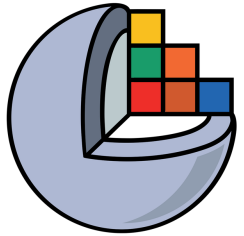


3D Slicer

SlicerMorph workshop

- Chi Zhang
- Postdoctoral fellow
- Dr. Murat Maga's lab
- Seattle Children's Research Institute

3D Slicer and SlicerMorph

- 3D Slicer
  - An open-source biomedical imaging platform
  - Many customized extensions
  - A community of developers and researchers (Forum: https://discourse.slicer.org)

- The SlicerMorph extension
  - A sub-community of Slicer: https://github.com/SlicerMorph/SlicerMorph
  - A toolkit for biologists and biological anthropologists
  - Build protocols and a community for 3D data sharing and collection

Plan for today

- Overview of 3D Slicer interface & resources
- 3D volume segmentation
- The Markup module & other SlicerMorph utilities
- The GPA module
- Load SlicerMorph & 3D Slicer landmark data into R
  - Using SlicerMorphR R package

3D Slicer user interface and I/O

- UI: User Interface — 3D Slicer documentation
- Extension Manager: Getting Started — 3D Slicer documentation
  - Install SlicerMorph: SlicerMorph installation
- Loading & Saving data: https://slicer.readthedocs.io/en/latest/user_guide/data_loading_and_saving.html

Load CT image series using SlicerMorph utilities

- ImageStacks module for general image series (Tutorials/README.md at main · SlicerMorph/Tutorials (github.com))

- SkyScanReconImport module for SkyScan Bruker microCT image series (https://github.com/SlicerMorph/Tutorials/blob/main/SkyscanReconImport/README.md)

- GEVolImport module for GE Tome microCT scanner: https://github.com/SlicerMorph/SlicerMorph/tree/master/GEVolImport

DICOM (Digital Imaging and Communication in Medicine)

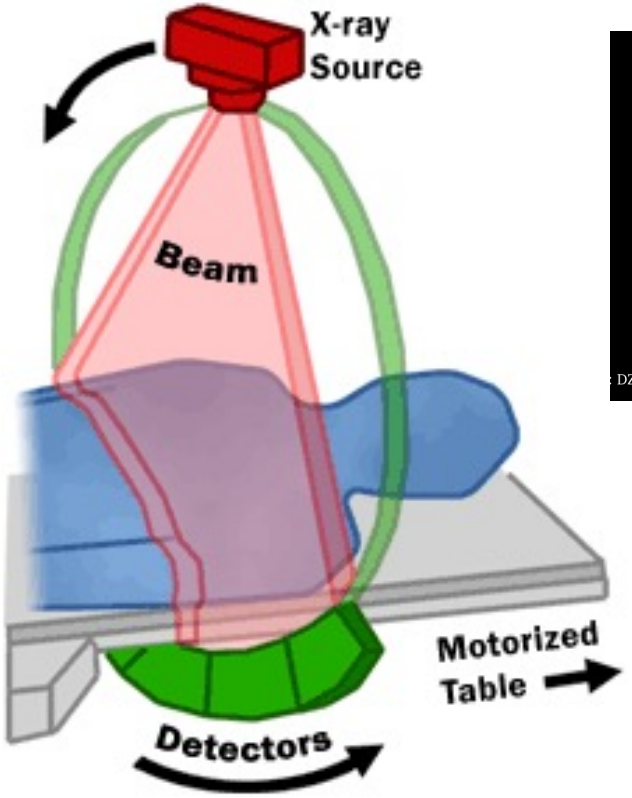
- DICOM official website: https://www.dicomstandard.org/current

- Recommend using external DICOM converter, such as DCM2NIIX, to convert into Slicer compatible format for volumetric data (e.g., NRRD or NIFTI)

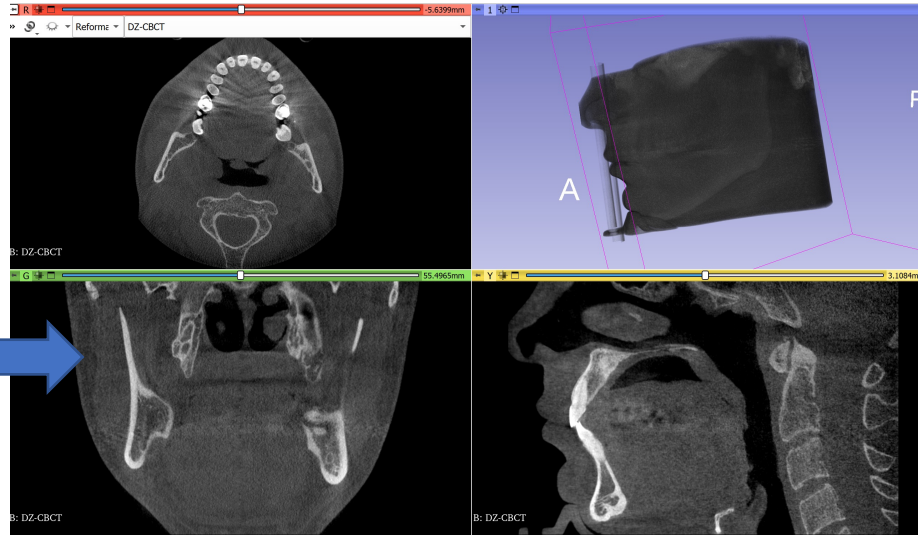
- Add DICOM Data module in 3D Slicer: https://github.com/SlicerMorph/Spr_2021/blob/main/Day_1/DICOM/DICOM.md

Biomedical imaging basics

- CT scanning (X-ray → detector)
  - 2D CT image stack/series → reconstruction → 3D volume
  - CT images are intensity maps: X-ray absorption

