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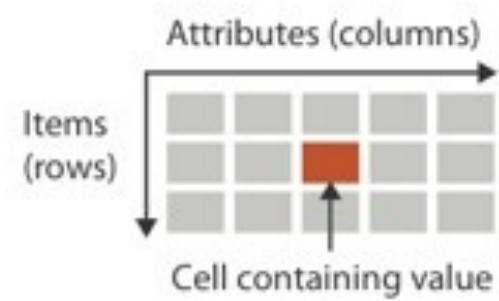
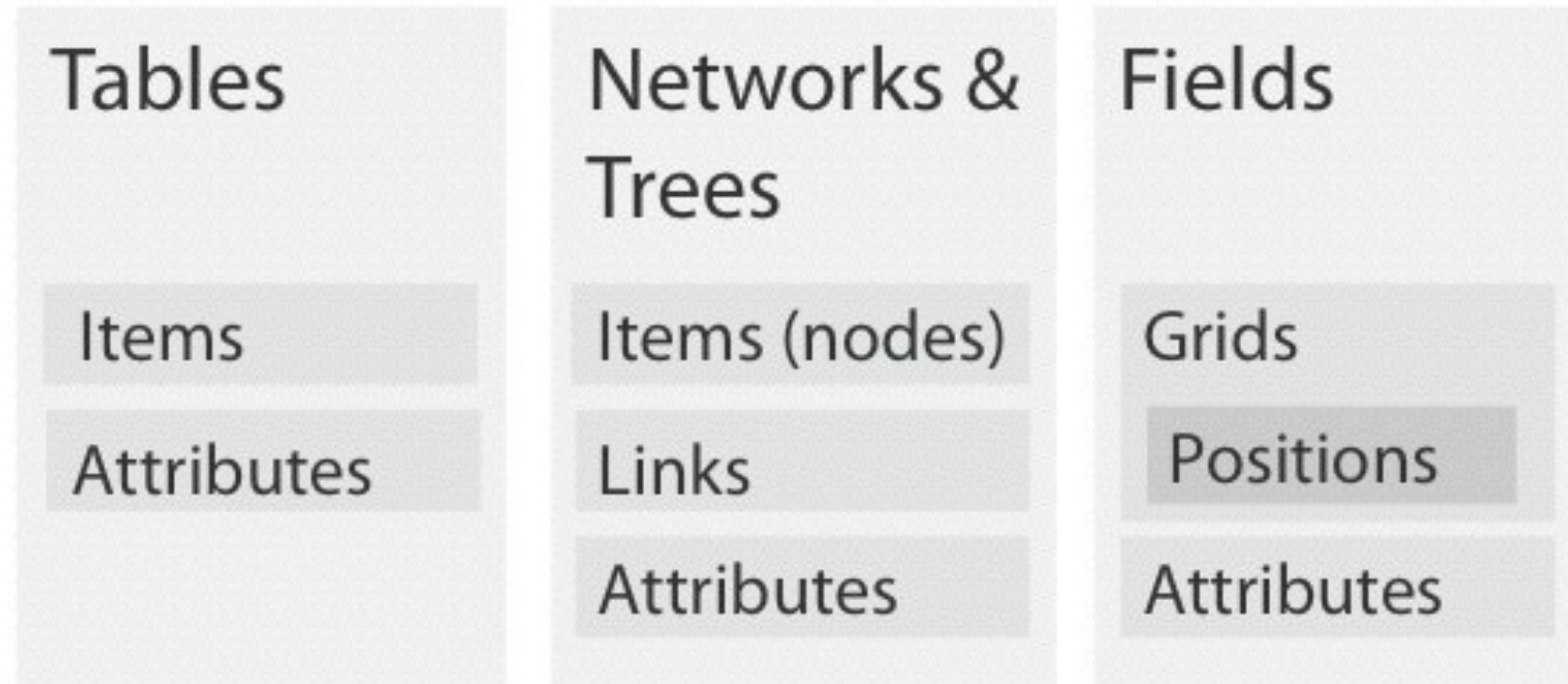
# Visualization for Data Science

## DS-4630 / CS-5630 / CS-6630

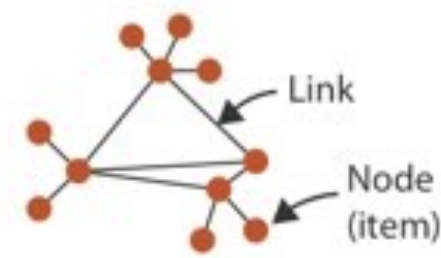
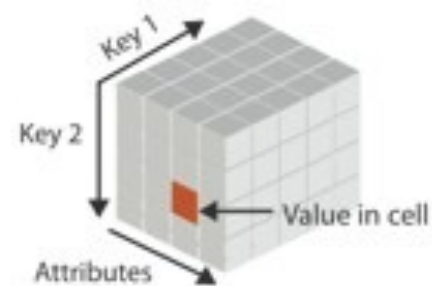
### Visualizing Fields

Note: This content is covered in detail in CS 6635/5635 Visualization for Scientific Data

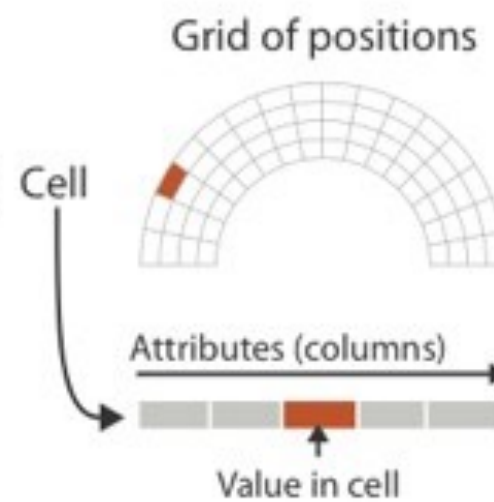
# dataset types



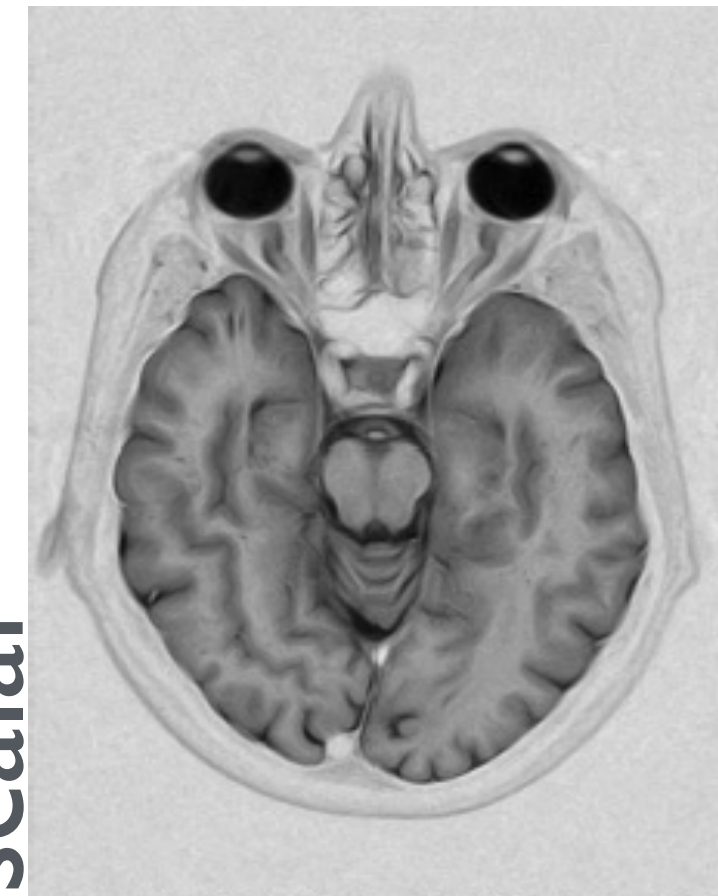
→ *Multidimensional Table*



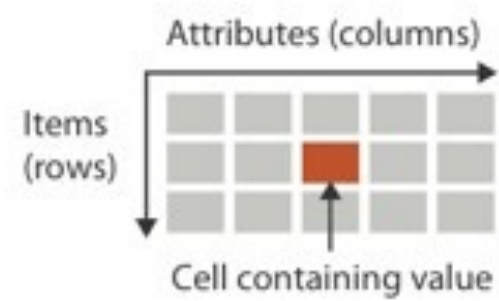
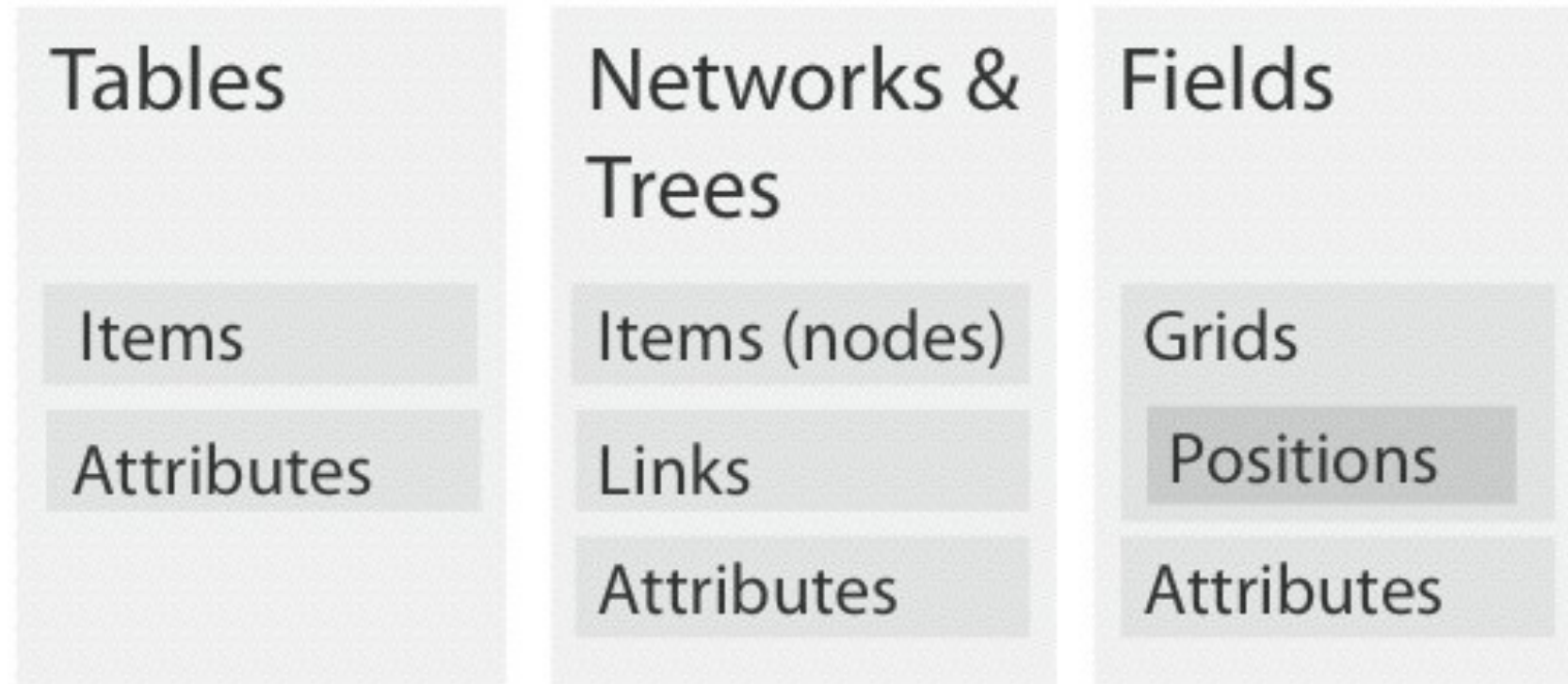
→ *Trees*



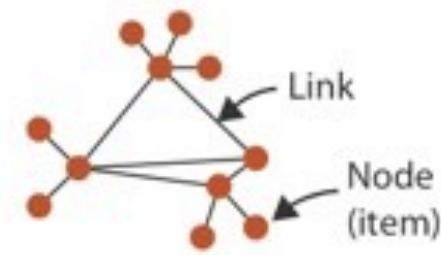
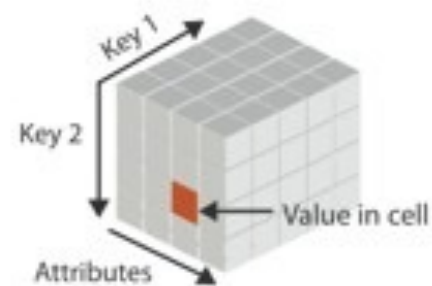
scalar



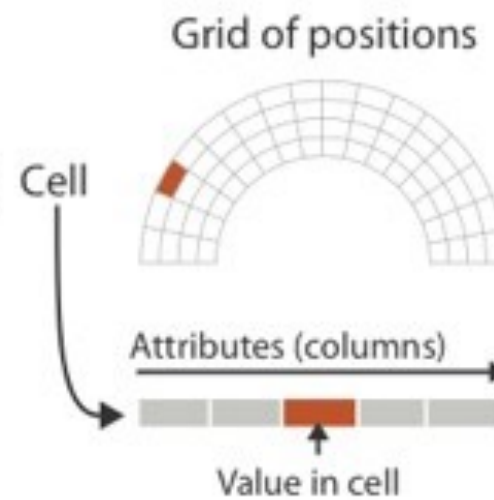
# dataset types



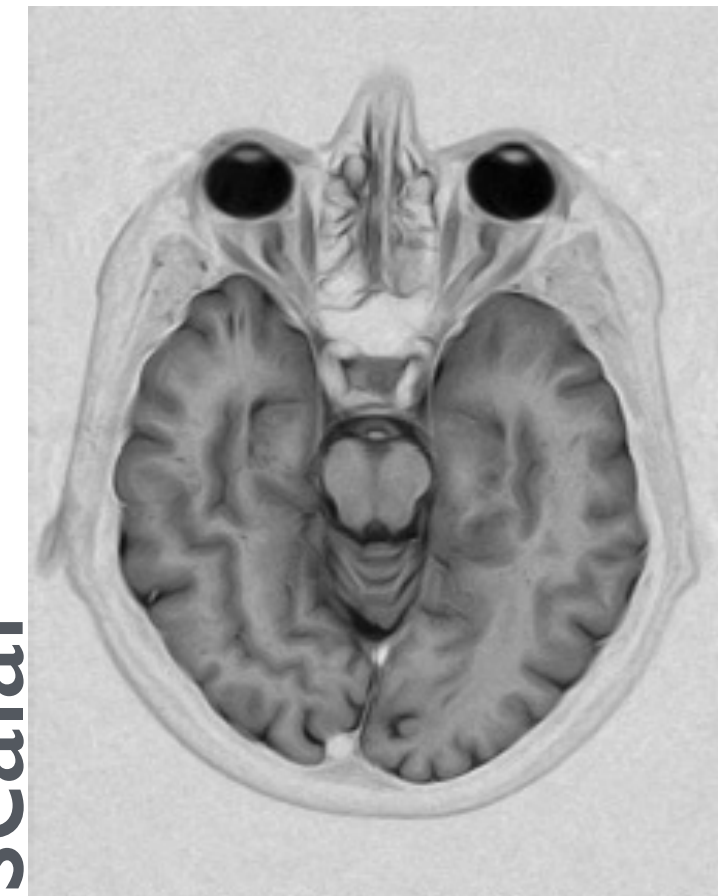
→ *Multidimensional Table*



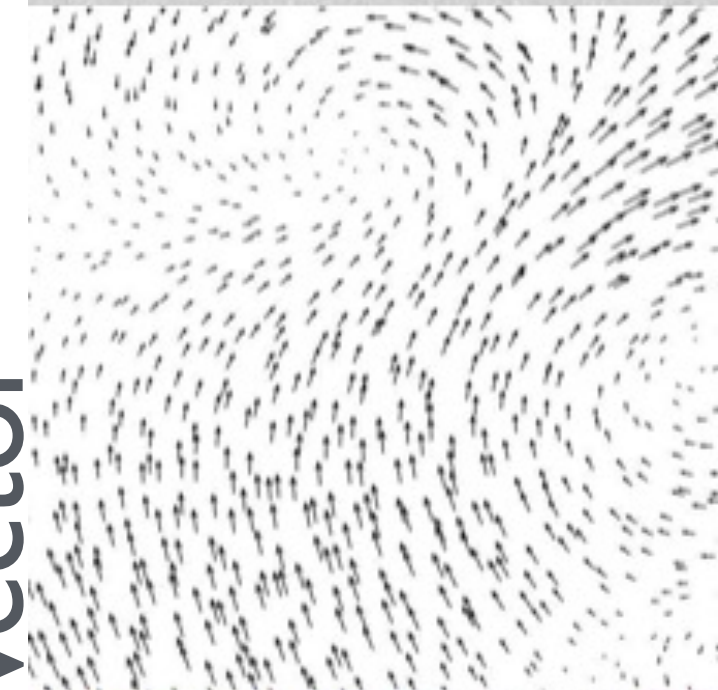
→ *Trees*



scalar

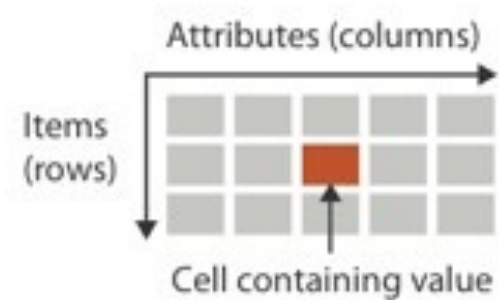
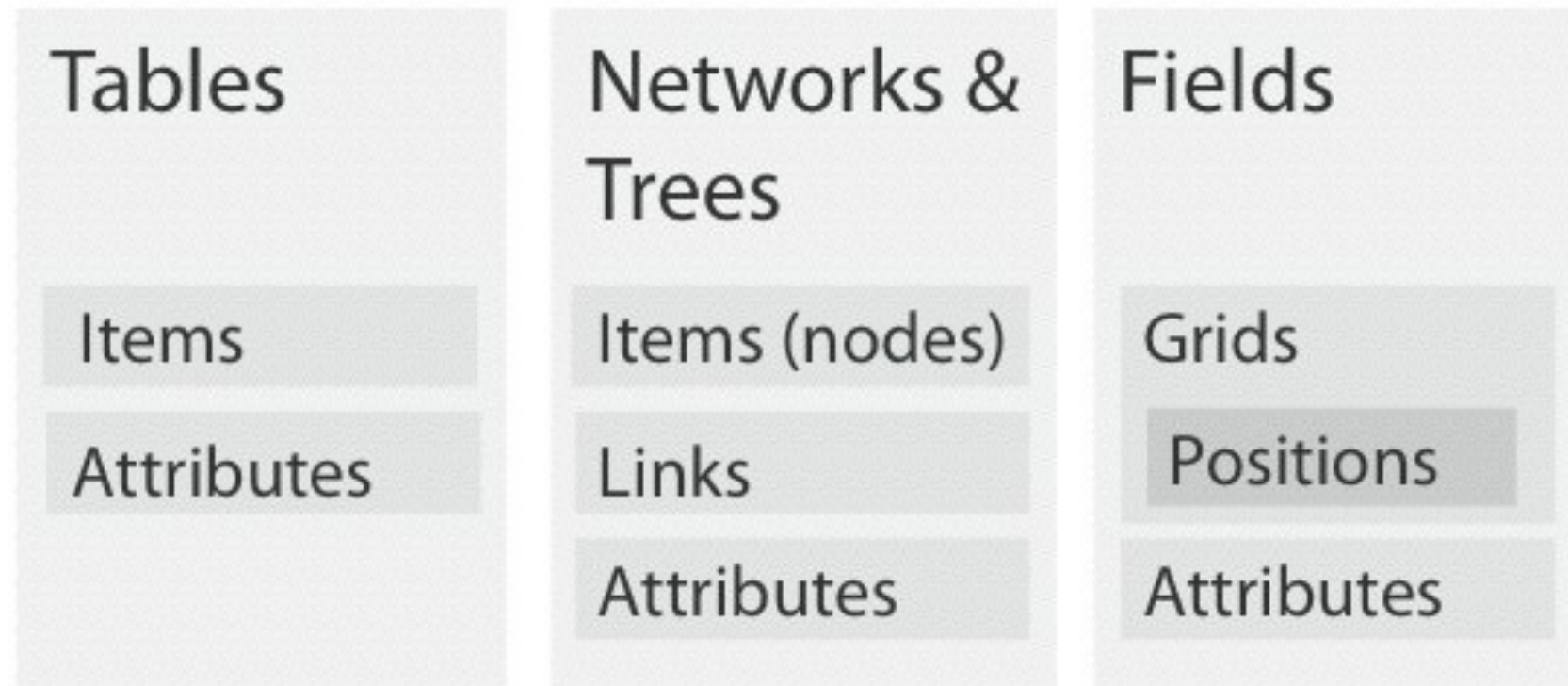


vector

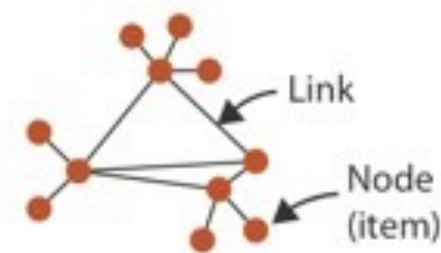
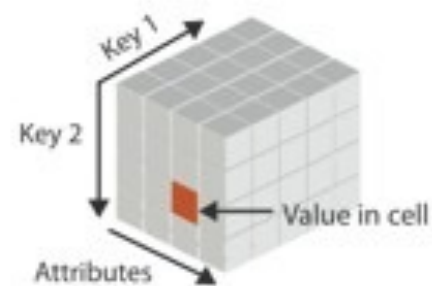




