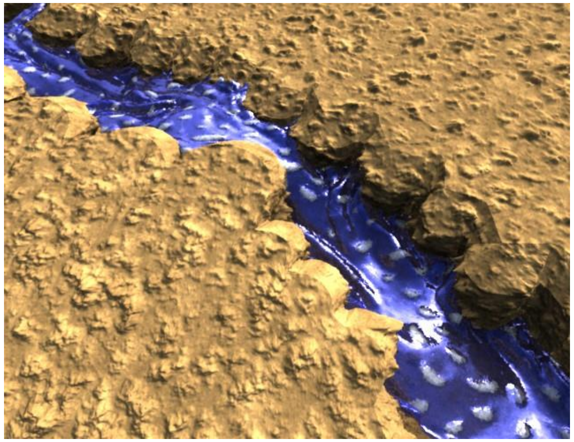
Navier-Stokes equations for viscous, incompressible liquids.

$$\nabla \cdot \mathbf{u} = 0$$

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

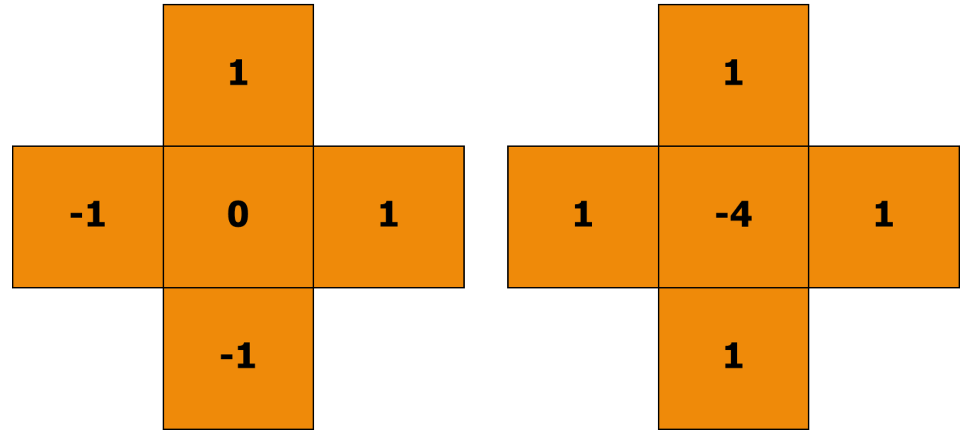




Navier-Stokes Solution

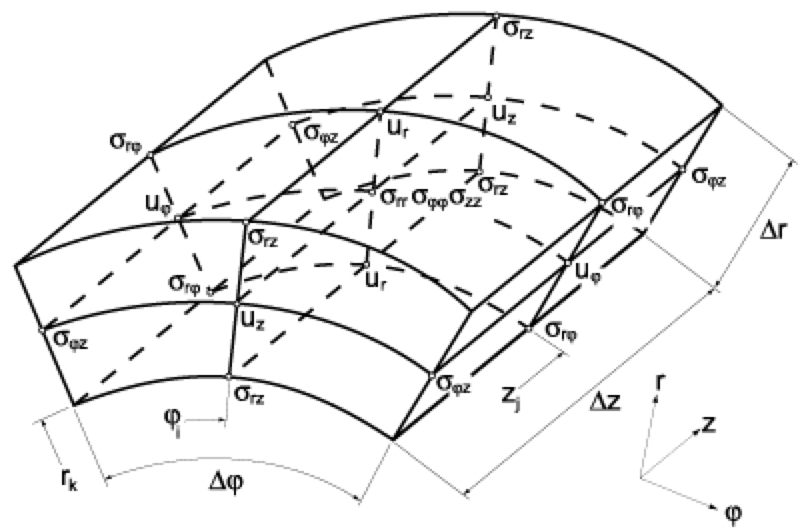
Via finite differencing

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