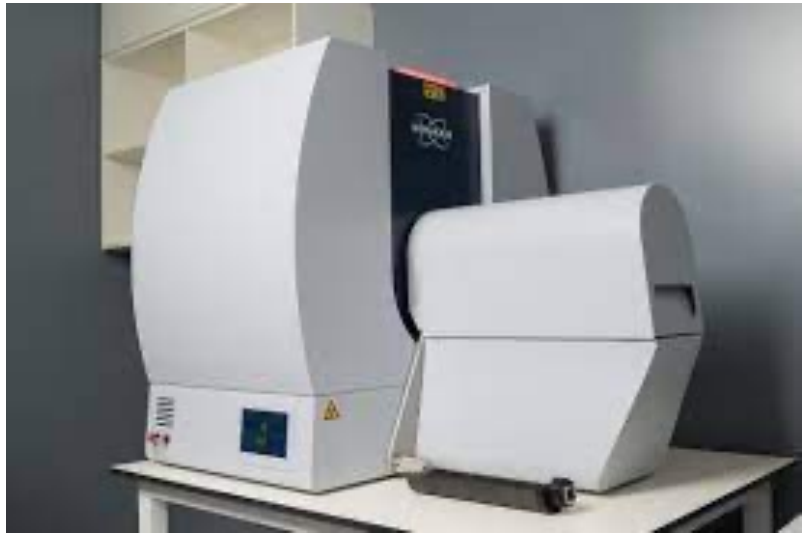


2D CT image stack

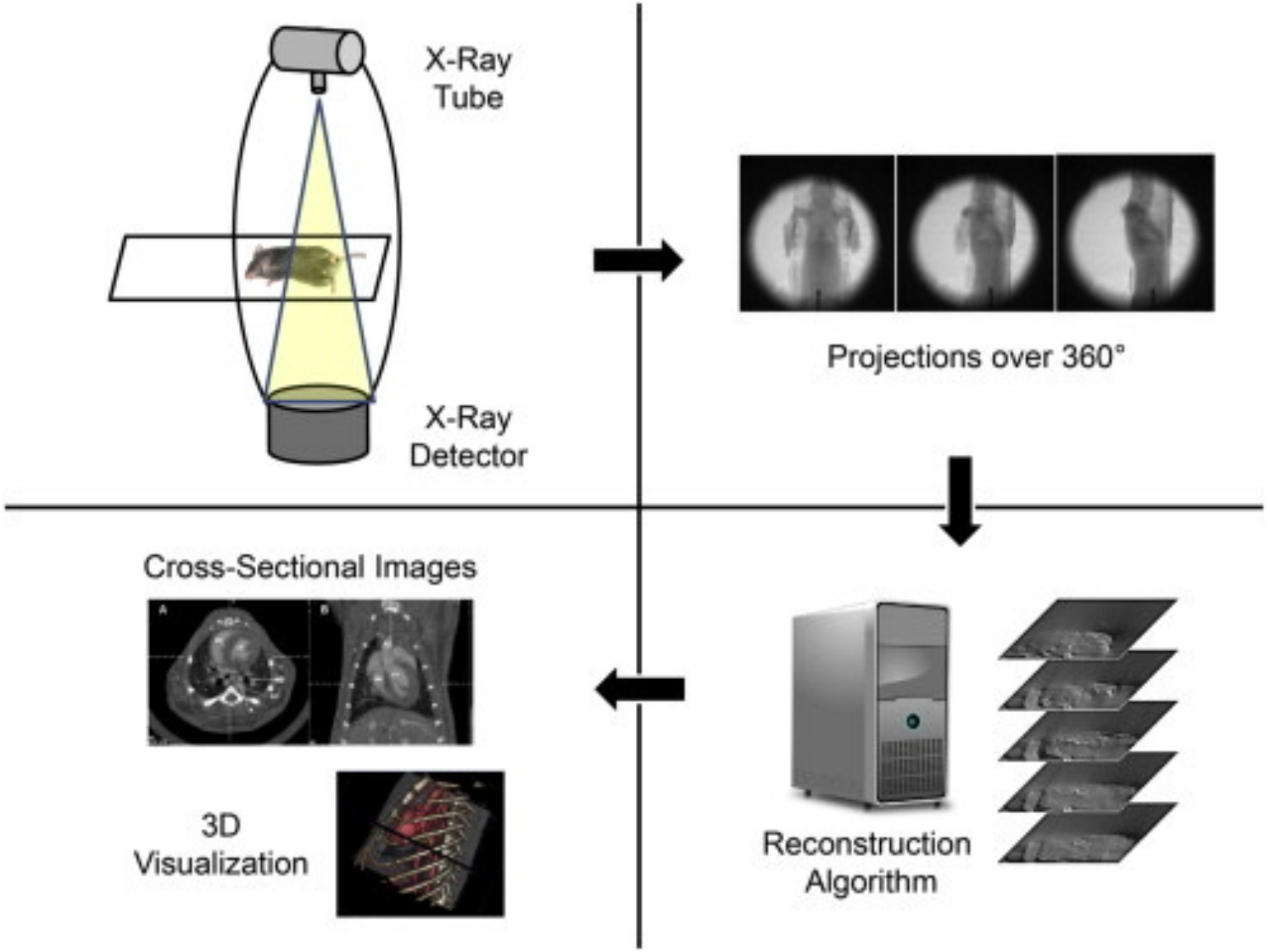


Software reconstruction:
3D volume (3D cross sectional images)

MicroCT (unit: micron or even nanometer)