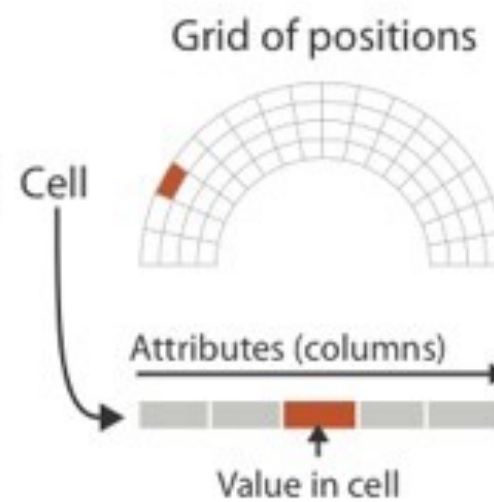
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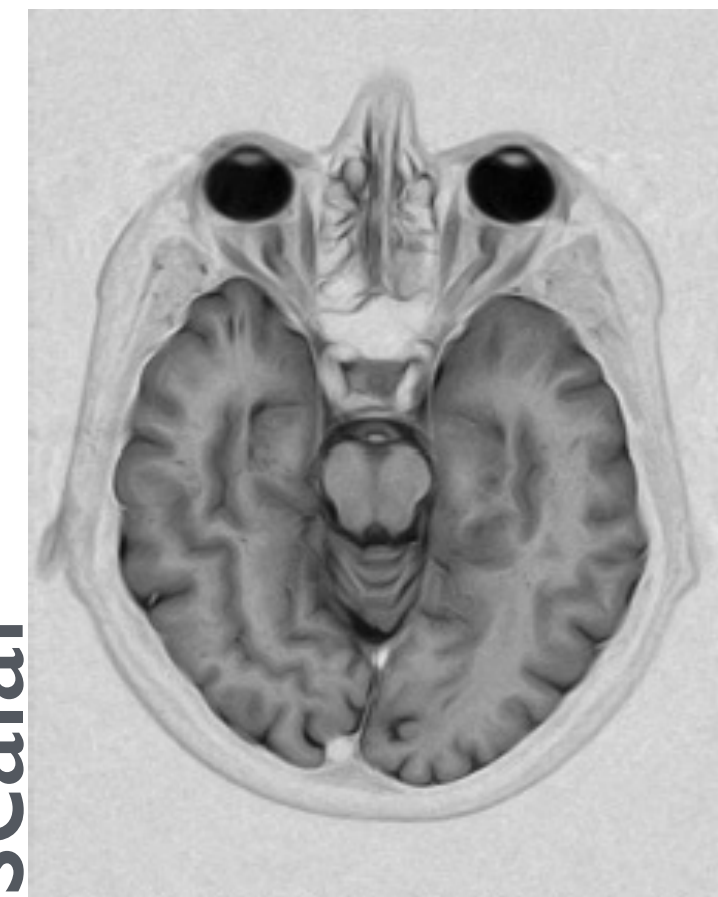
→ *Multidimensional Table*



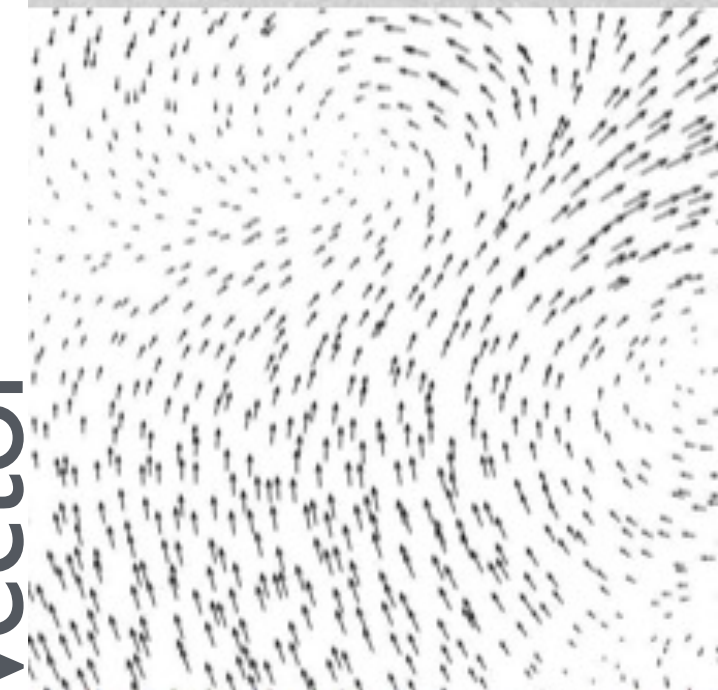
→ *Trees*



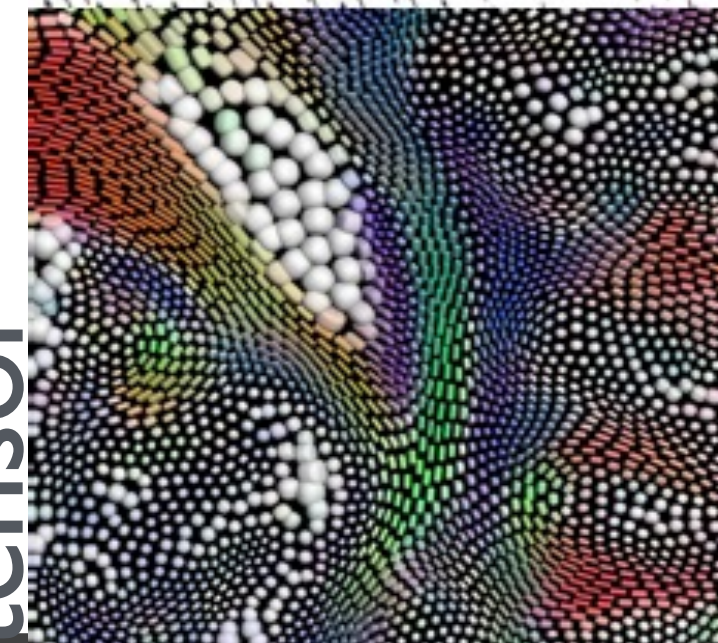
scalar



vector



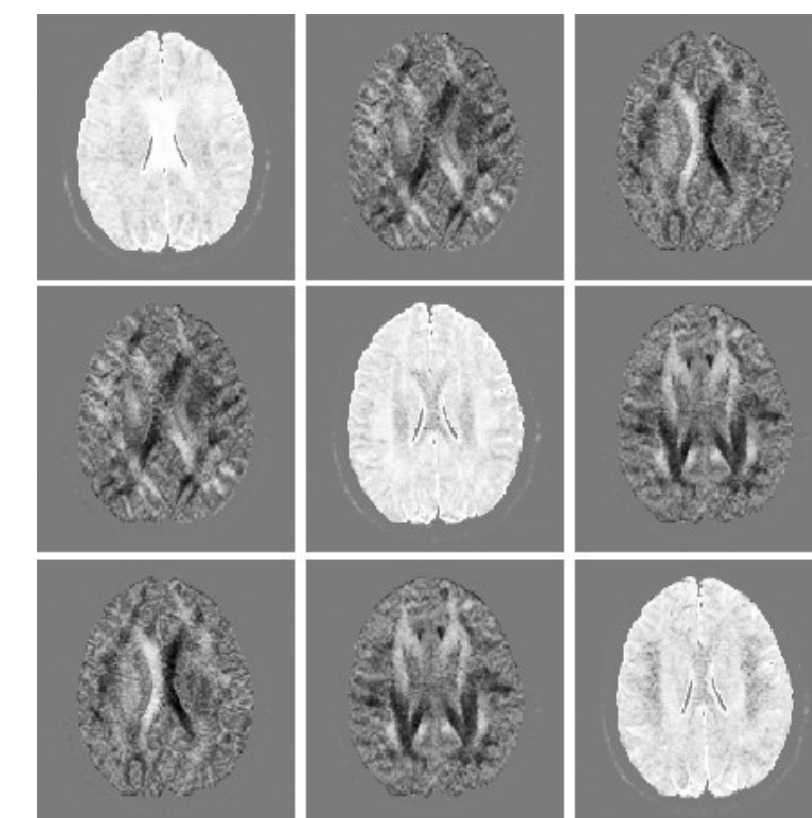
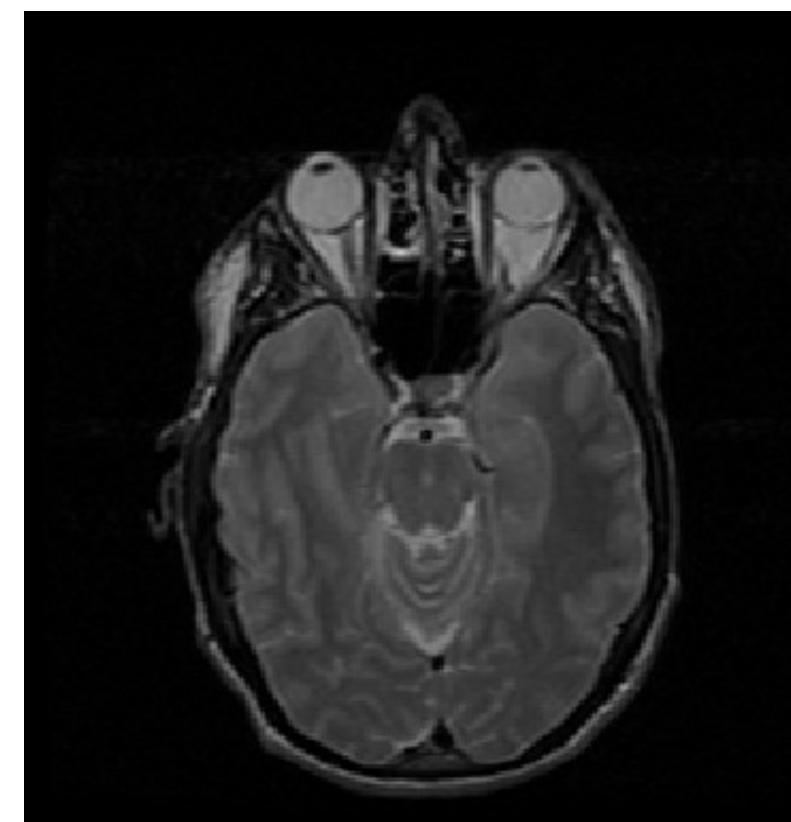
tensor



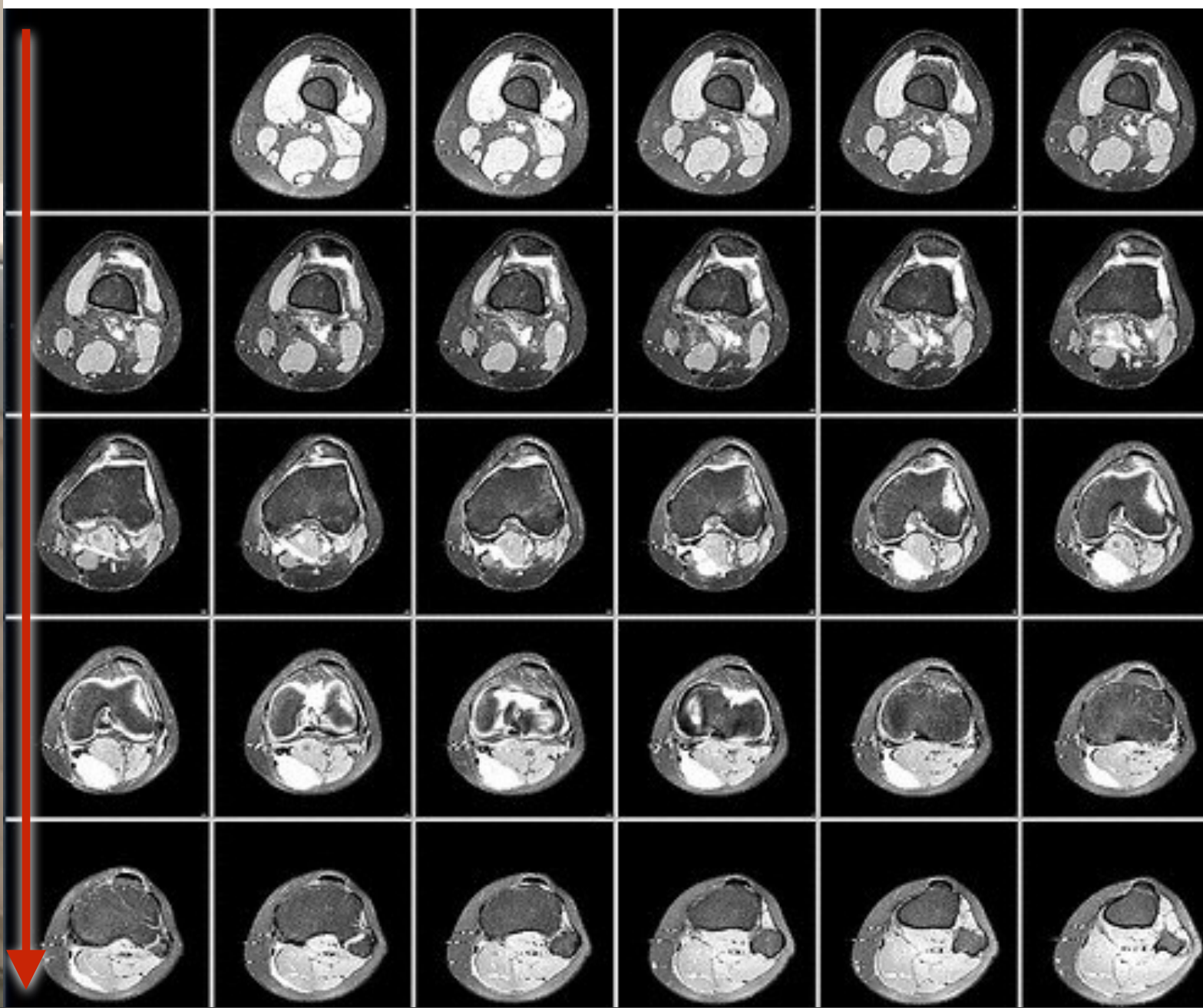
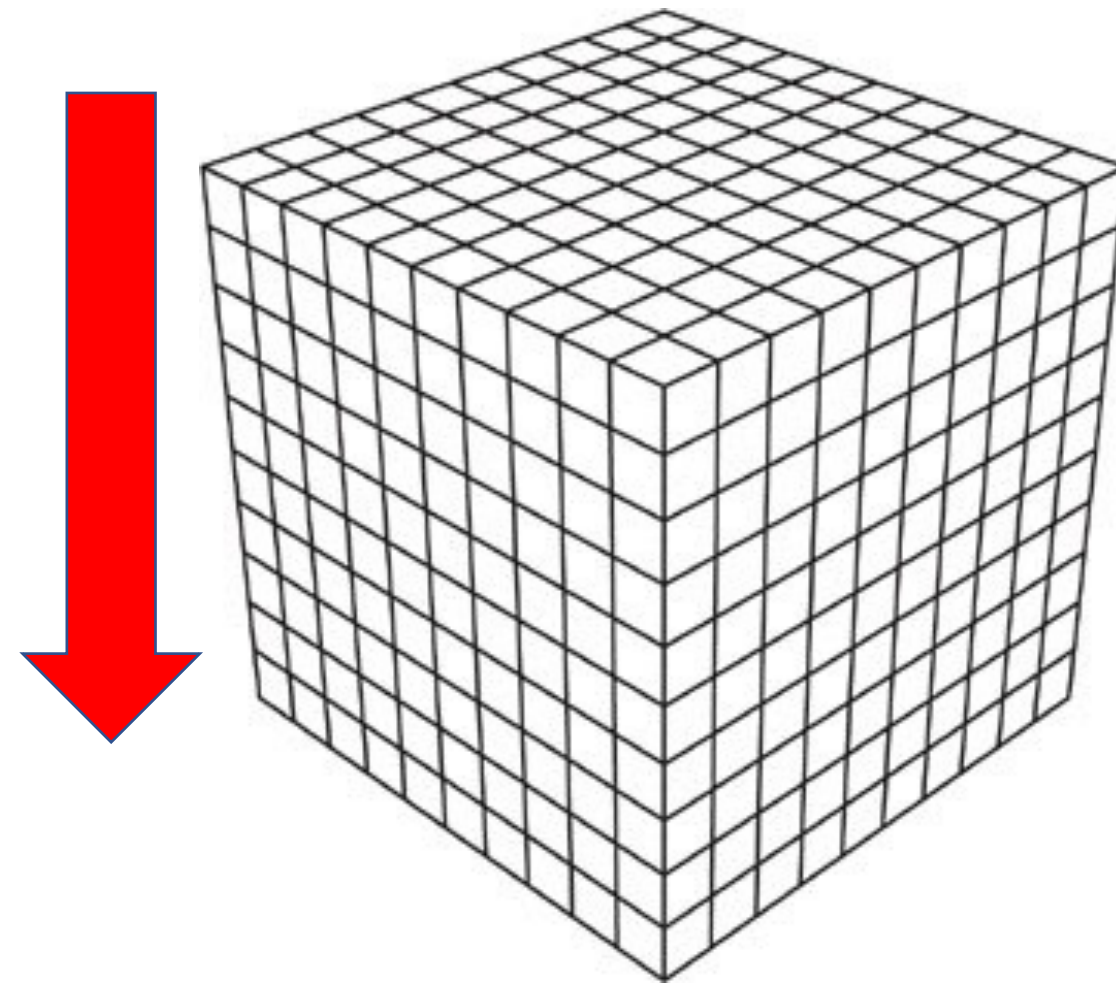


# Scalar Field Visualization Usefulness

- Measured sources of data
  - CT (computed tomography)
  - PET (positron emission tomography)
  - MRI (magnetic resonance imaging)
  - Ultrasound
  - Confocal Microscopy
  - And others



