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Biota Modelling From an Academic Perspective

October 30th, 2019

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PNNL-SA-148235

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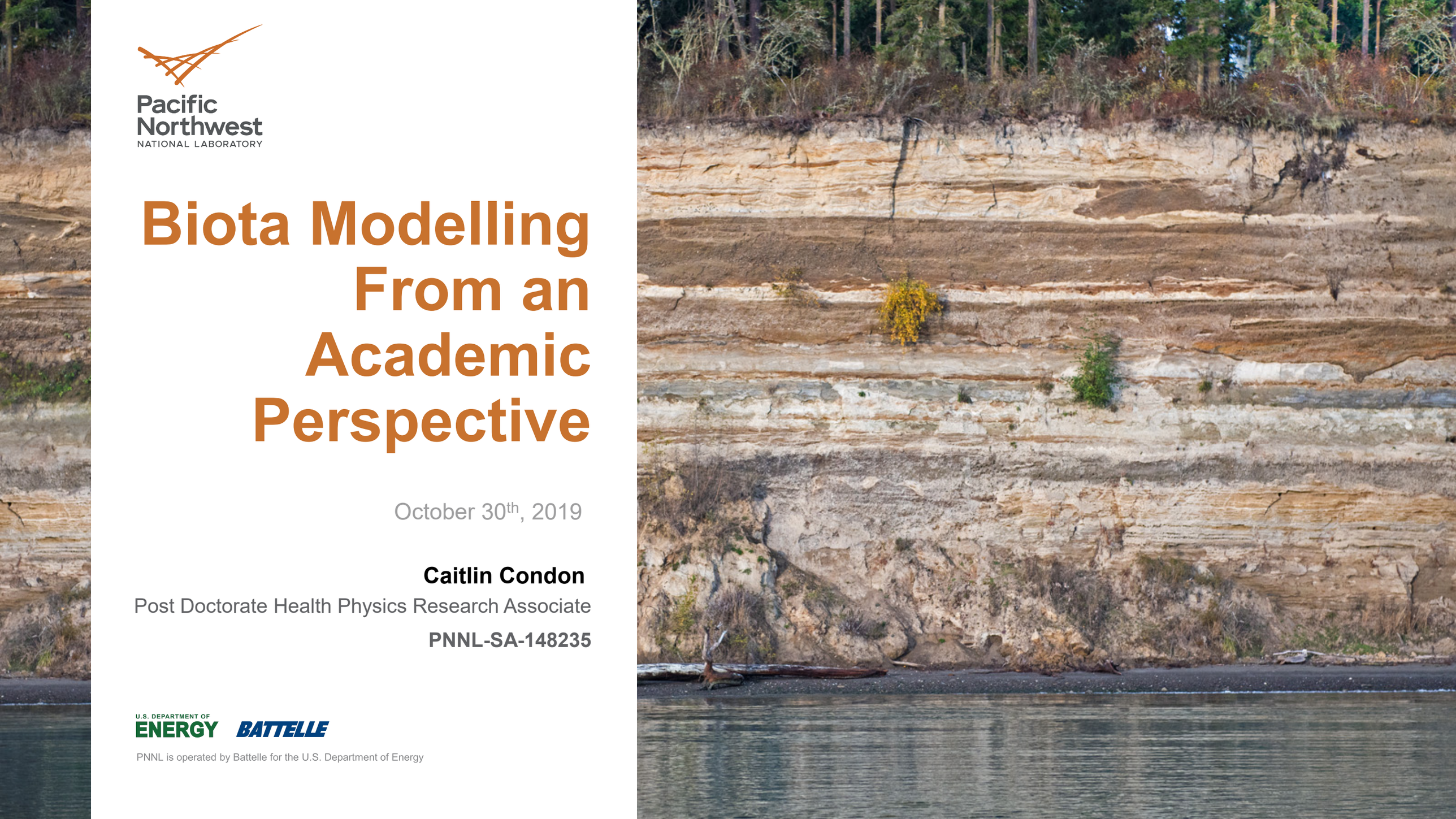