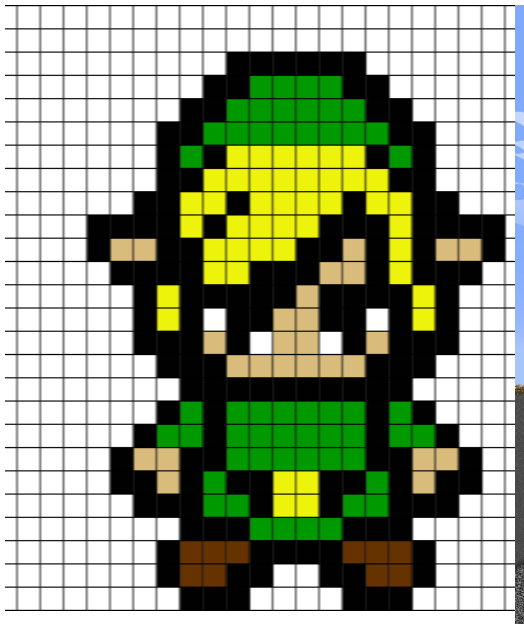


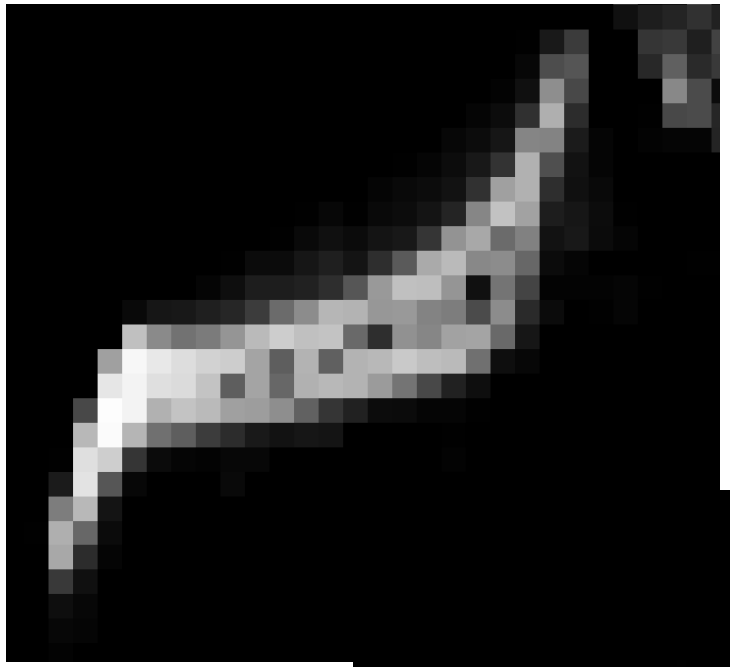
Skyscan Bruker microCT

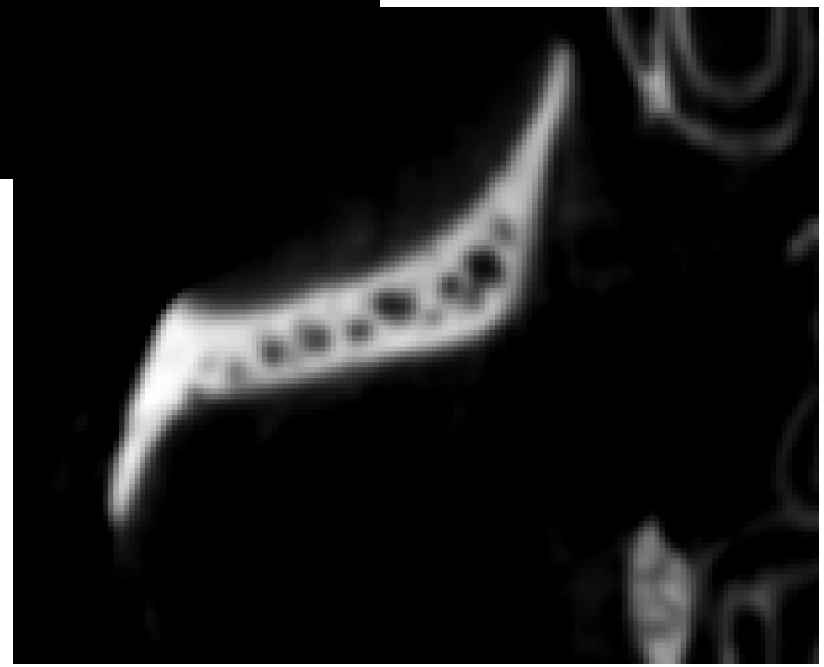


Resolution of volume: pixels and voxels

- Pixels: smaller pixel = higher resolution
- Pixel value: intensity value







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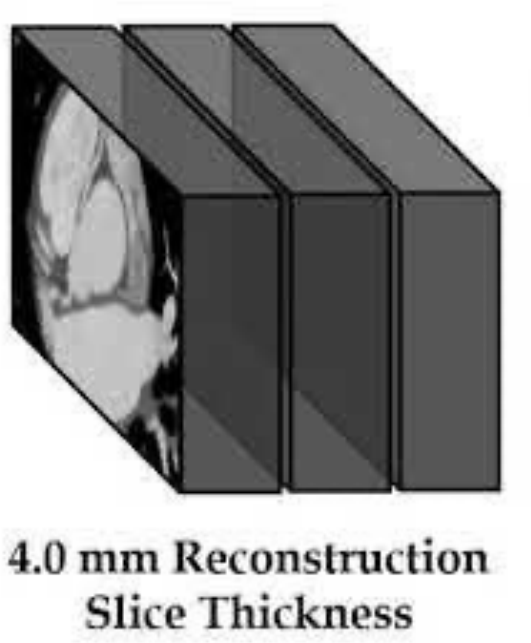
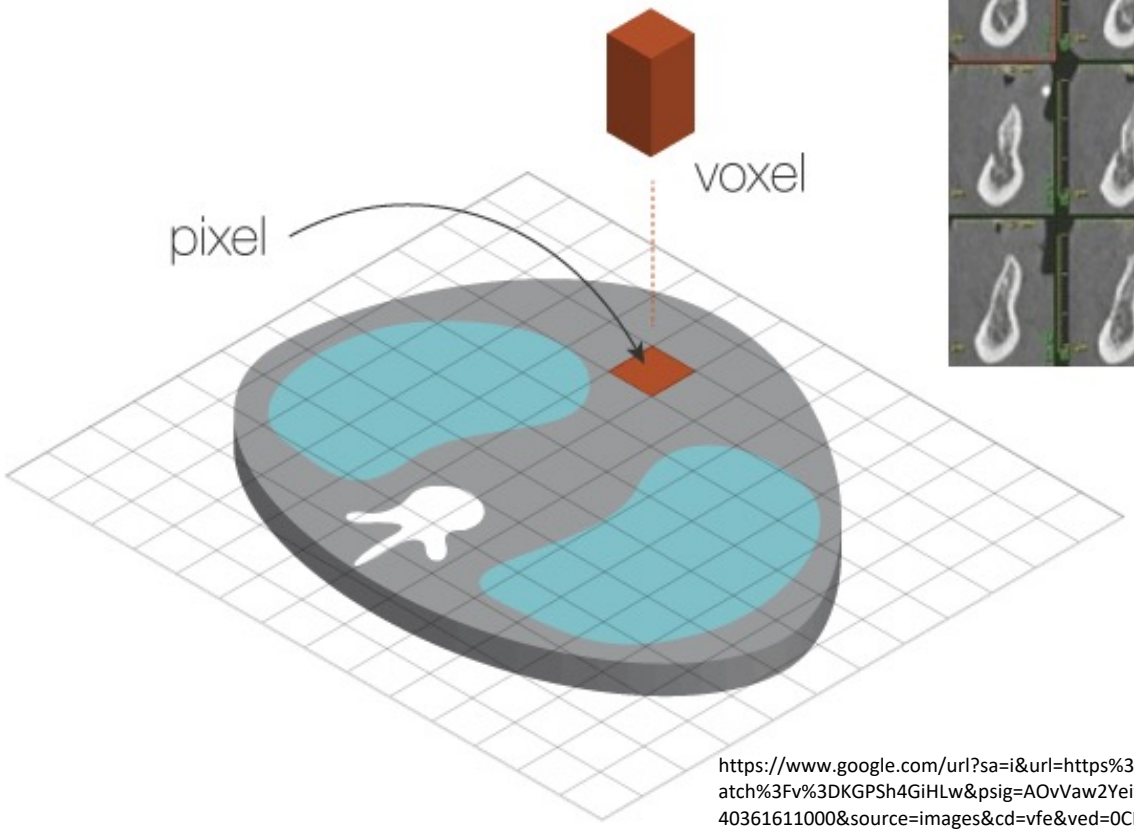
https://www.planetminecraft.com/project/toon-link-the-continuing-story-of-my-nintendozelda-pixel-art-obsession/