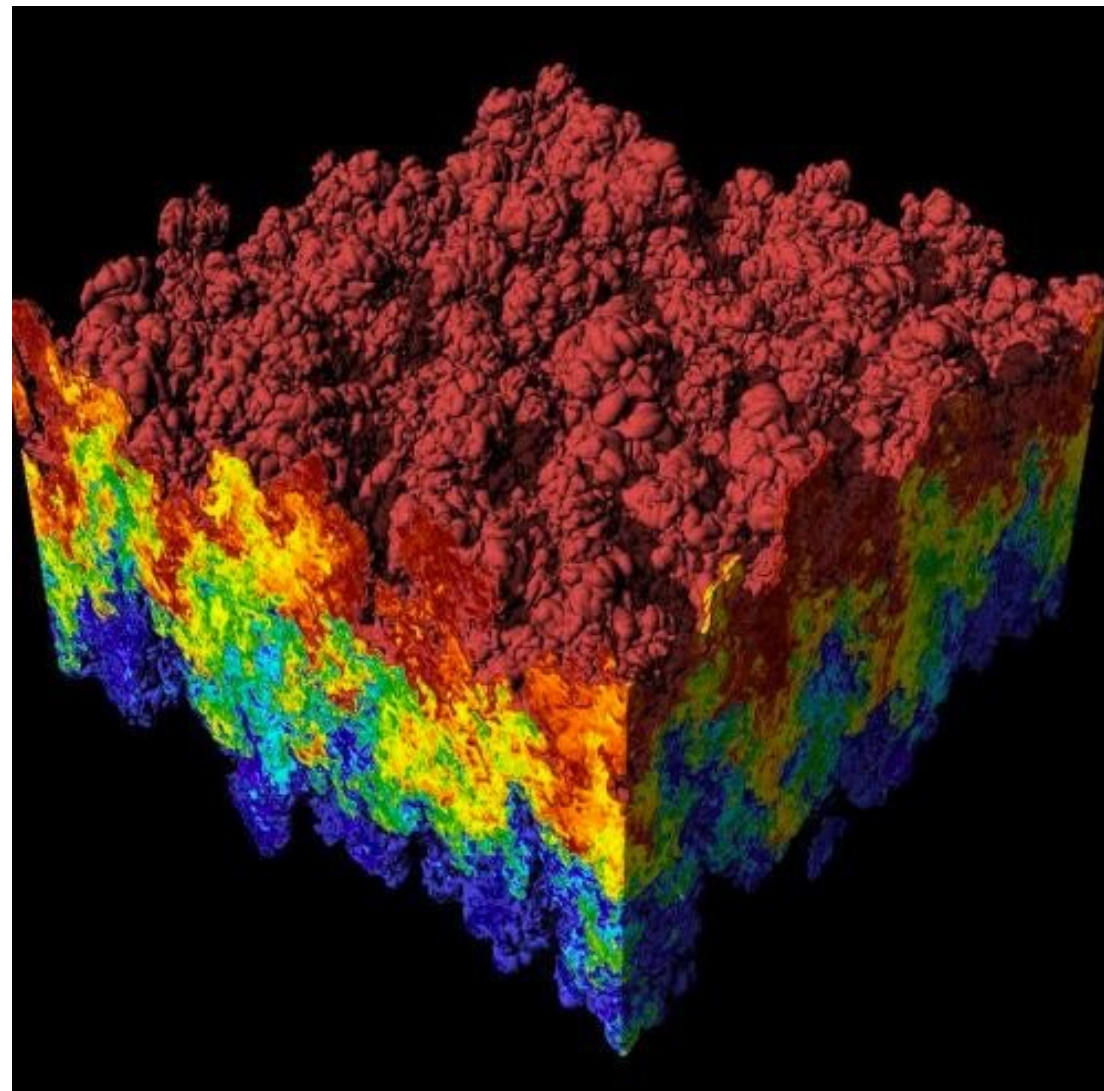




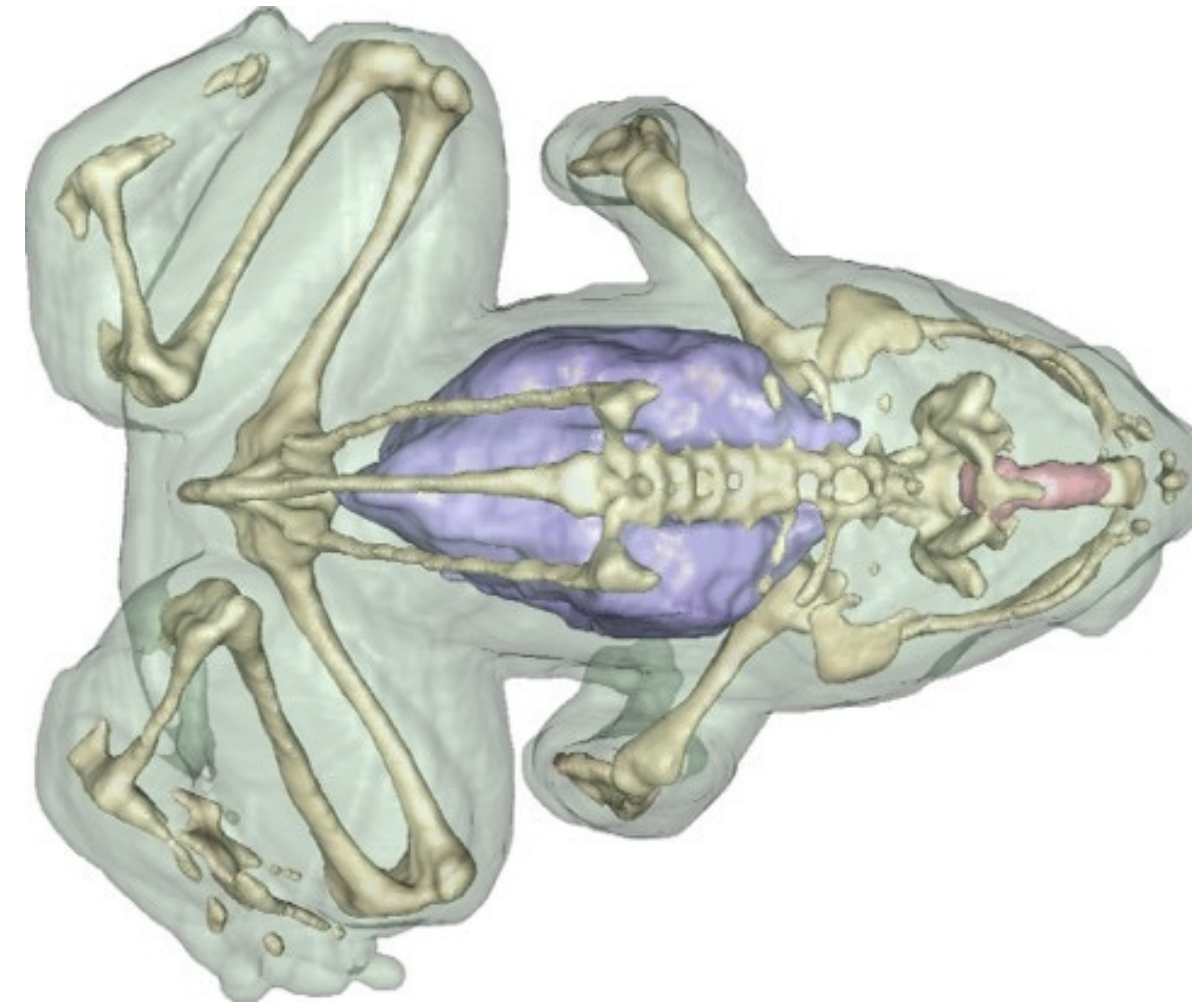


# Common Approaches

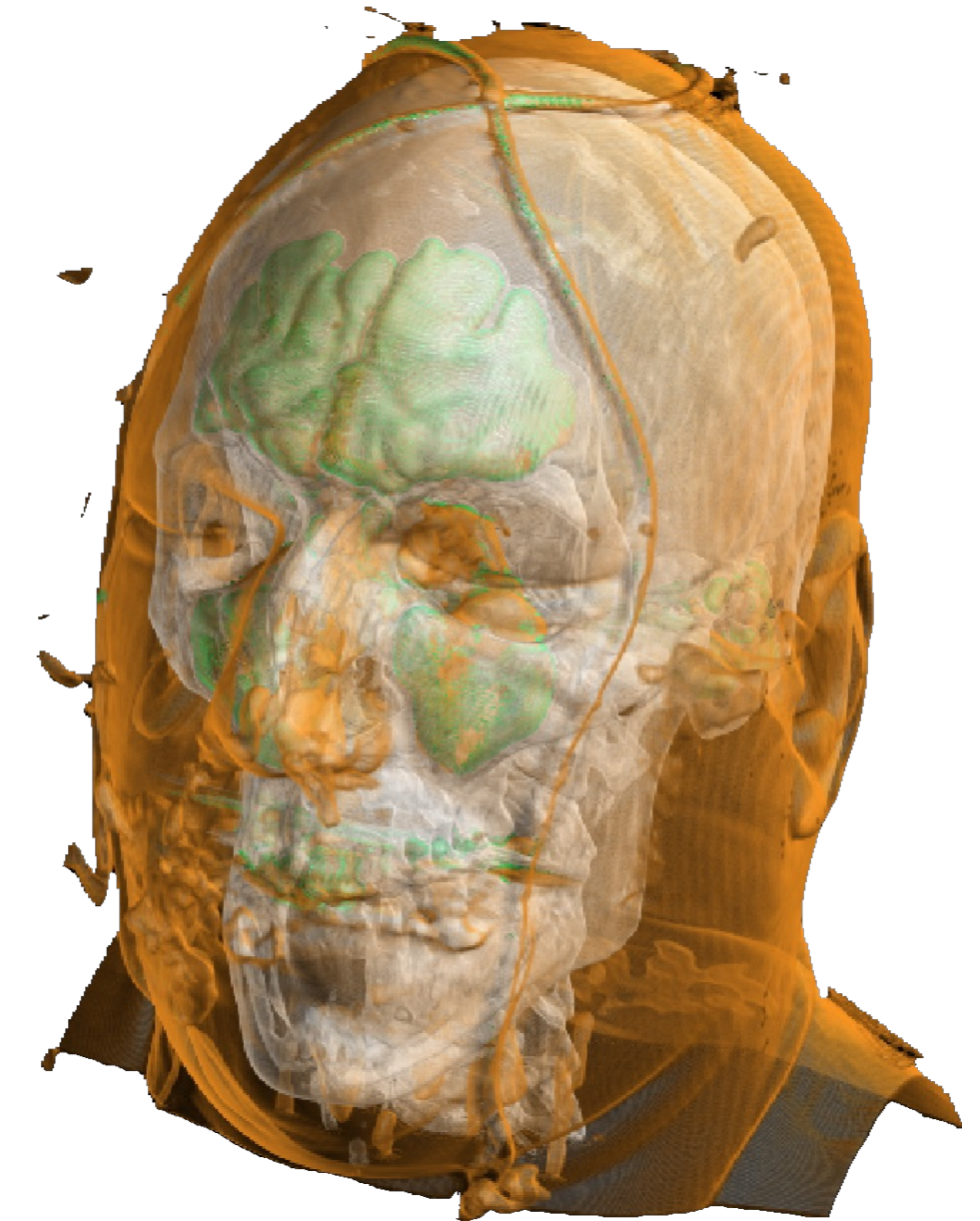
Color Mapping



Contouring



Volume Rendering



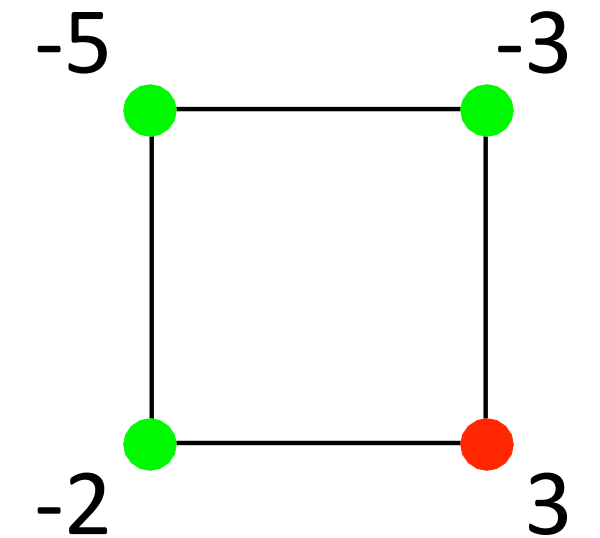






# Contours in 2D

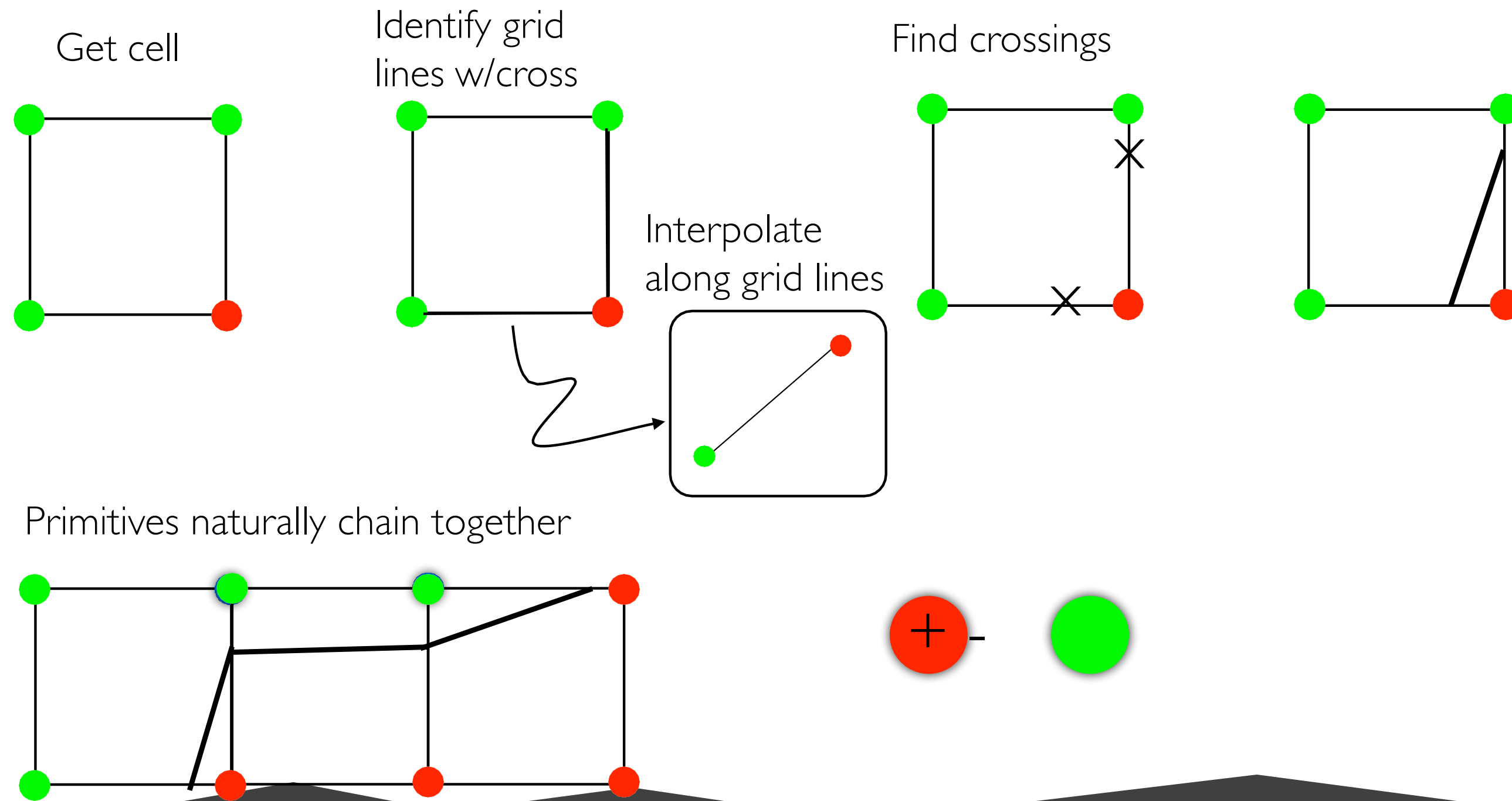
- Assign geometric primitives (line segments) to individual cells (process one cell at a time)
- Consider sign of the values at vertices
- Intersections occur on edges with sign change
- Determine exact position of intersection interpolate along grid edges
- To draw multiple contours, select thresholds instead of 0





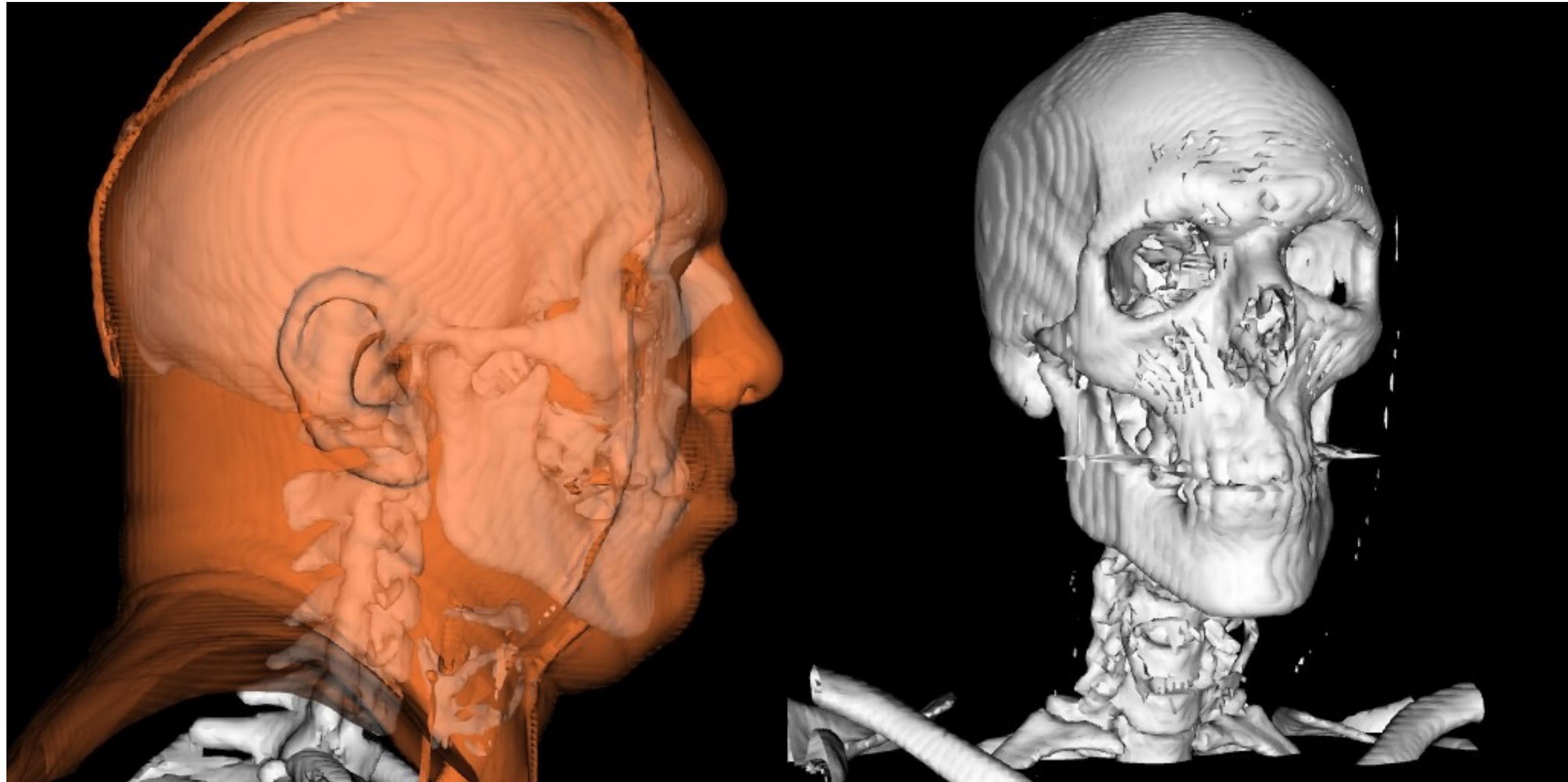
# Contours in 2D

- Idea: primitives must cross every grid line connecting two grid points of opposite sign





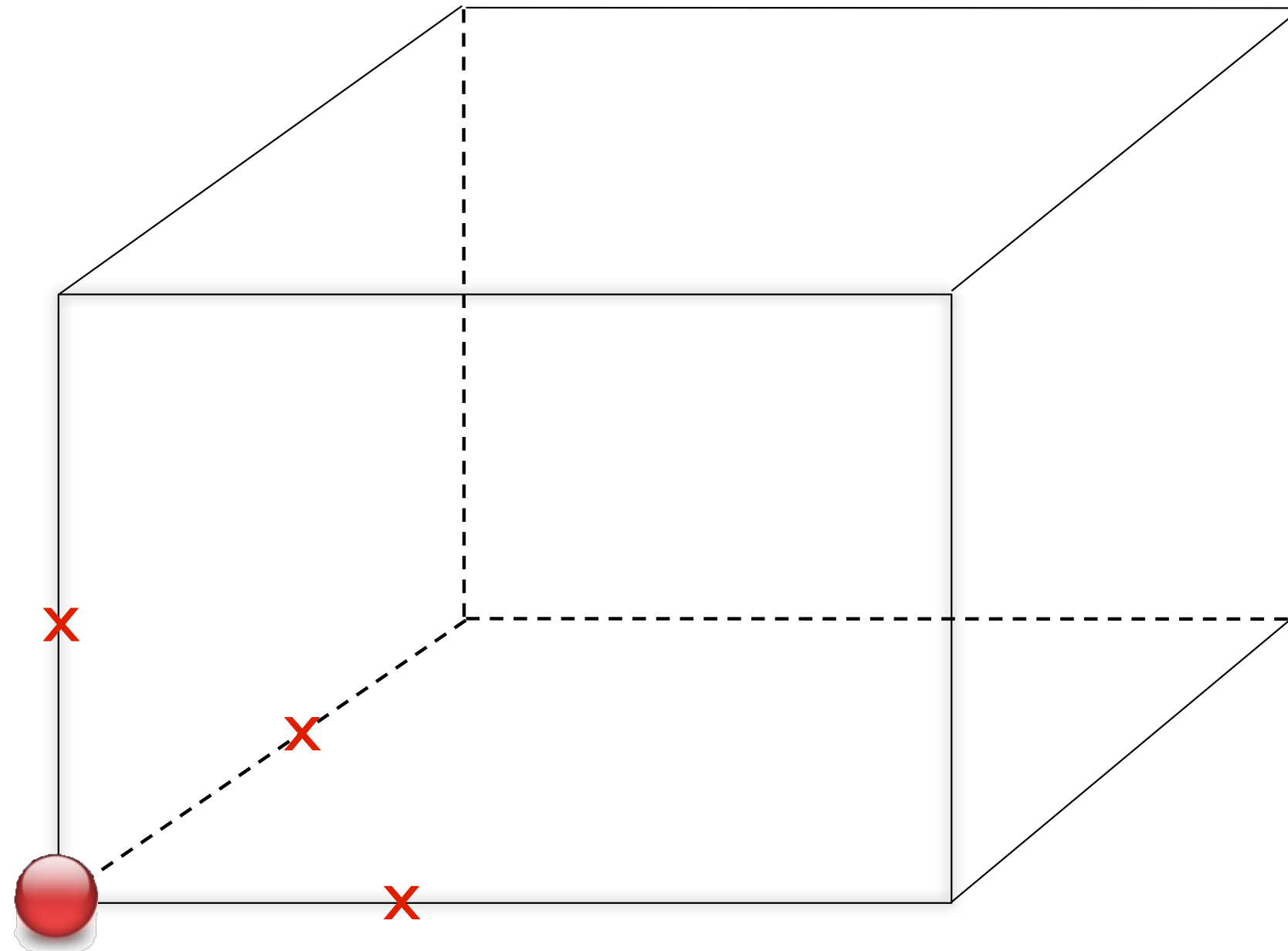
# 3D Contours: Isosurfaces





# Isosurface Construction: One Positive Vertex

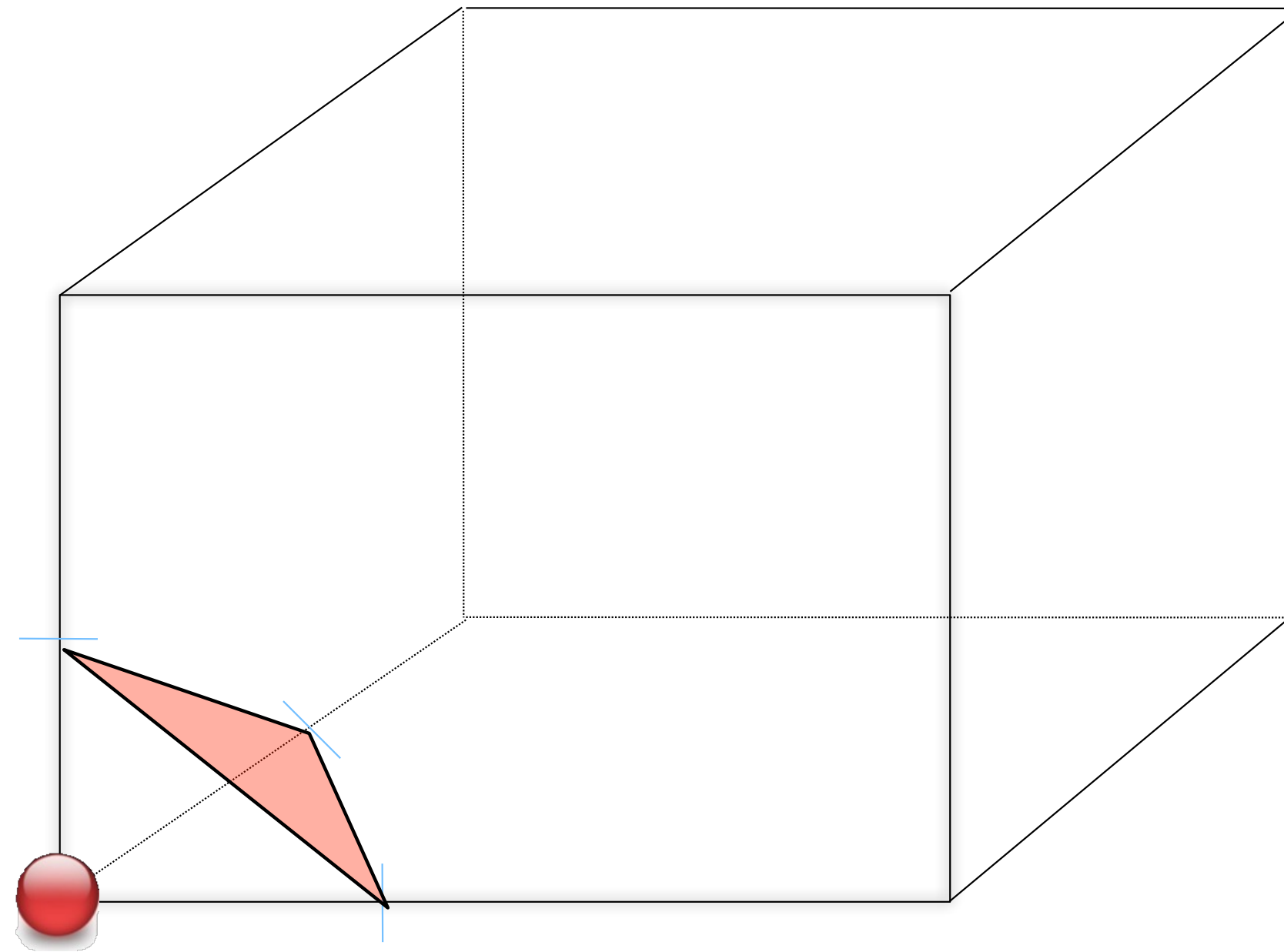
- Intersections with edges found by inverse linear interpolation (as in 2D contouring)





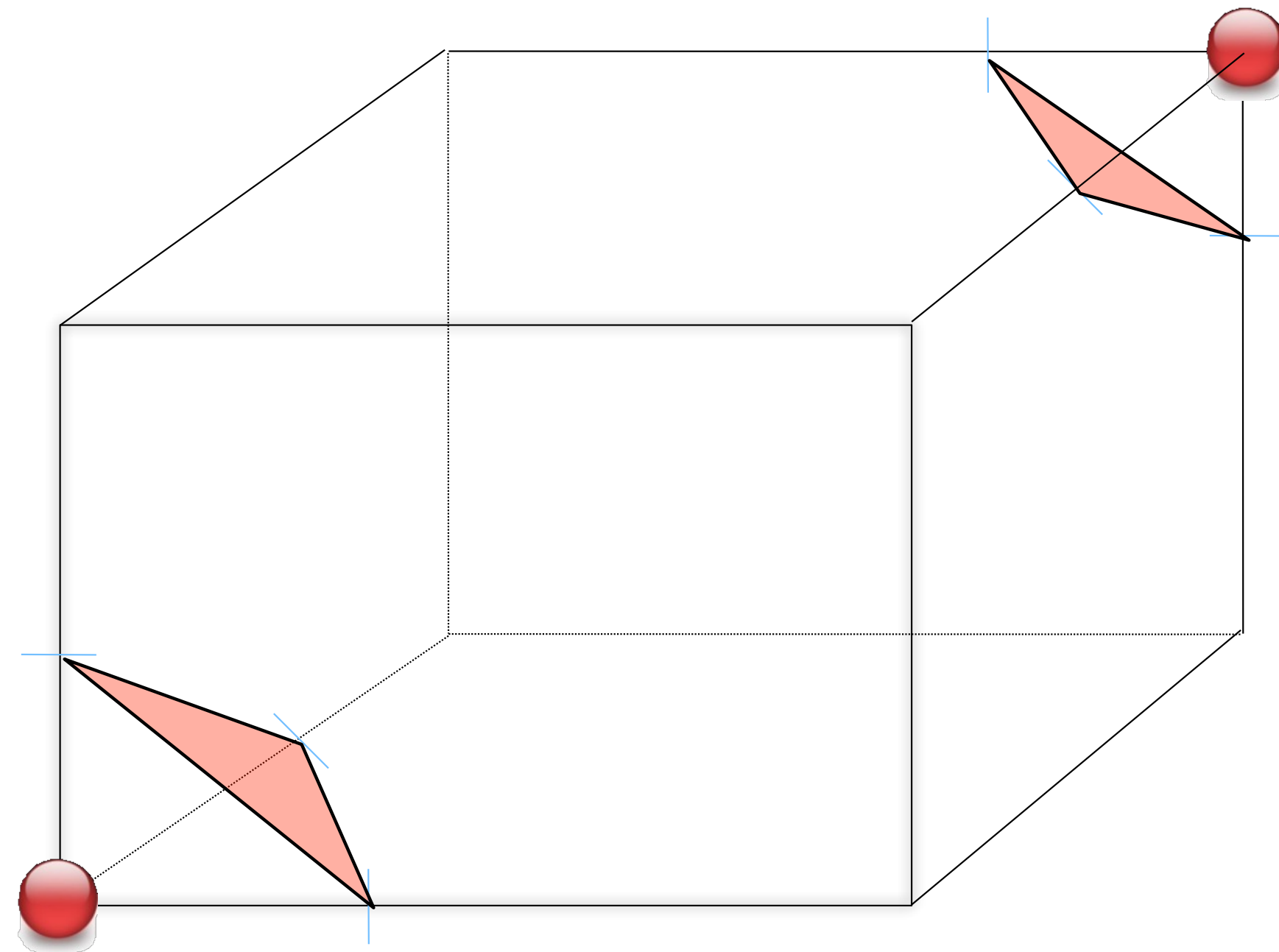
# Isosurface Construction: One Positive Vertex

- Joining edge intersections across faces forms a triangle as part of the isosurface



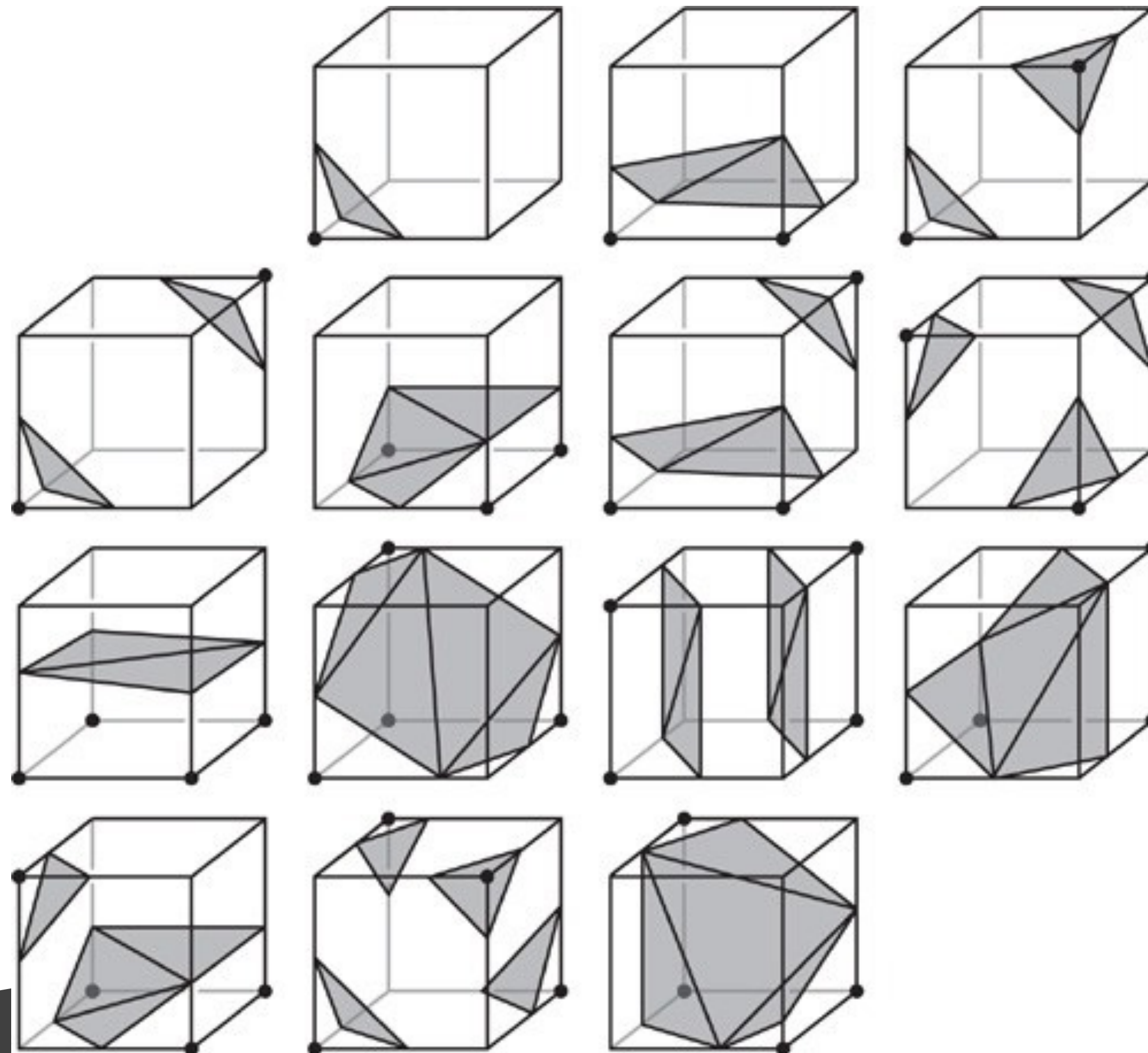


# Isosurface Construction: Two Positive Vertices at Opposite Vertices



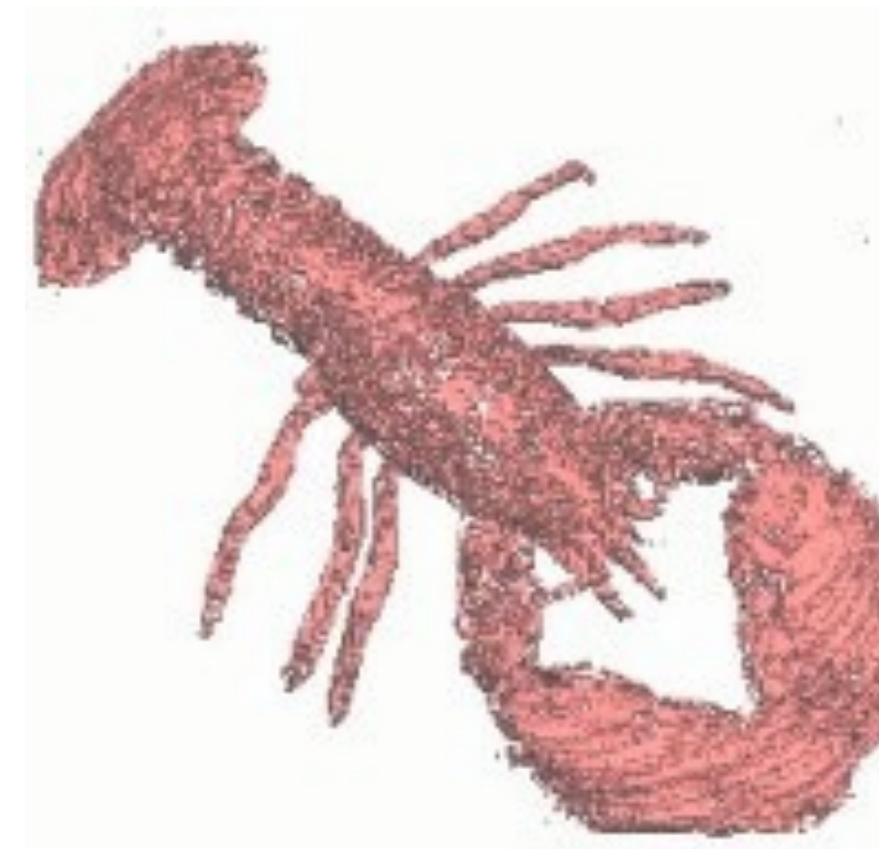
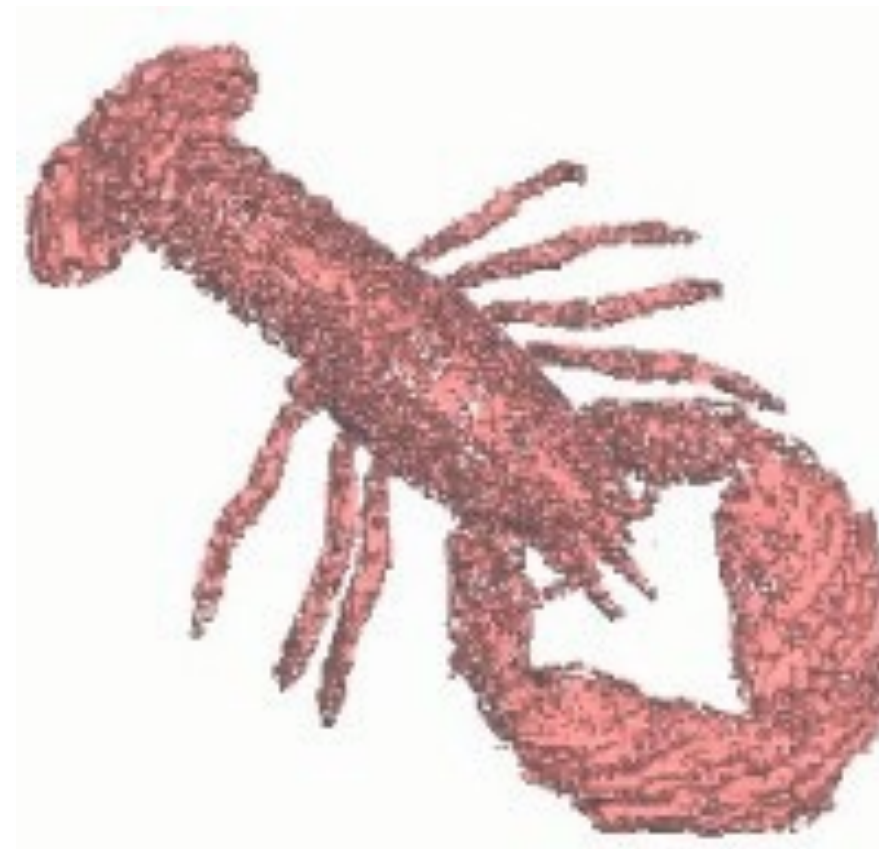
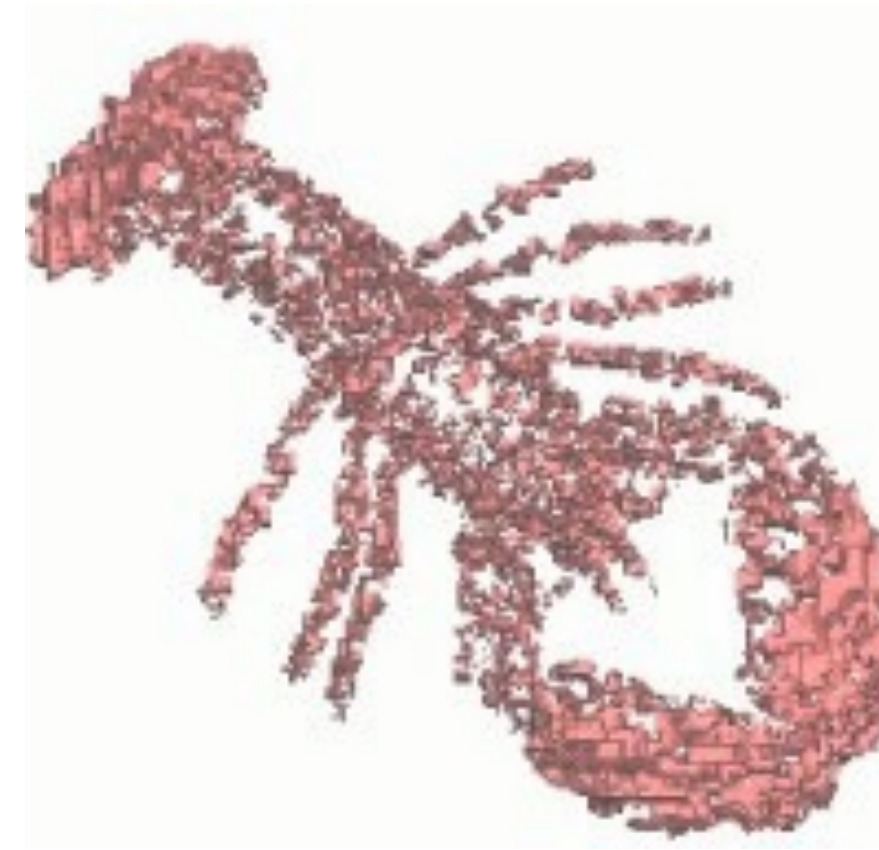