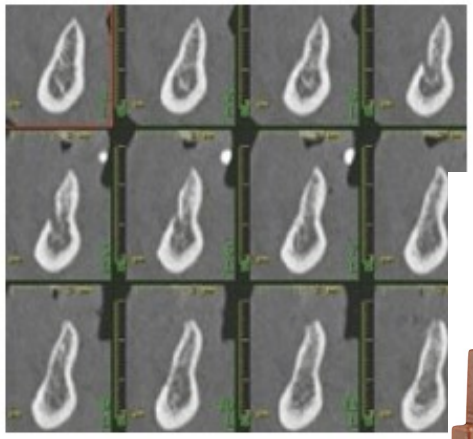
Voxels: volume pixel

- Voxels: smallest unit of 3D volume; resolution of 3D volume
  - Voxel dimensions: x & y (pixel dimensins) + z (space between images)
  - Voxel value: intensity value



https://www.google.com/url?sa=i&url=https%3A%2F%2Fradiologykey.com%2Fcomputed-tomography-12%2F&psig=AOvVaw2yaAVsqLuQzTiMEY-8IdFW&ust=1680939664364000&source=images&cd=vfe&ved=0CBAQjRxqFwoTCMjQm5-kl_4CFQAAAAAdAAAAABAT

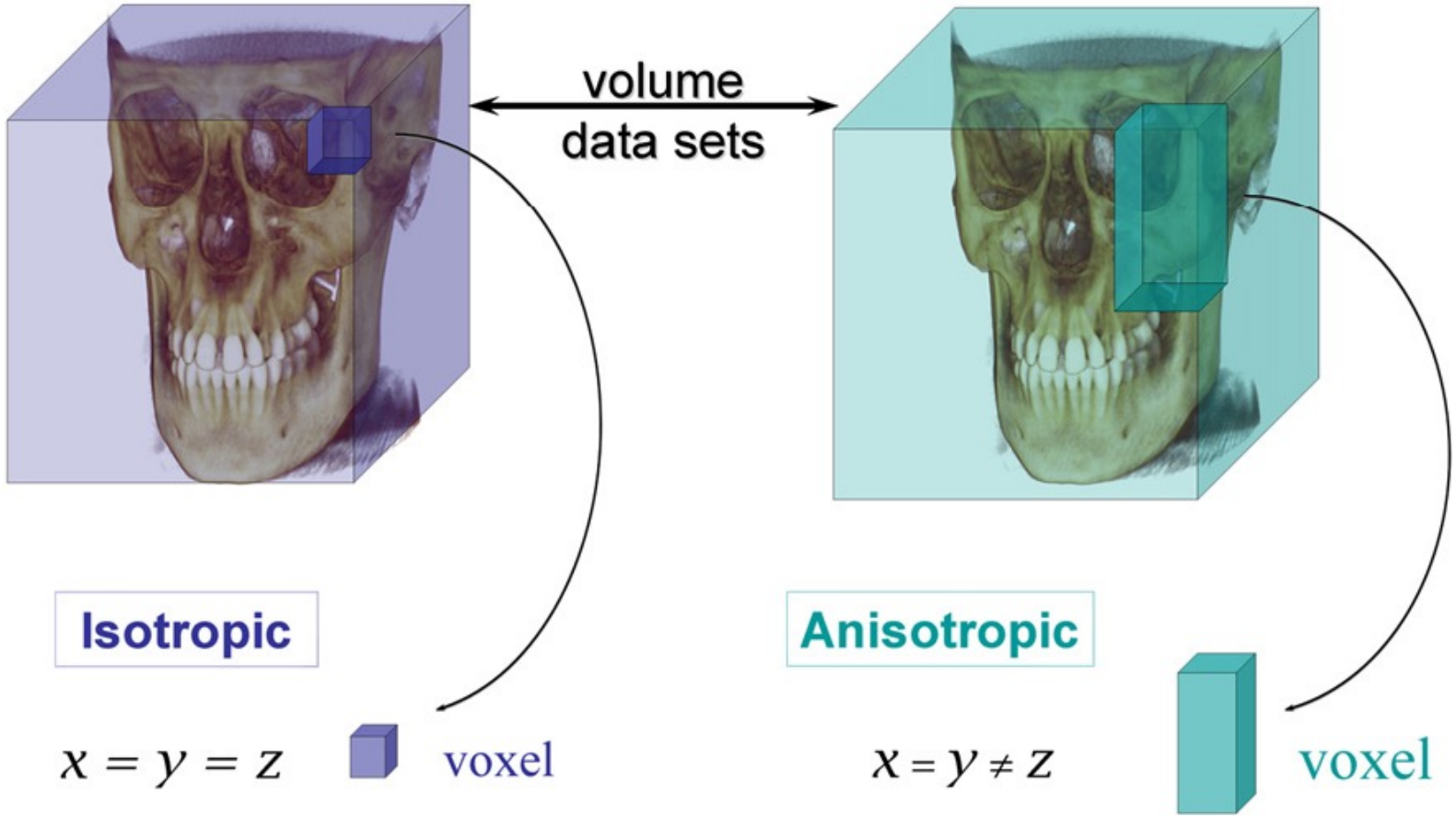




https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3DKGPSh4GiHLw&psig=AOvVaw2Yeit6msHO8RYnxN6oiskz&ust=1680940361611000&source=images&cd=vfe&ved=0CBAQjRxqFwoTCPDCnfukl_4CFQAAAAdAAAAABAI