# Canonical Cases



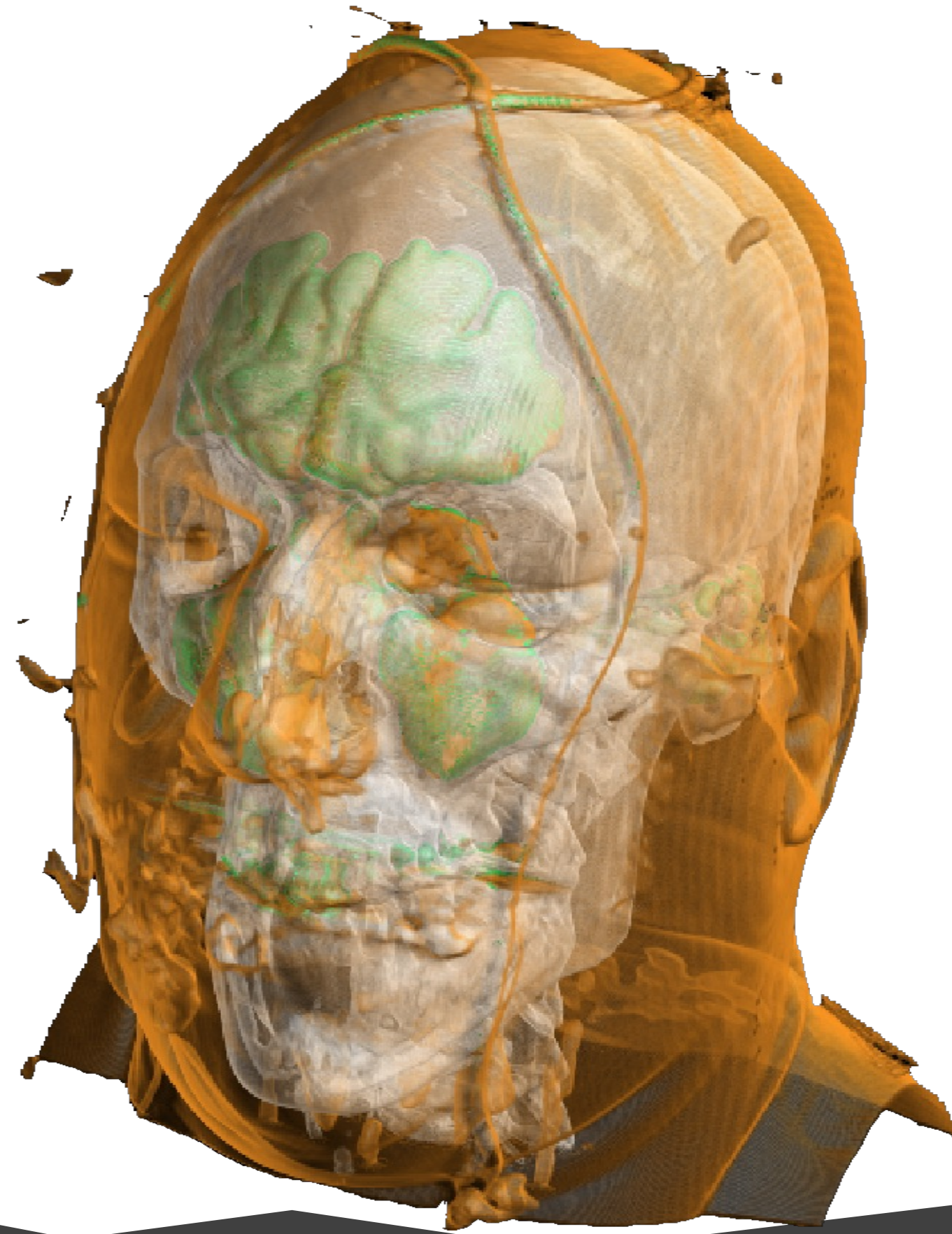


# Changing the Threshold





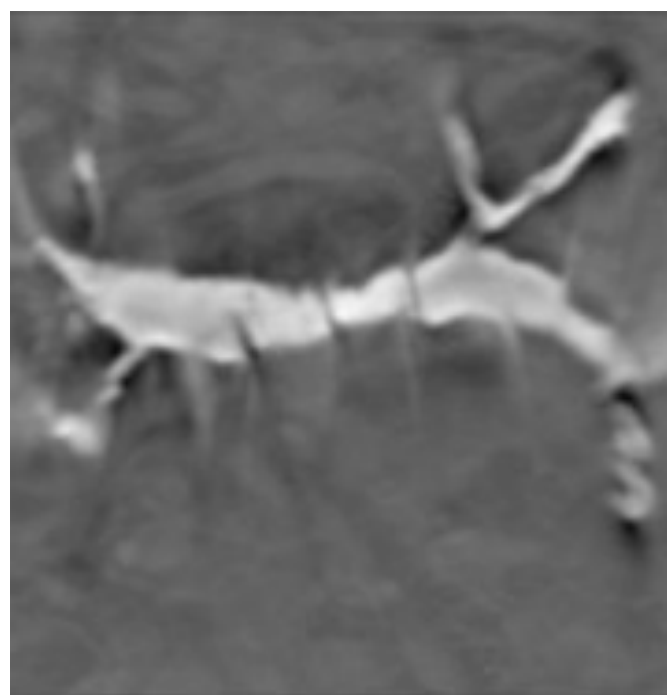
# Volume Rendering



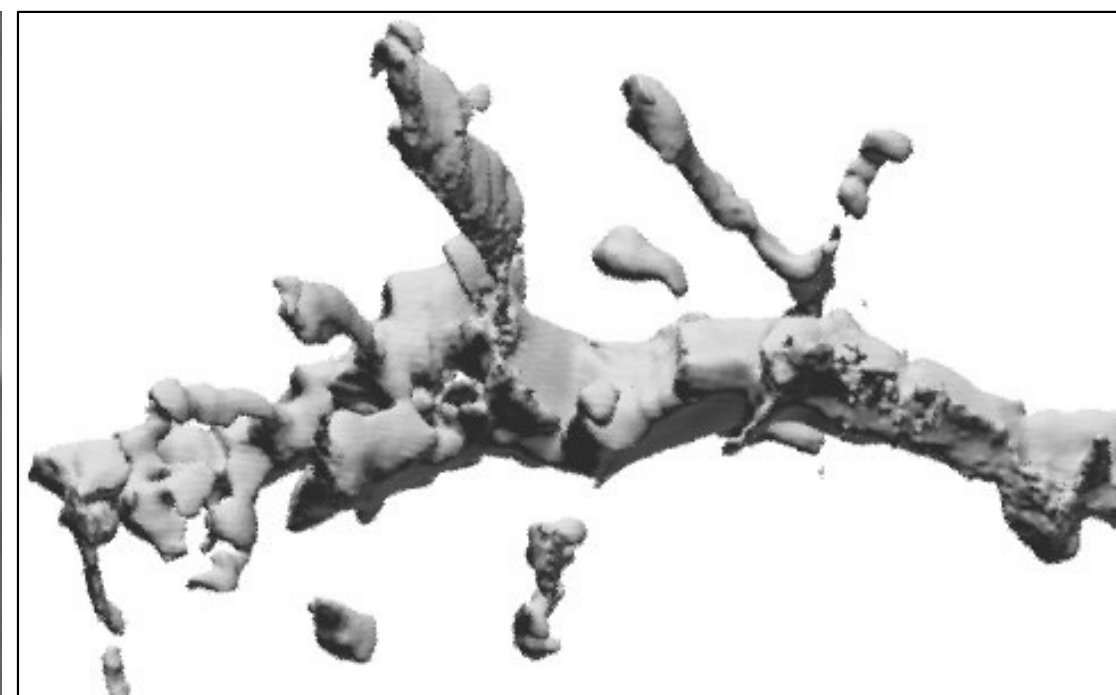


# Limitations

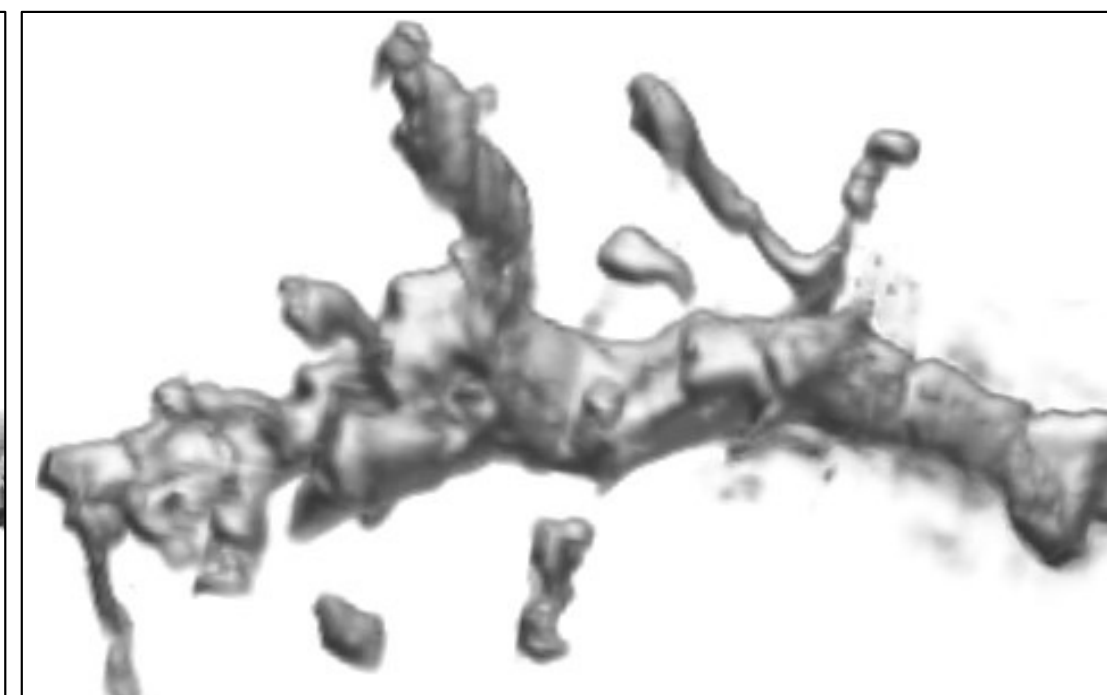
- Isosurfacing is "binary"
- point inside isosurface?
- voxel contributes to image?
- Is a hard, sharp boundary necessarily appropriate for the visualization task?



Slice



Isosurface



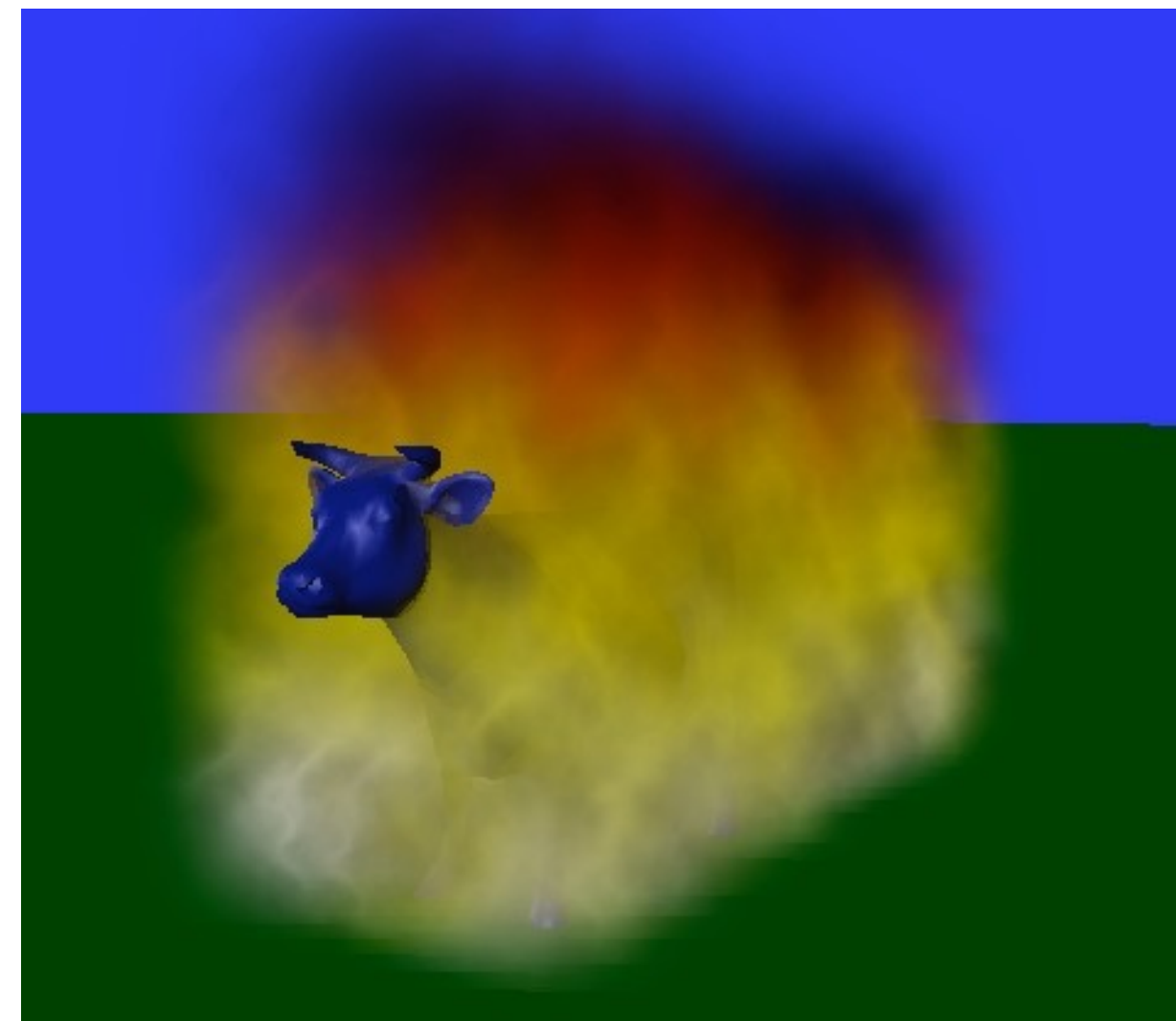
Volume Rendering

# Isosurfacing is Limited

- Isosurfacing poor for ...
- measured, "real-world" (noisy) data amorphous, "soft" objects



virtual angiography



bovine combustion simulation

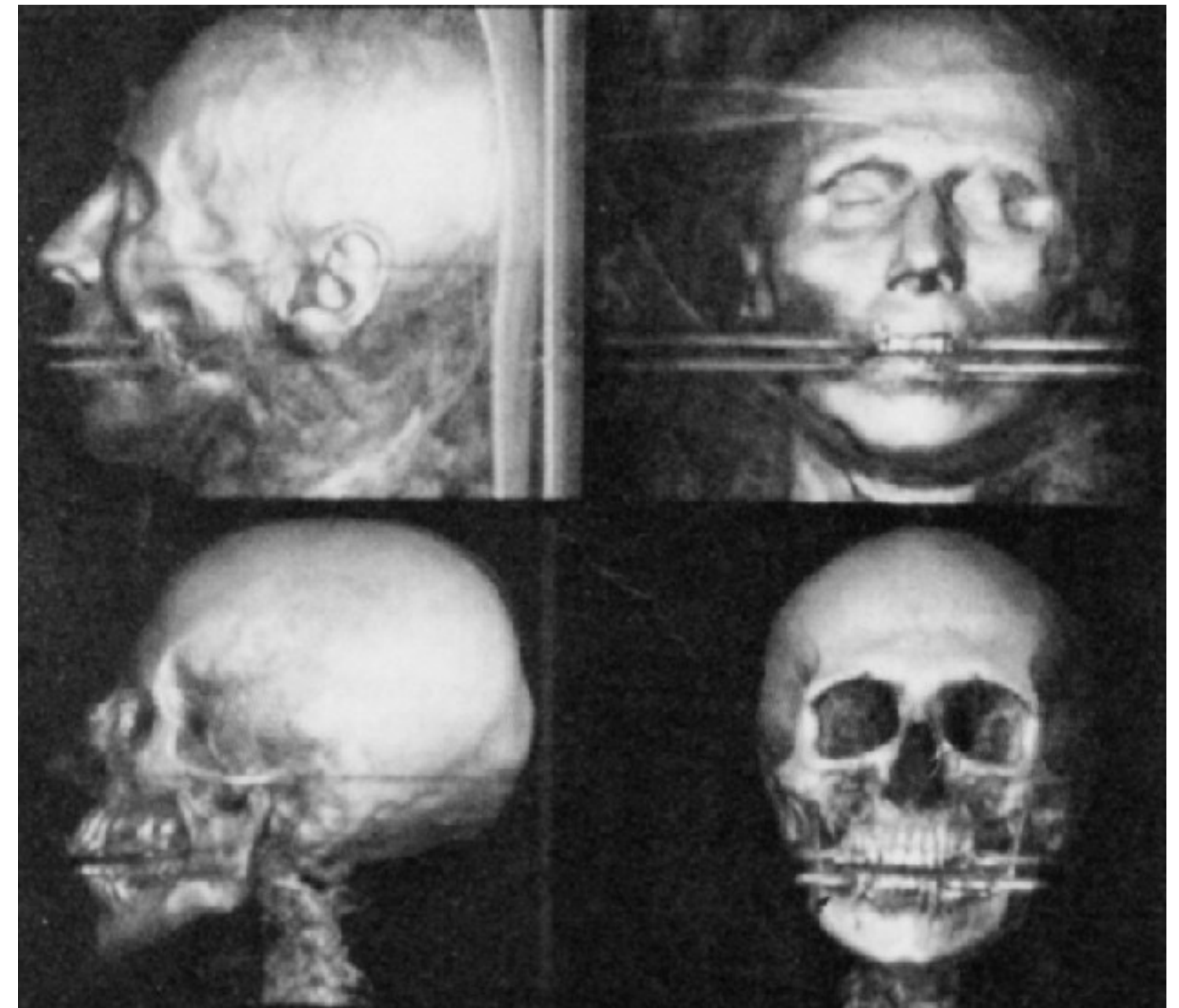


# "Every voxel contributes to image"

- Basic Idea of Volume Rendering
  - Greater flexibility

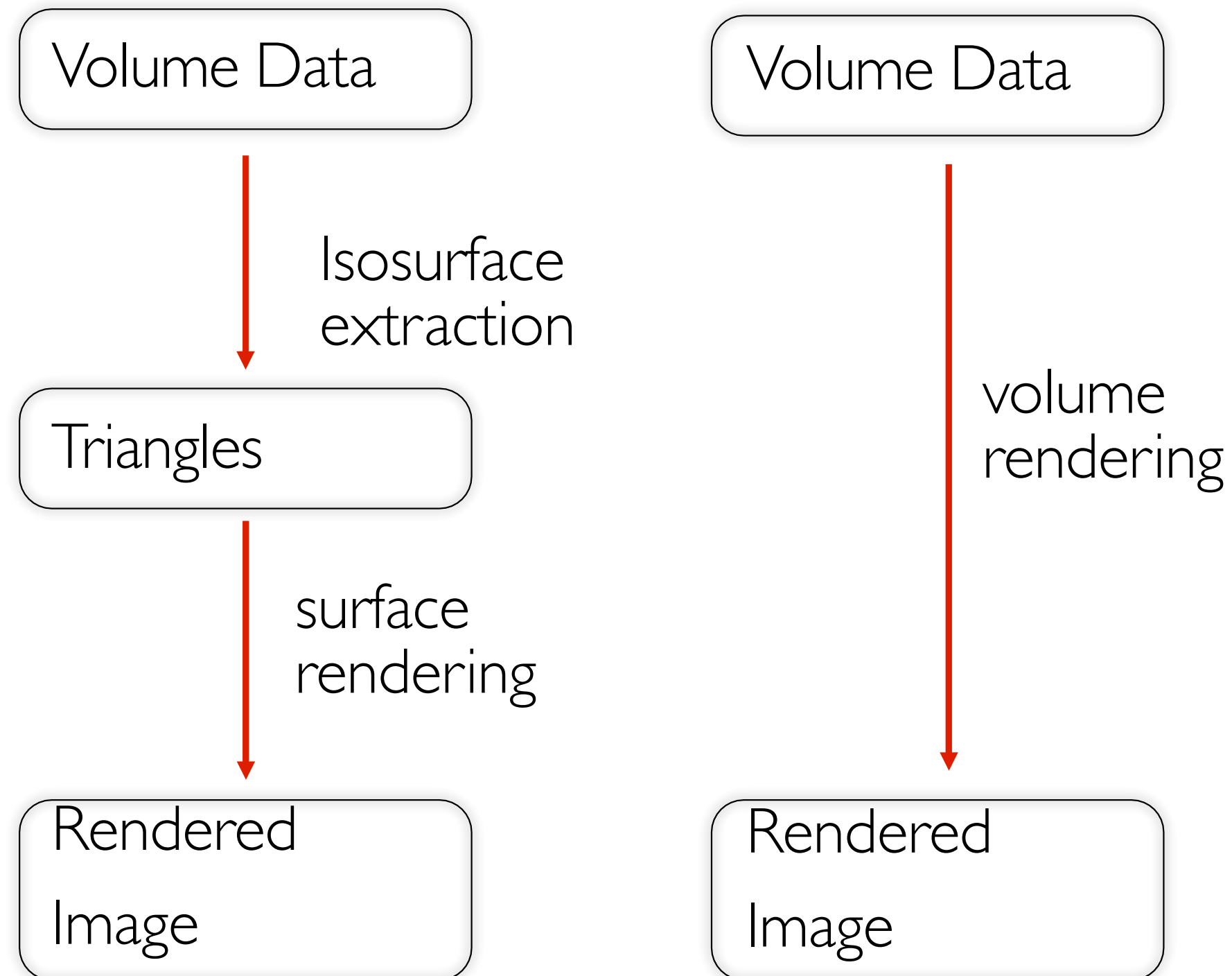
Marc Levoy, 1988

*"Display of Surfaces from  
Volume Data"*



# Pipelines: Isosurface vs. Volume Rendering

*"no intermediate geometric structures"*

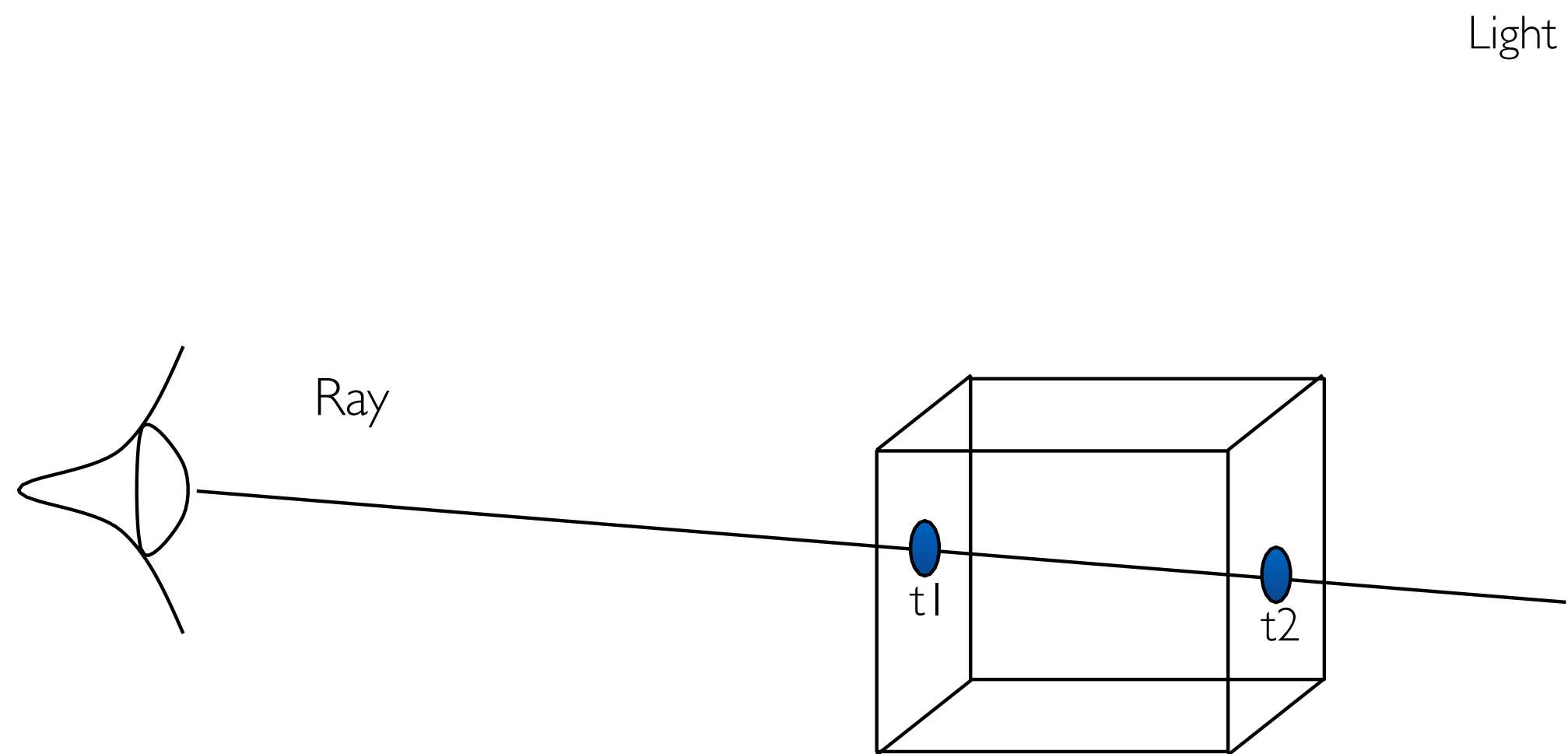




# Direct volume rendering

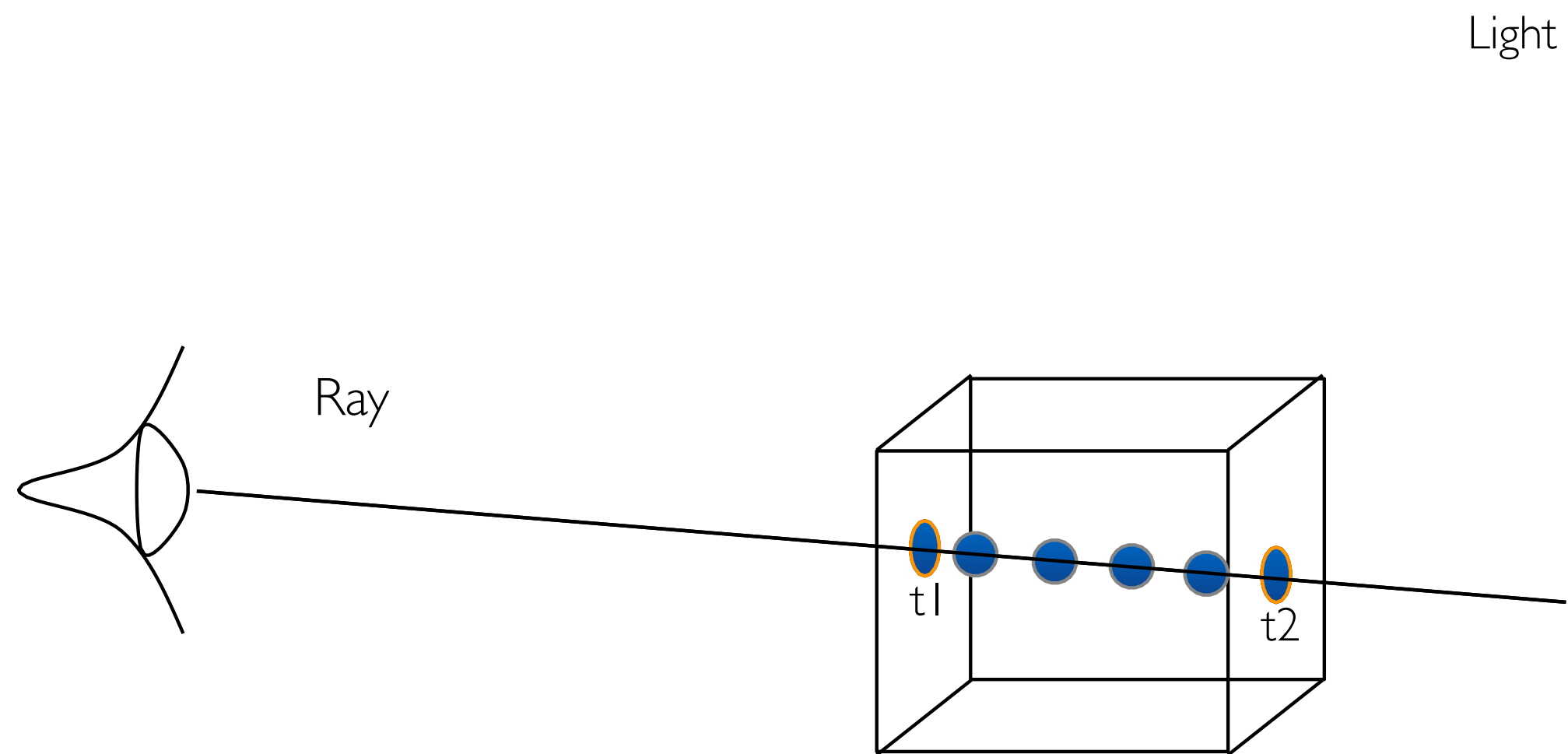
- Directly get a 3D representation of the volume data
- The data is considered to represent a semi-transparent light-emitting medium
  - Even gaseous phenomena can be simulated
- Approaches are based on the laws of physics (light emission, absorption, scattering)
- The volume data is used as a whole (look inside, see all interior structures)