Isotropic vs Anistropic

- **Isotropic**: identical x, y & z for each voxel; microCT
- **Anistropic**: unidentical x, y & z (usually z is larger); some medical CT



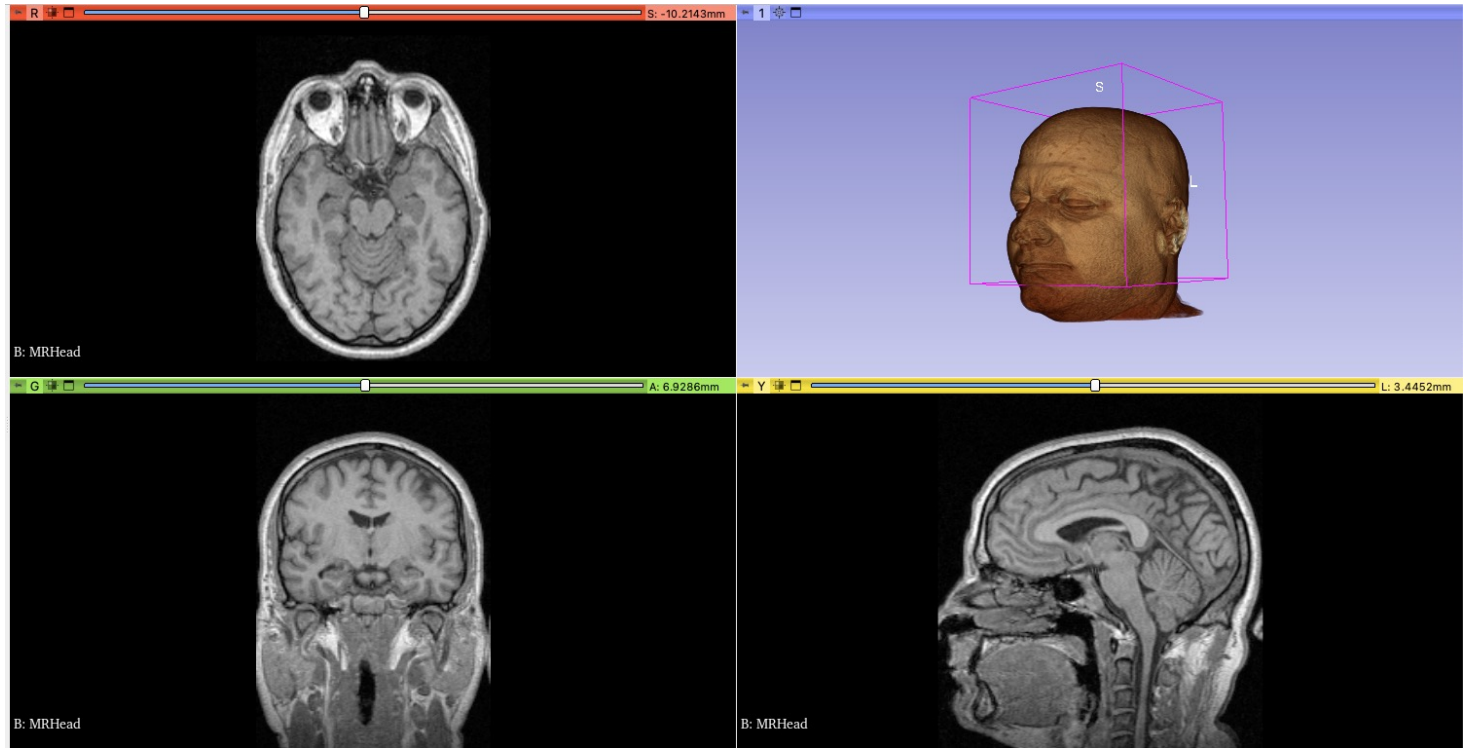
https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.semanticscholar.org%2Fpaper%2FWhat-is-cone-beam-CT-and-how-does-it-work-Scarfe-Farman%2Fd9be4743ecdf022d40491dba0ad39409bf7896ec&psig=AOvVaw3kOwZpYrSbdIErUdrb-Xcd&ust=1680941414777000&source=images&cd=vfe&ved=0CBAQjRxqFwoTCJDgyvyol_4CFQAAAAAdAAAAABAc

Volumes & Crop Volume

- https://github.com/SlicerMorph/Spr_2021/blob/main/Day_1/CropVolume/CropVolume_and_Volumes.md