# Basic diagram

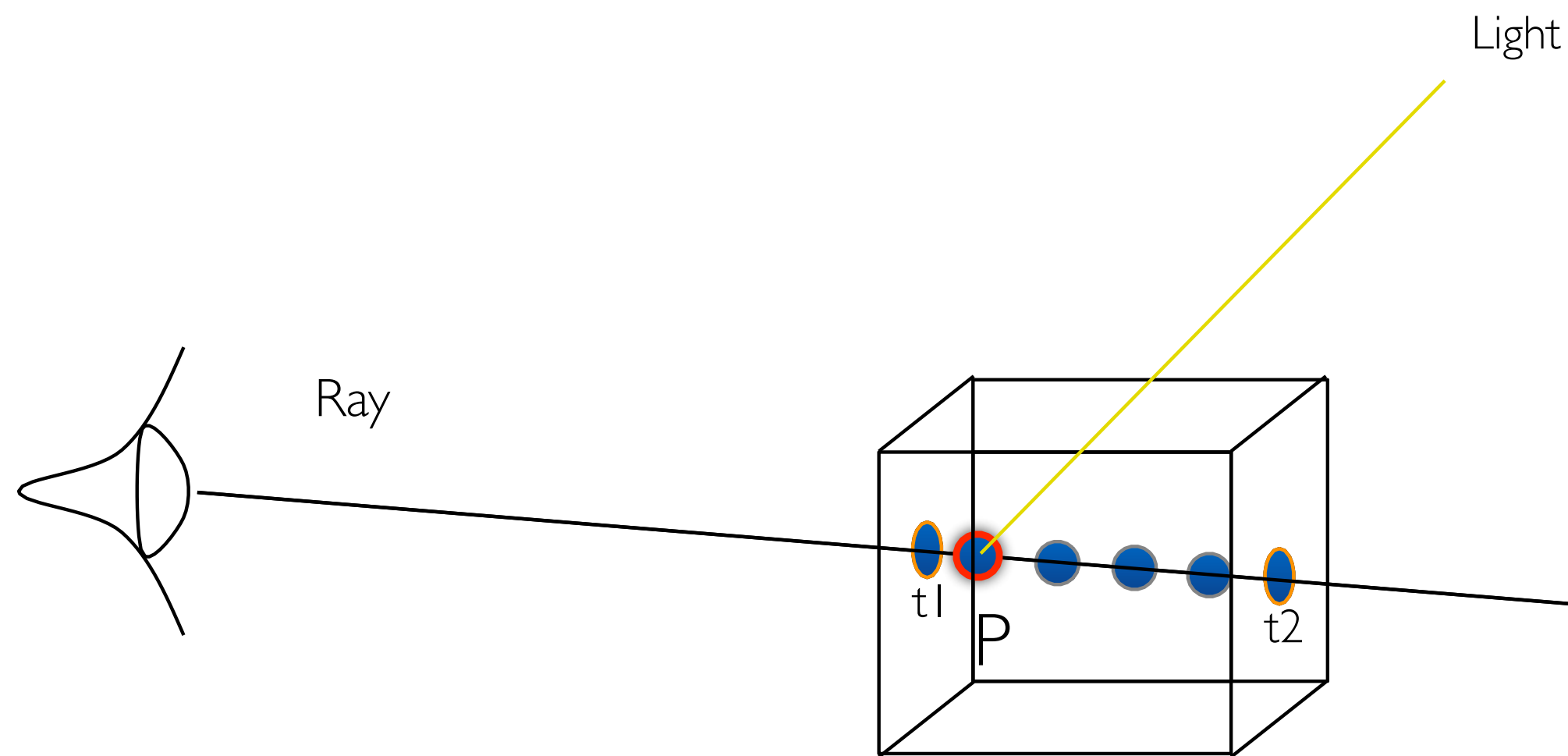




# Basic diagram

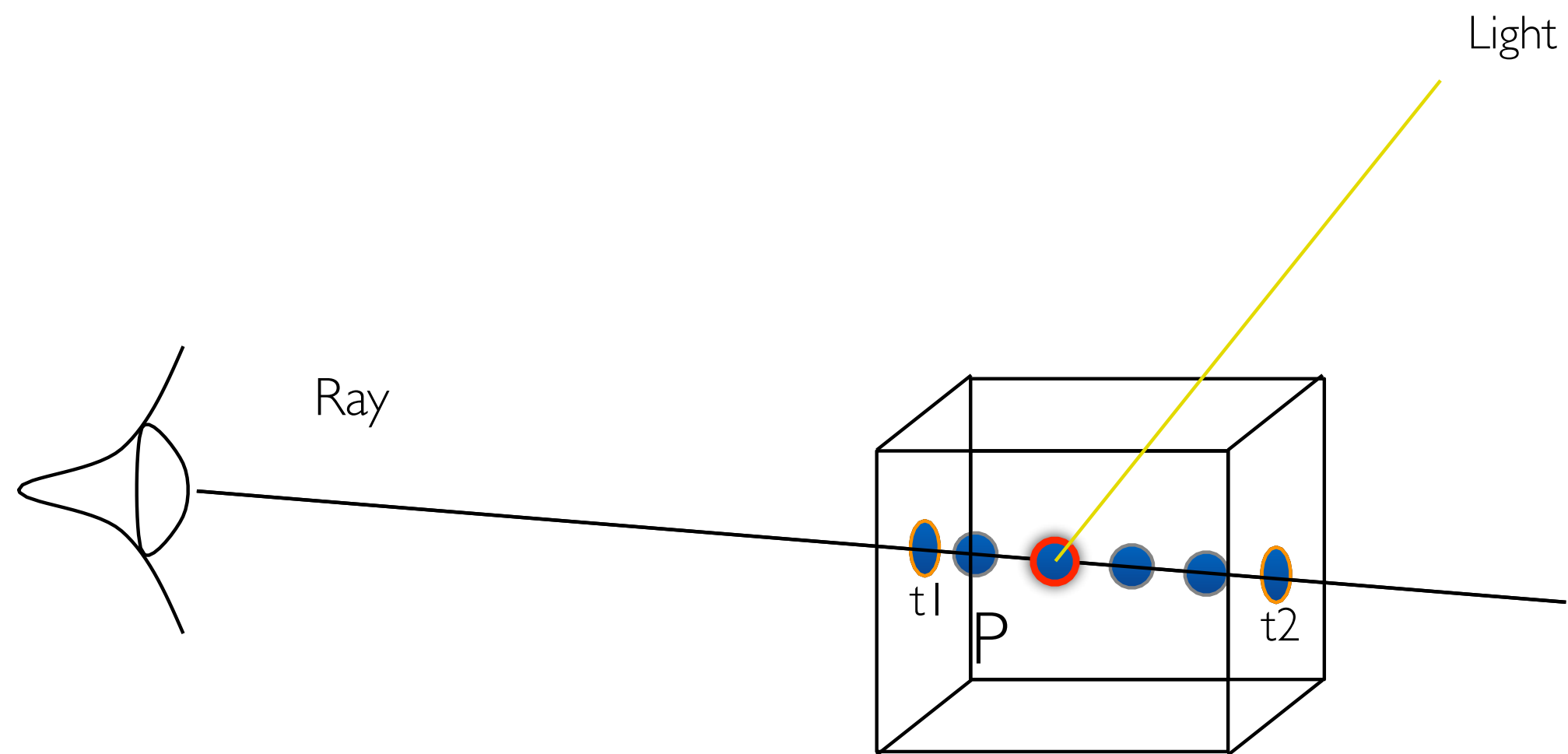


# Basic diagram

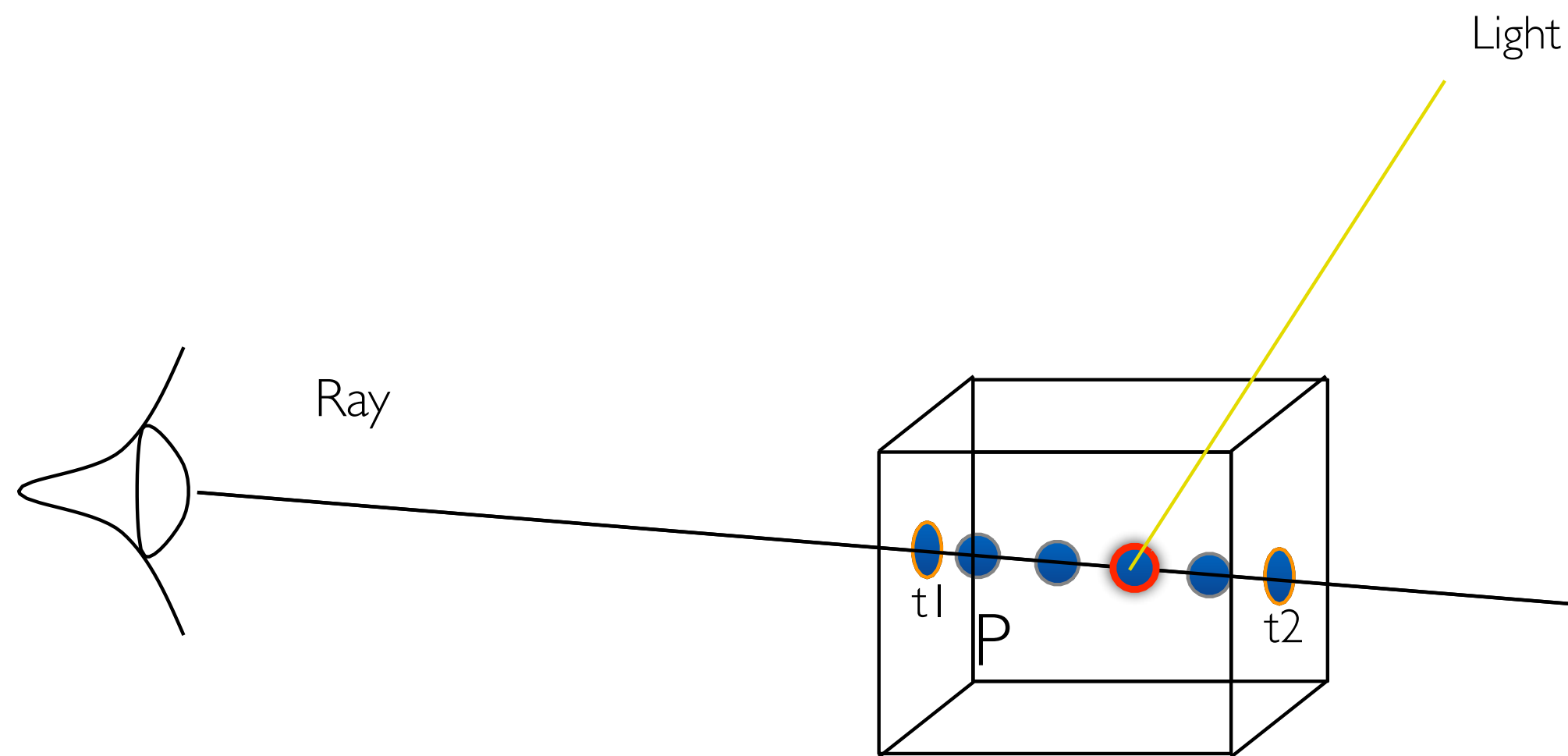




# Basic diagram

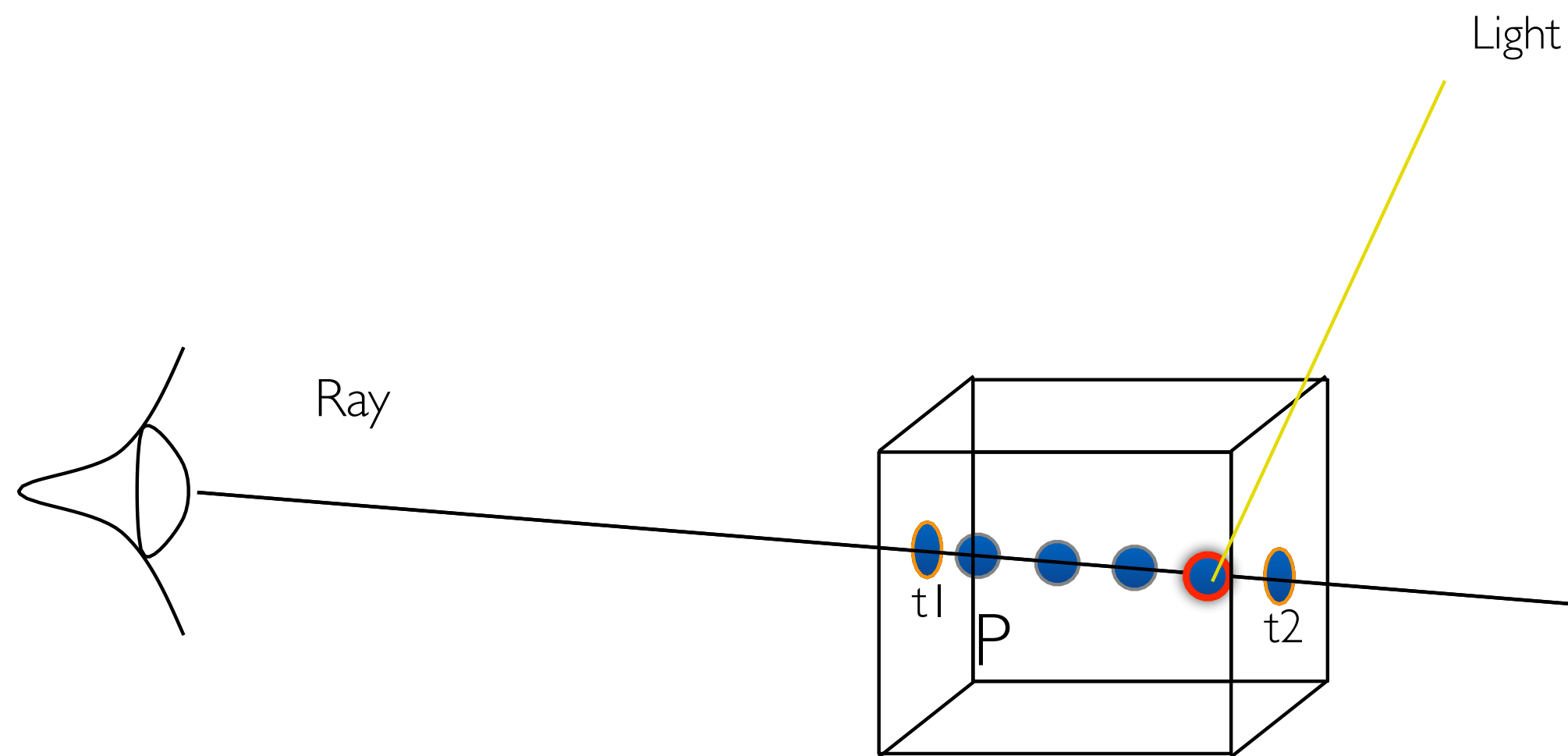


# Basic diagram

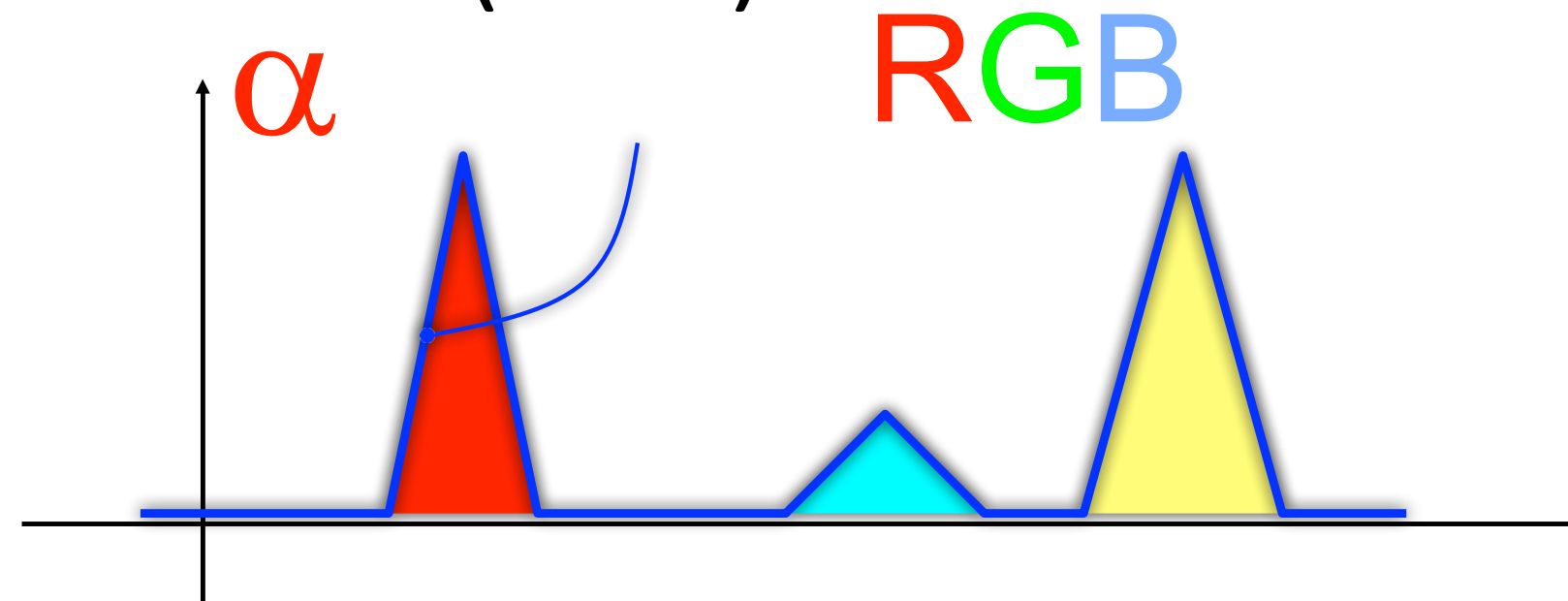




# Basic diagram



# Simulating Material Properties with Transfer Functions (TFs)

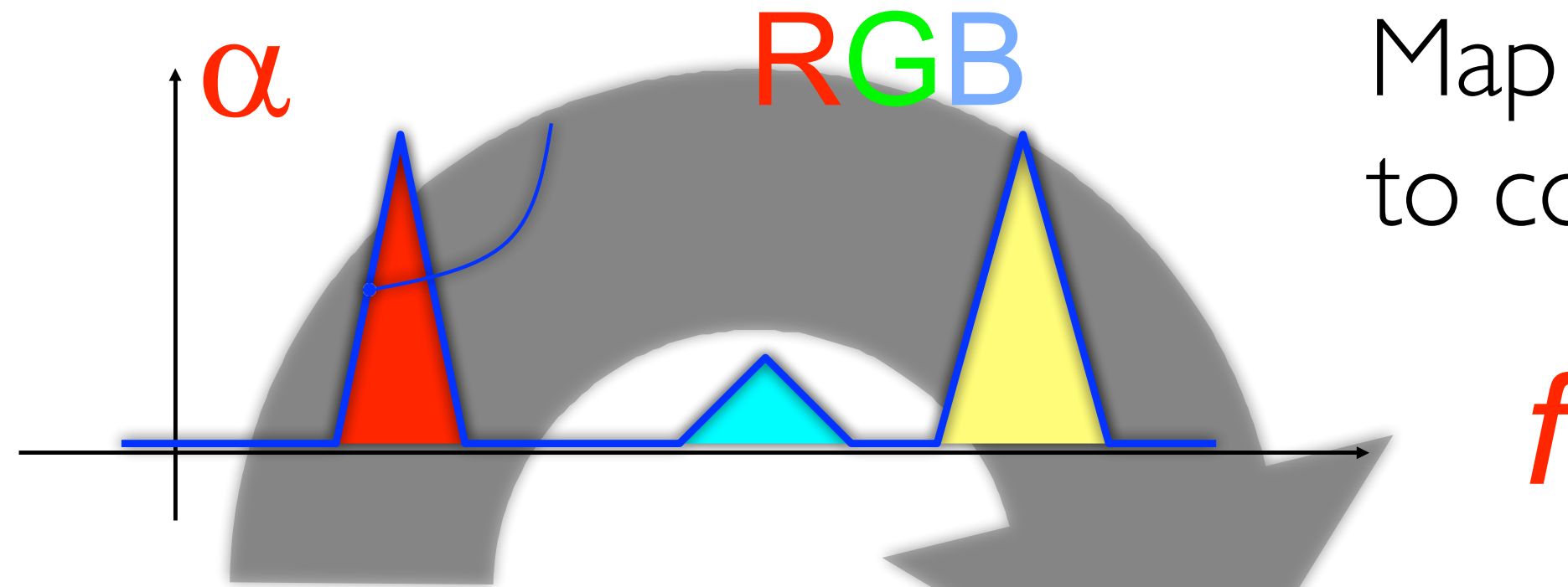


Map data value  $f$   
to color and opacity

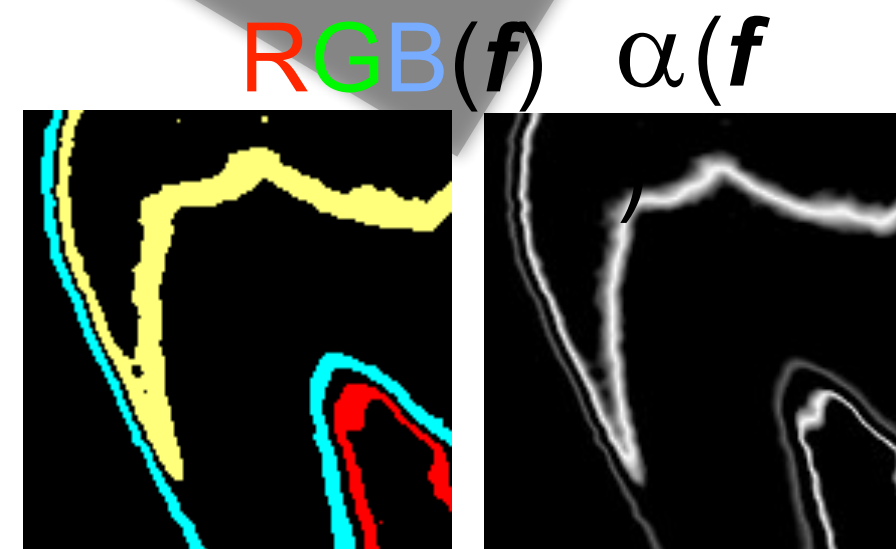
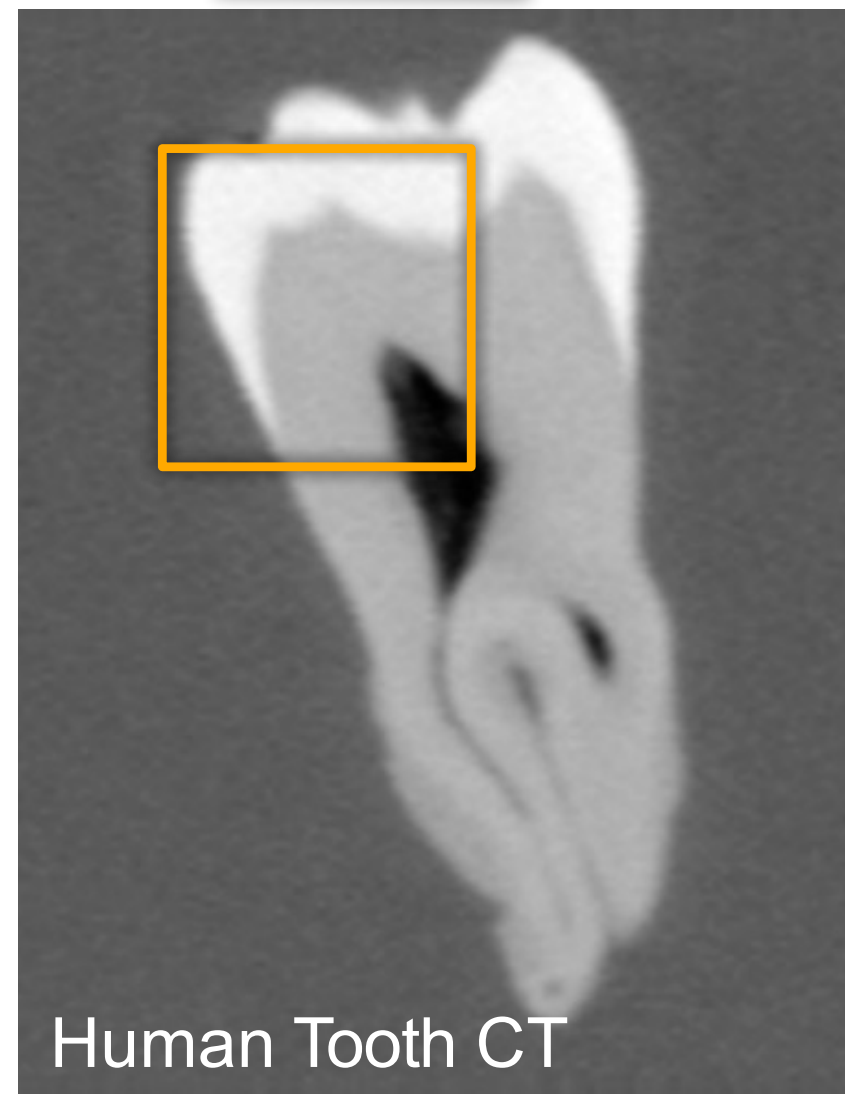
$f$



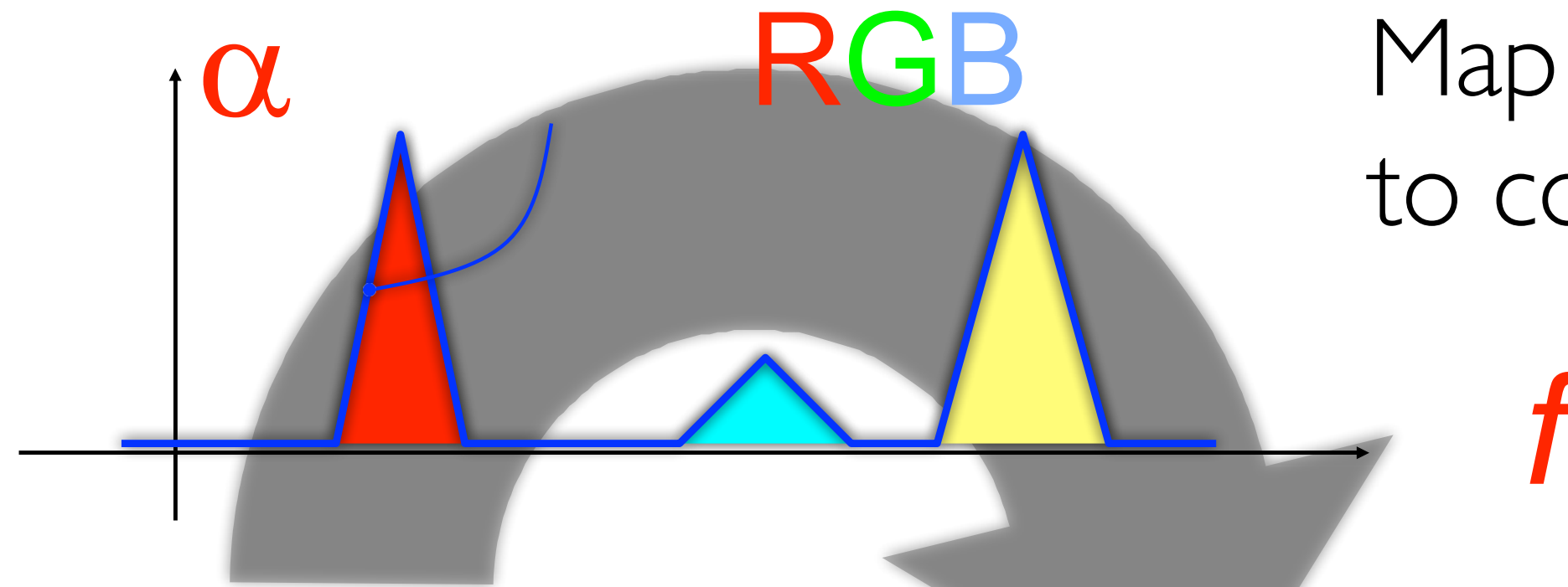
# Transfer Functions (TFs)