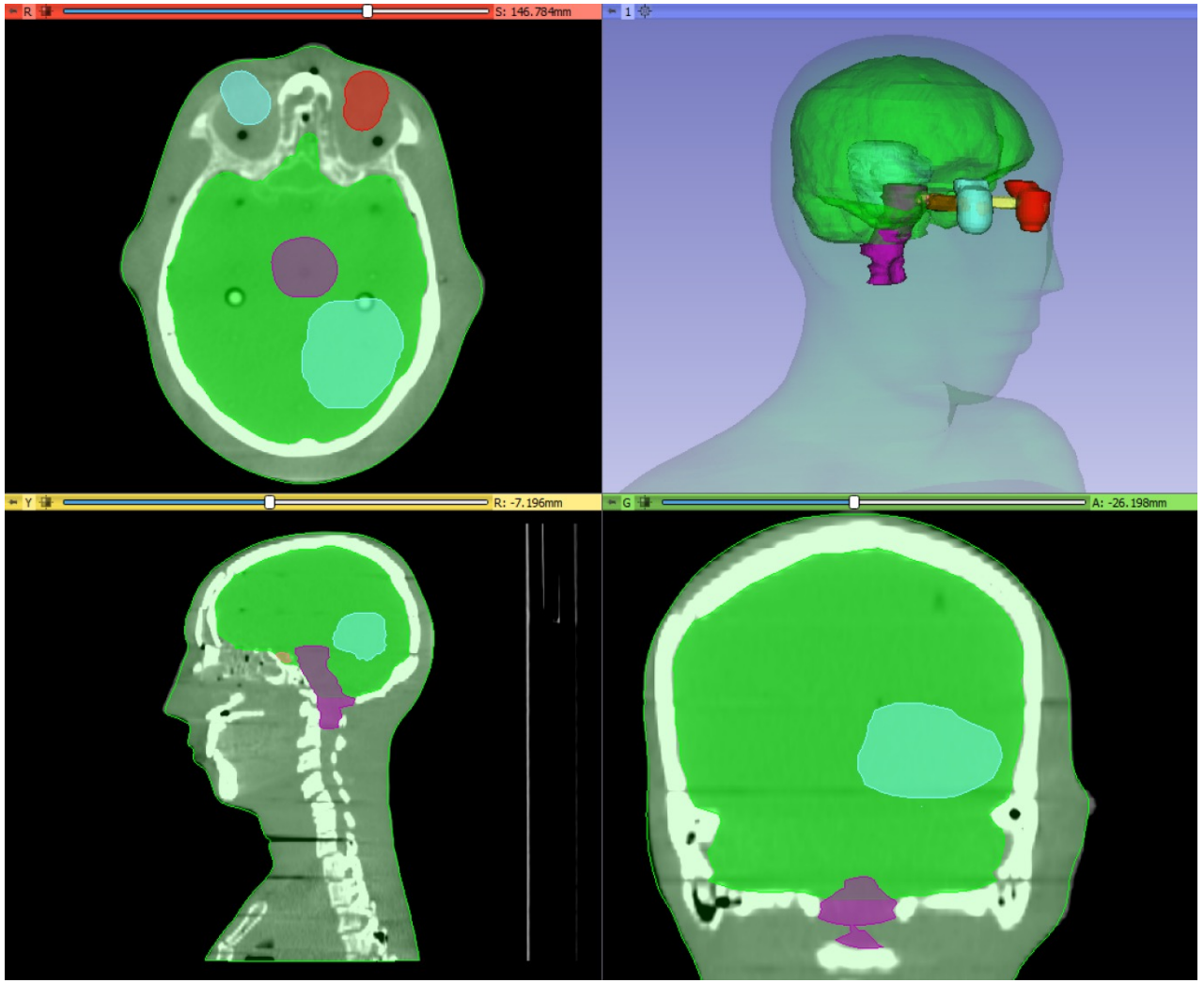
Volume rendering

- Only for visualization, not a segmentation or 3D surface model!
- **Volumes, Volume Rendering** & **Crop Volume** modules: Spr_2021/CropVolume_and_Volumes.md at main · SlicerMorph/Spr_2021 (github.com)