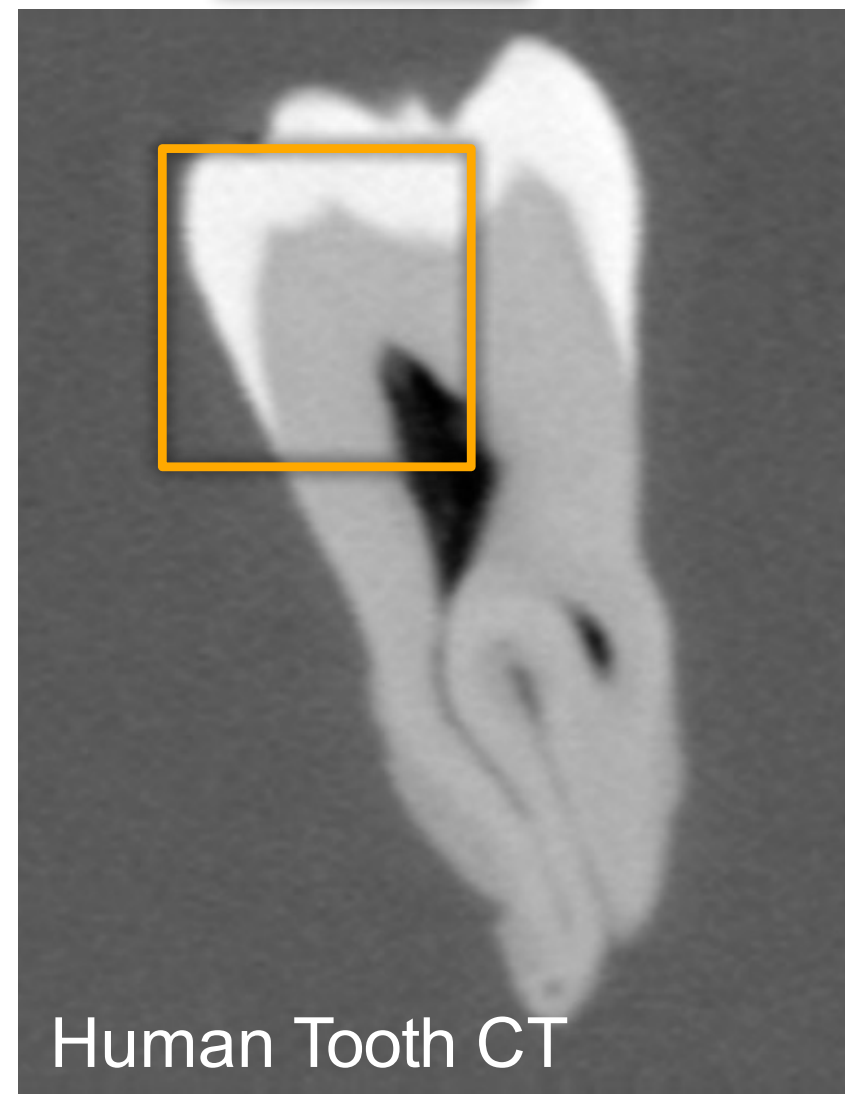
Map data value  $f$  to color and opacity



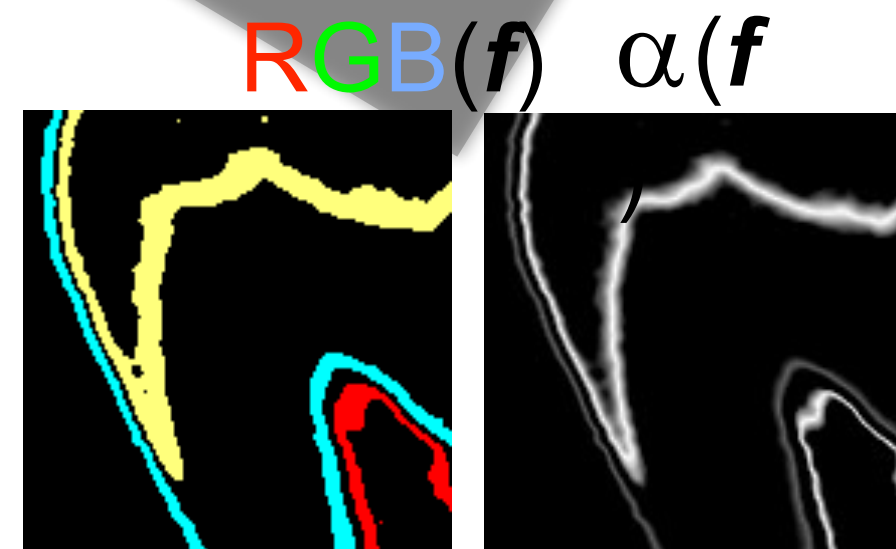
# Transfer Functions (TFs)



Map data value  $f$  to color and opacity



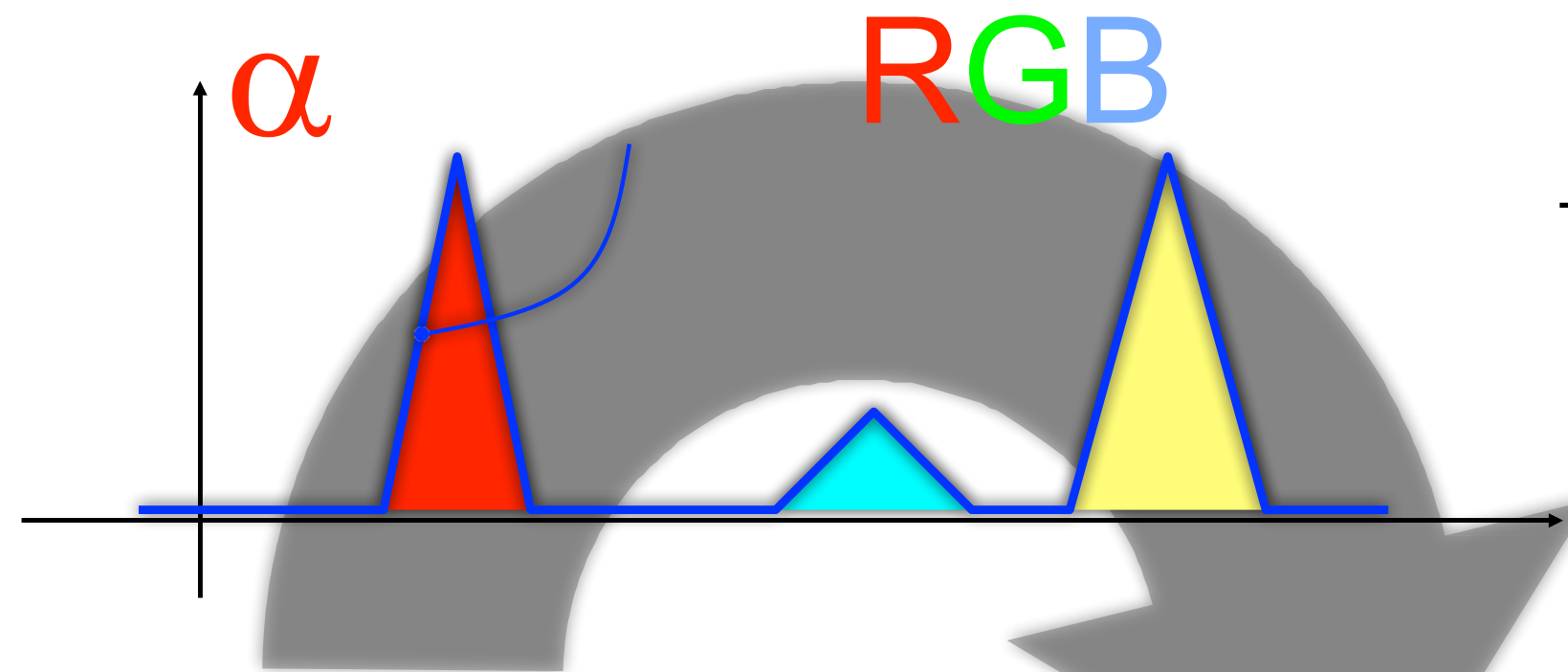
Human Tooth CT



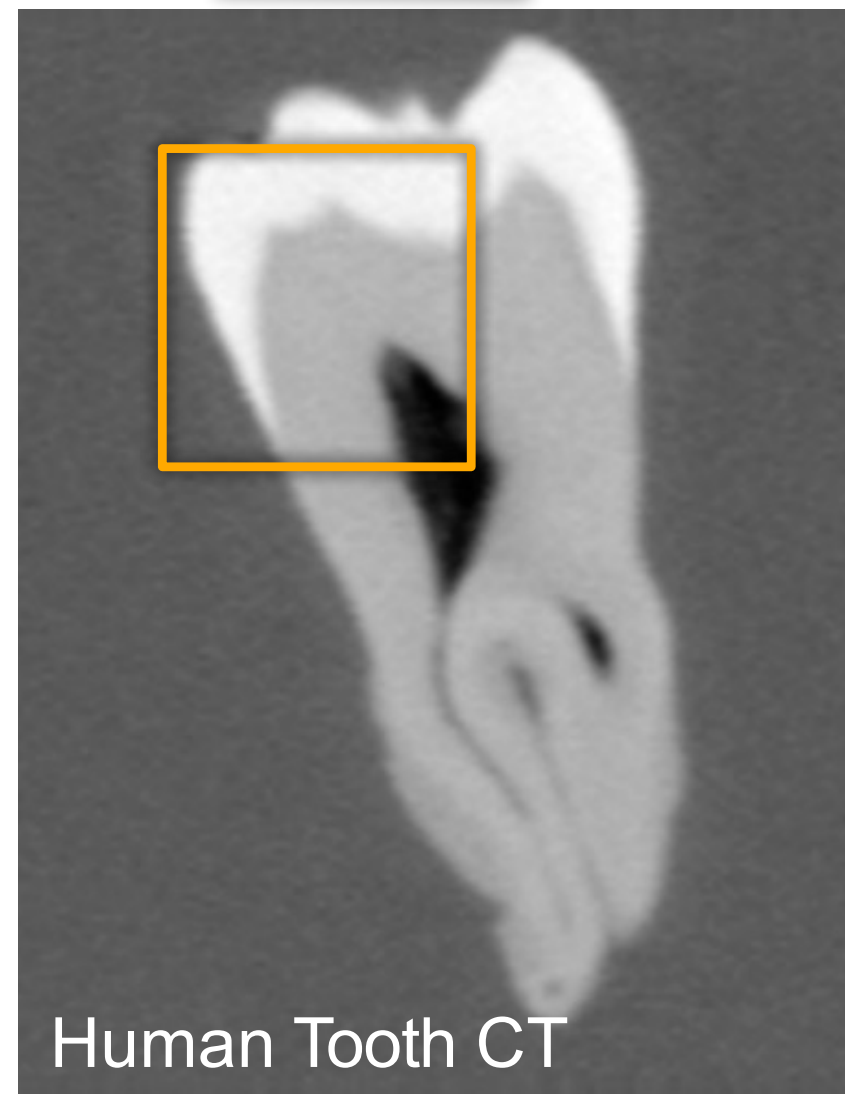
Shading,  
Compositing...



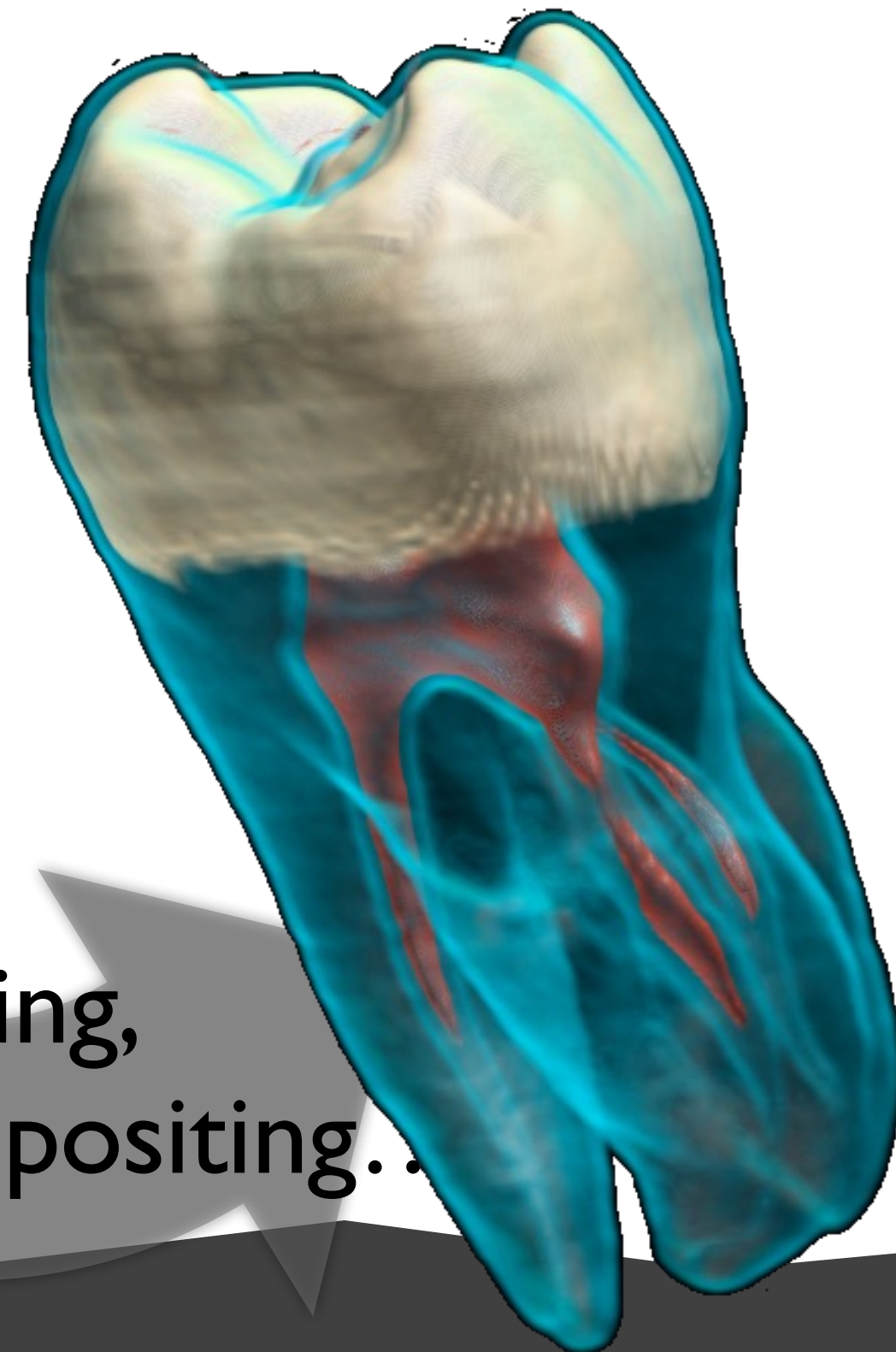
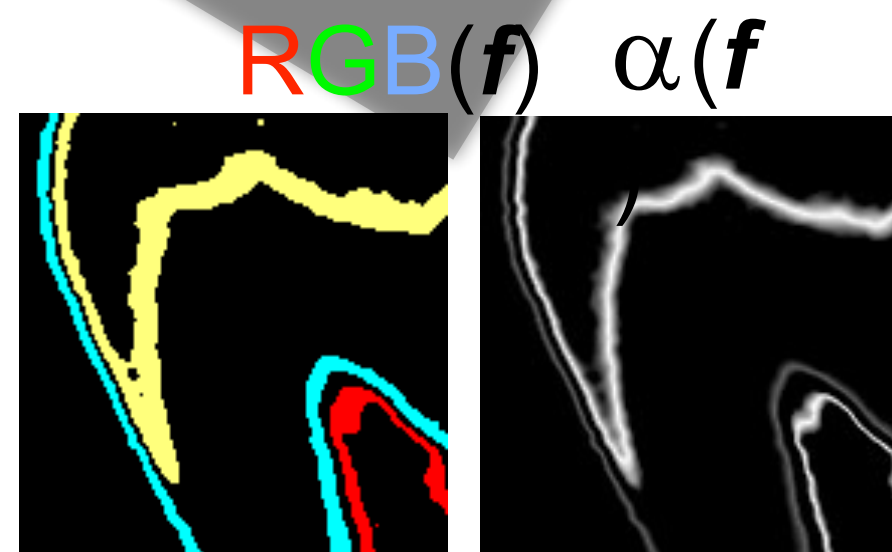
# Transfer Functions (TFs)



Map data value  $f$  to color and opacity

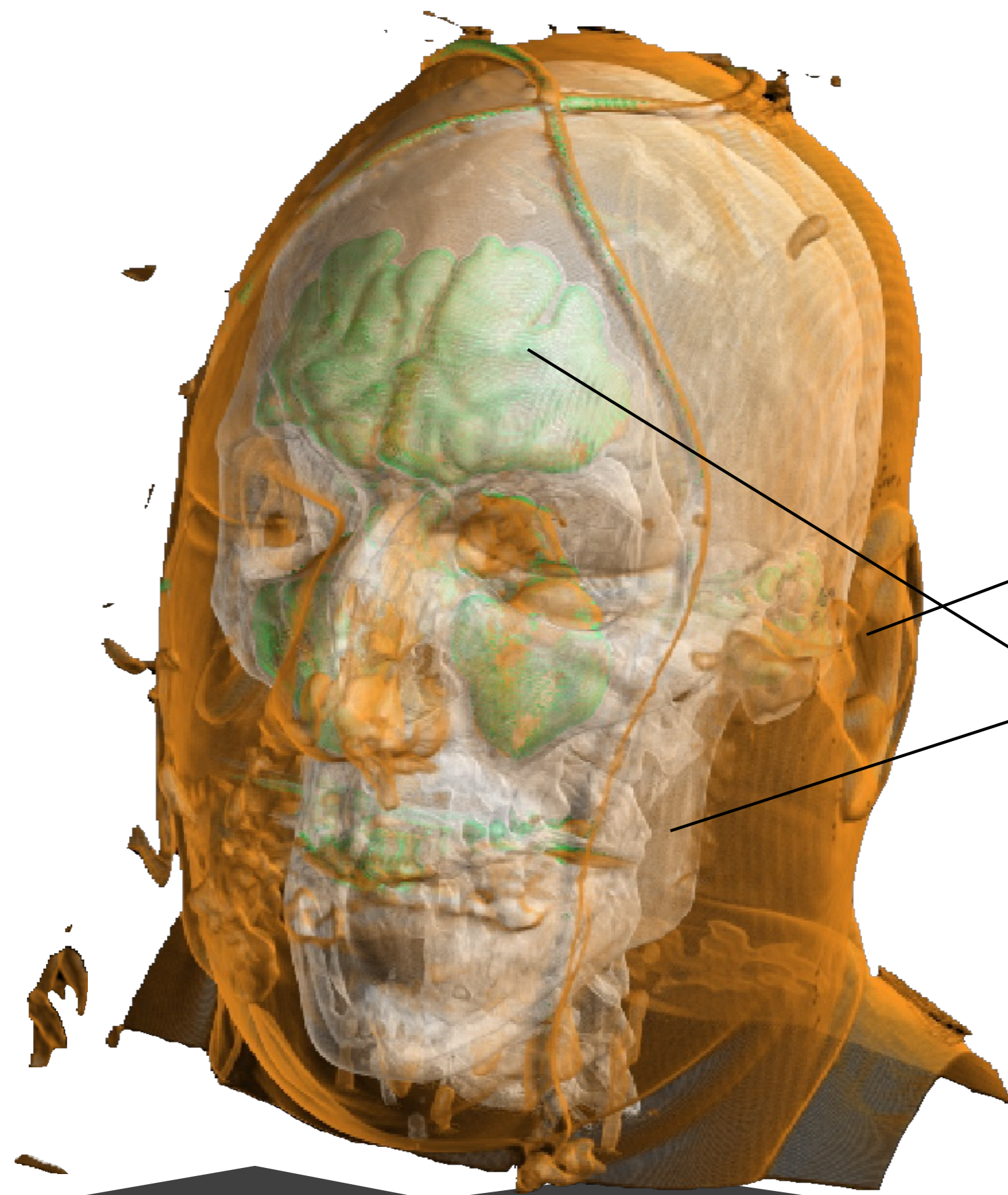


Human Tooth CT



Shading,  
Compositing...

# Volume Rendering



Transfer function, with shading

Skin/Air

Bone/Soft tissue

Bone/Air



# Volume Rendering Usefulness

- Synthetic sources of volume data
- CFD (computational fluid dynamics) Voxelization of discrete geometry