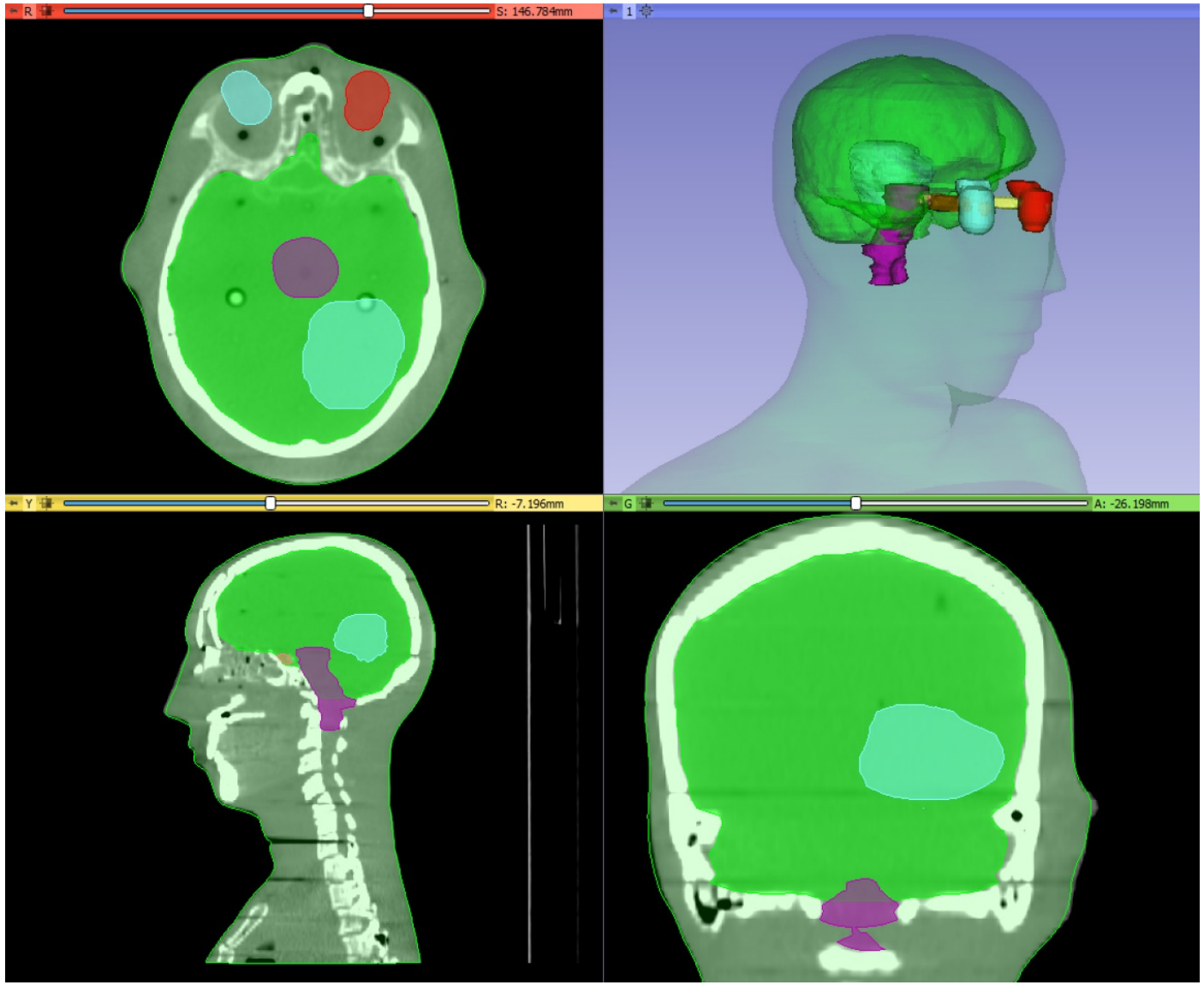
Segmentation

- A volume must be segmented
- Segmentation: select voxels into **segments** to represent regions of interests (e.g., bones, organs, blood vessels, tumor, etc.)
- https://github.com/SlicerMorph/Tutorials/tree/main/Segmentation
- https://slicer.readthedocs.io/en/latest/user_guide/image_segmentation.html



Representations of segmentation in Slicer

- Binary labelmap
  - Each voxel belongs to a unique segment
  - Also useful for deep learning auto-segmentation
- 3D representation



Export as labelmap volume & surface models

- Labelmap volume:
  - No overlap among segments
  - Save space
  - Useful for training deep learning-based automated segmentation

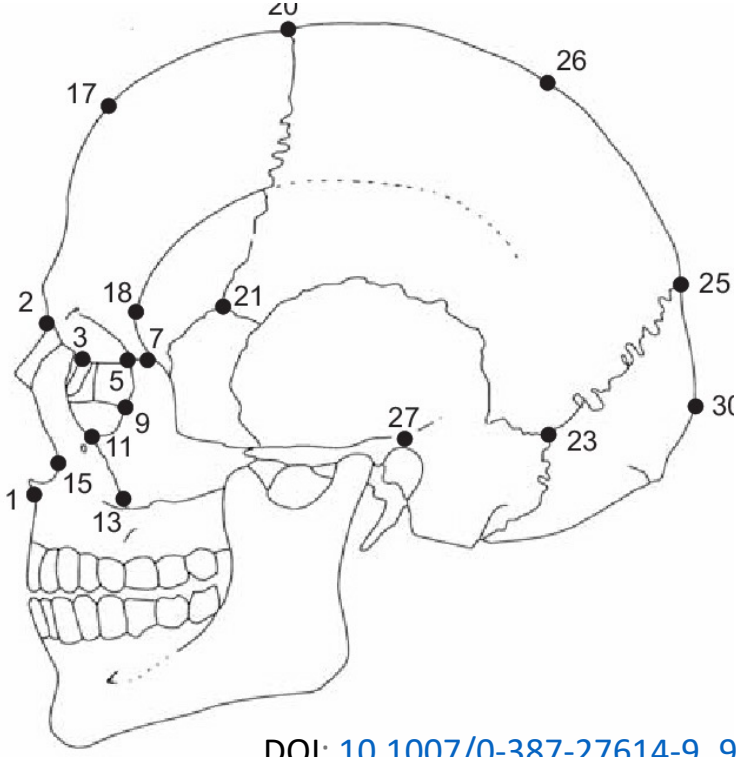
- Models: polygon models

3D surface models

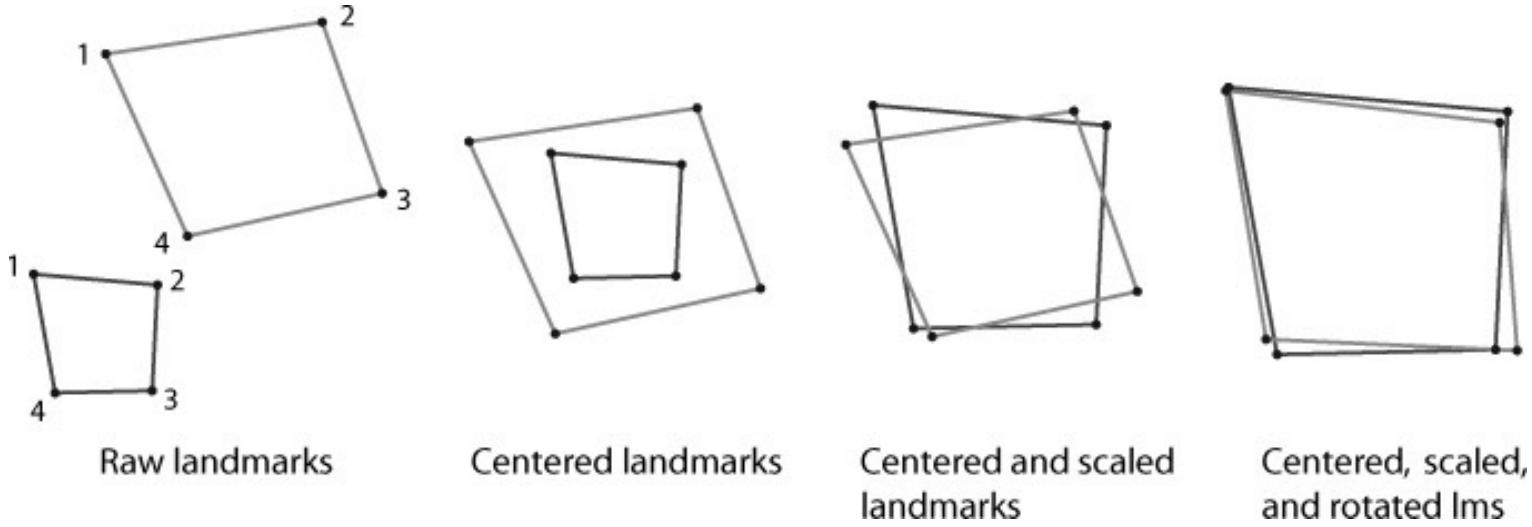
- Models module: https://github.com/SlicerMorph/Spr_2021/blob/main/Day_1/Models/Models.md
- Surface Toolbox: https://slicer.readthedocs.io/en/5.2/user_guide/modules/surfacetoolbox.html
- Dynamic Modeler: https://slicer.readthedocs.io/en/5.2/user_guide/modules/dynamicmodeler.html

Geometric morphometrics

- Placing homologous landmarks and record 3D coordinates
- Generalized Procrustes Analysis (GPA)/Procrustes superimposition



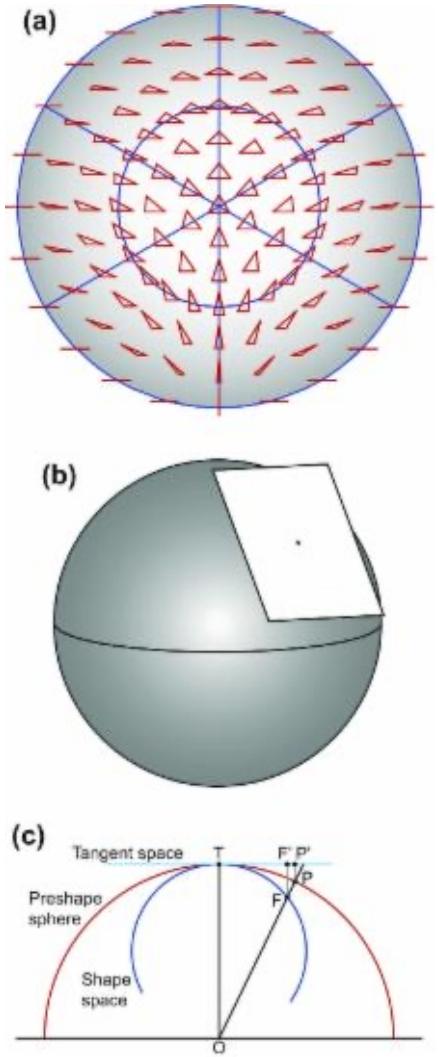
DOI: 10.1007/0-387-27614-9_9

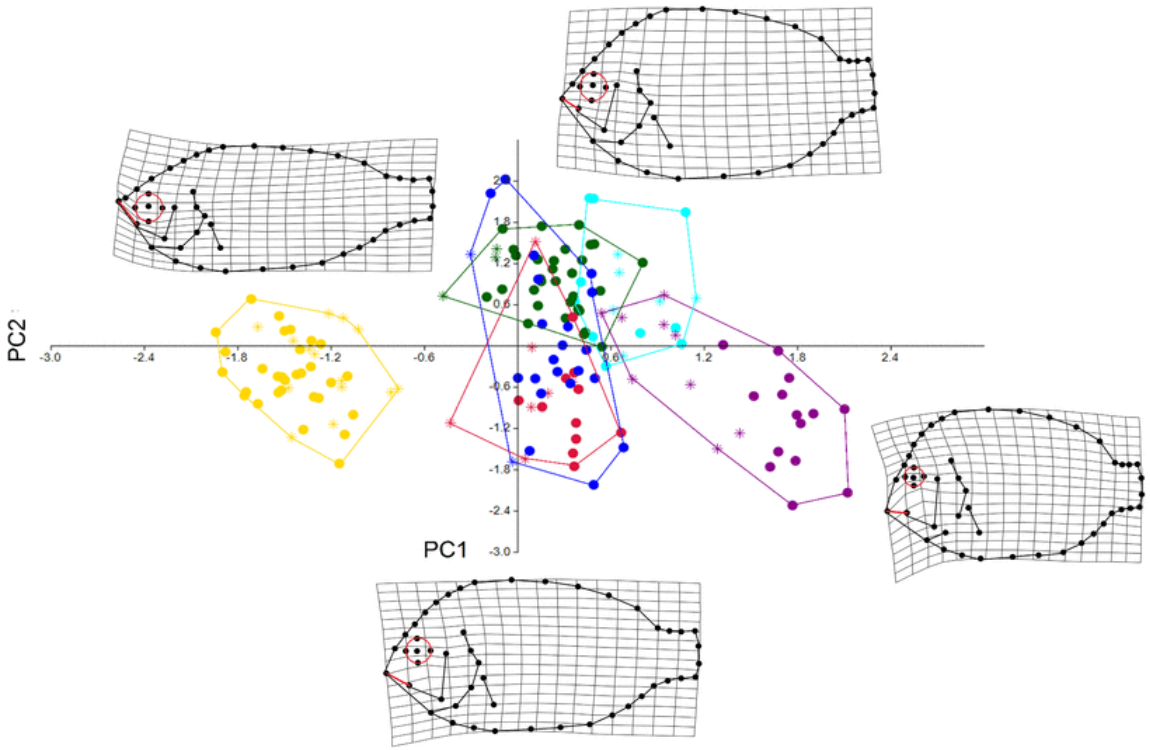


Mitteroecker, P., & Huttegger, S. M. (2009). The concept of morphospaces in evolutionary and developmental biology: mathematics and metaphors. *Biological Theory*, *4*, 54-67.

Geometric morphometrics

- Shape space
- Principal Component Analysis (PCA)





DOI: 10.1007/s00435-017-0391-6

Klingenberg, C. P. (2016). Size, shape, and form: concepts of allometry in geometric morphometrics. *Development genes and evolution*, *226*(3), 113-137.

Placing landmarks

- The Markup module: https://github.com/SlicerMorph/Tutorials

- 3D Slicer utilities:
  - Semilandmark patches: https://github.com/SlicerMorph/Tutorials/tree/main/CreateSemiLMPatches
  - Pseudolandmarks: https://github.com/SlicerMorph/Tutorials/tree/main/PseudoLMGenerator

Automated landmarking in SlicerMorph

- ALPACA
  - https://github.com/SlicerMorph/Tutorials/tree/main/ALPACA
  - Publication: https://doi.org/10.1111/2041-210X.13689

- MALPACA and templates selection
  - https://github.com/SlicerMorph/Tutorials/tree/main/MALPACA
  - Publication: https://doi.org/10.1371/journal.pone.0278035

The GPA module

- Visualization and trouble shooting

- https://github.com/SlicerMorph/Tutorials

- SlicerMorphR R package: Load 3D Slicer & SlicerMorph landmark data into R
  - Github Repository: https://github.com/SlicerMorph/SlicerMorphR
  - https://github.com/SlicerMorph/Tutorials/tree/main/GPA_3
  - For loading MALPACA estimates and outlier removing, see the Appendix of https://doi.org/10.1371/journal.pone.0278035

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