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OUTLINE

- Dosimetry to Non-Human Biota
- Models of Non-Human Biota
- Conclusions

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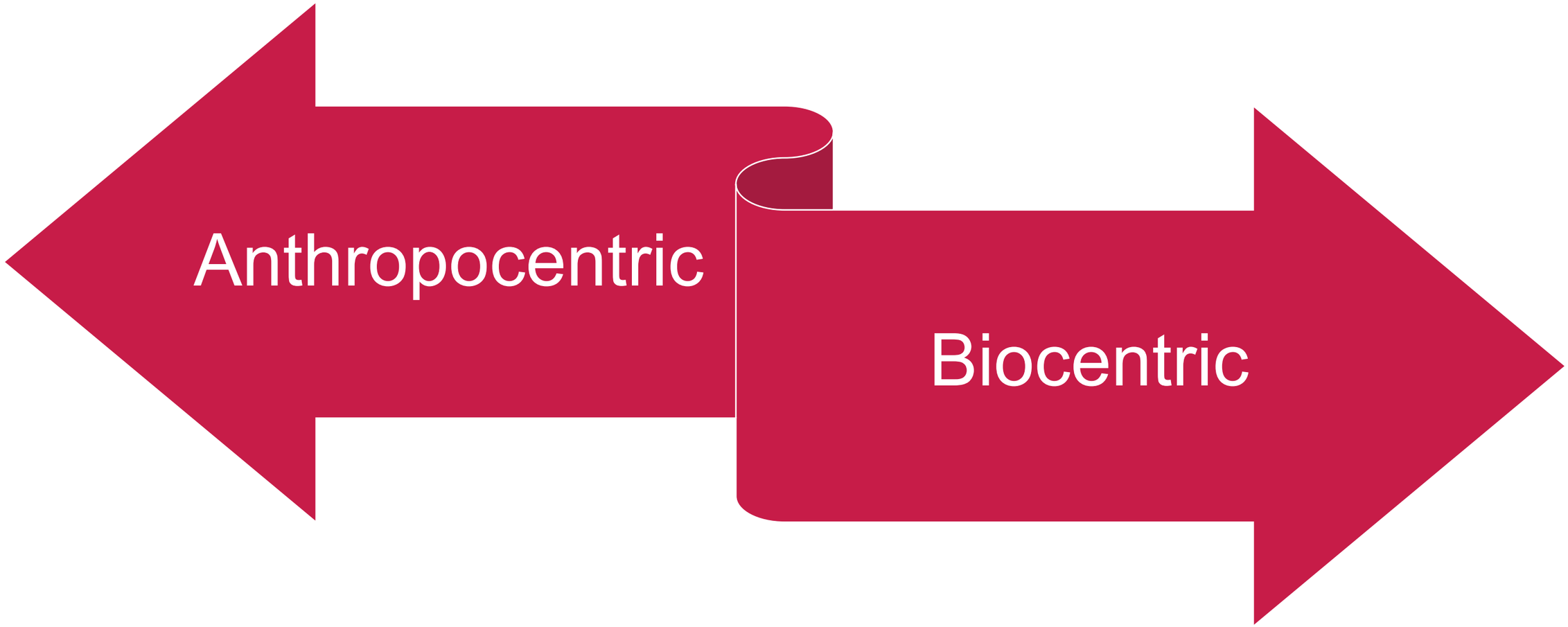
Two Ways To Approach Modelling



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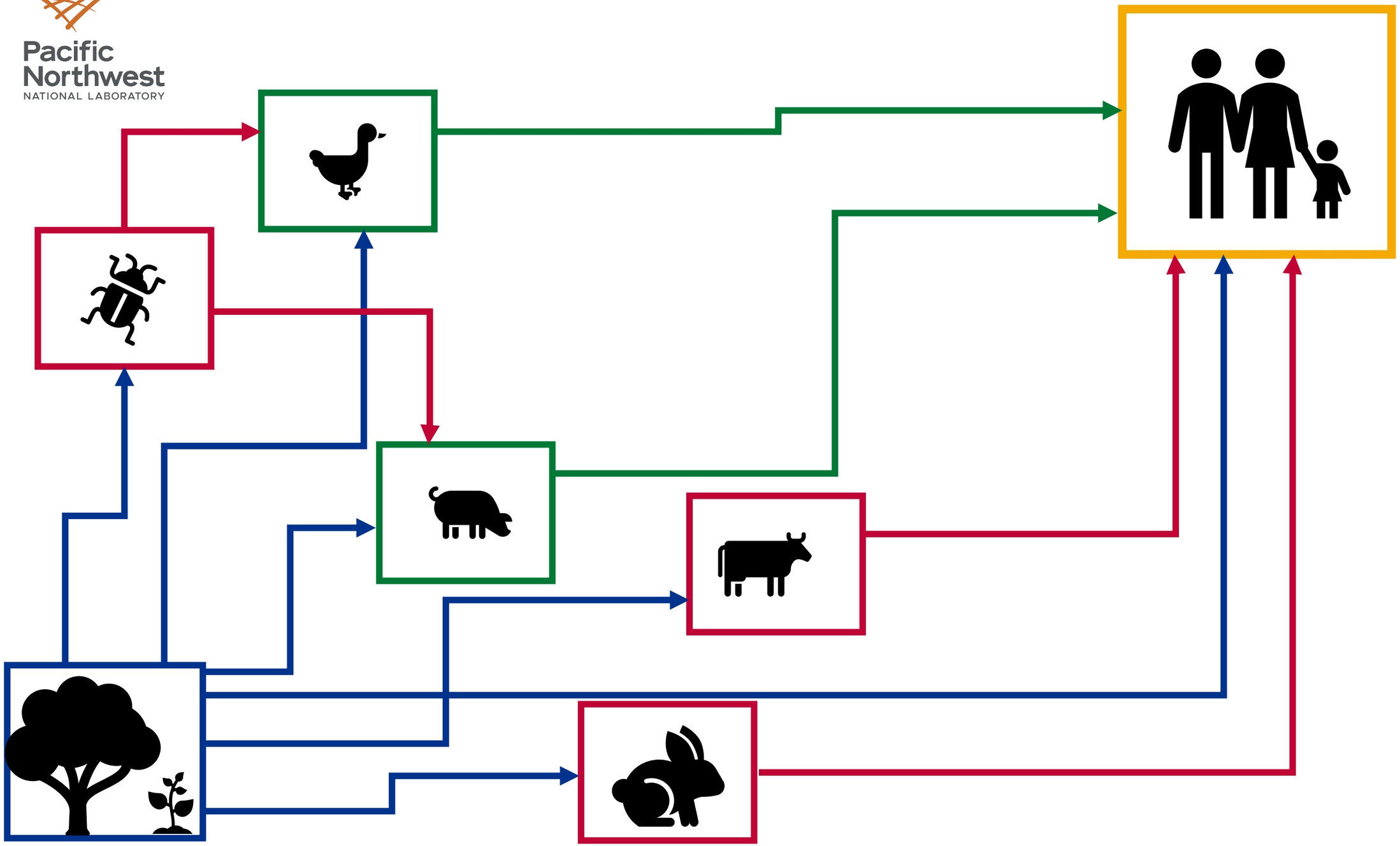


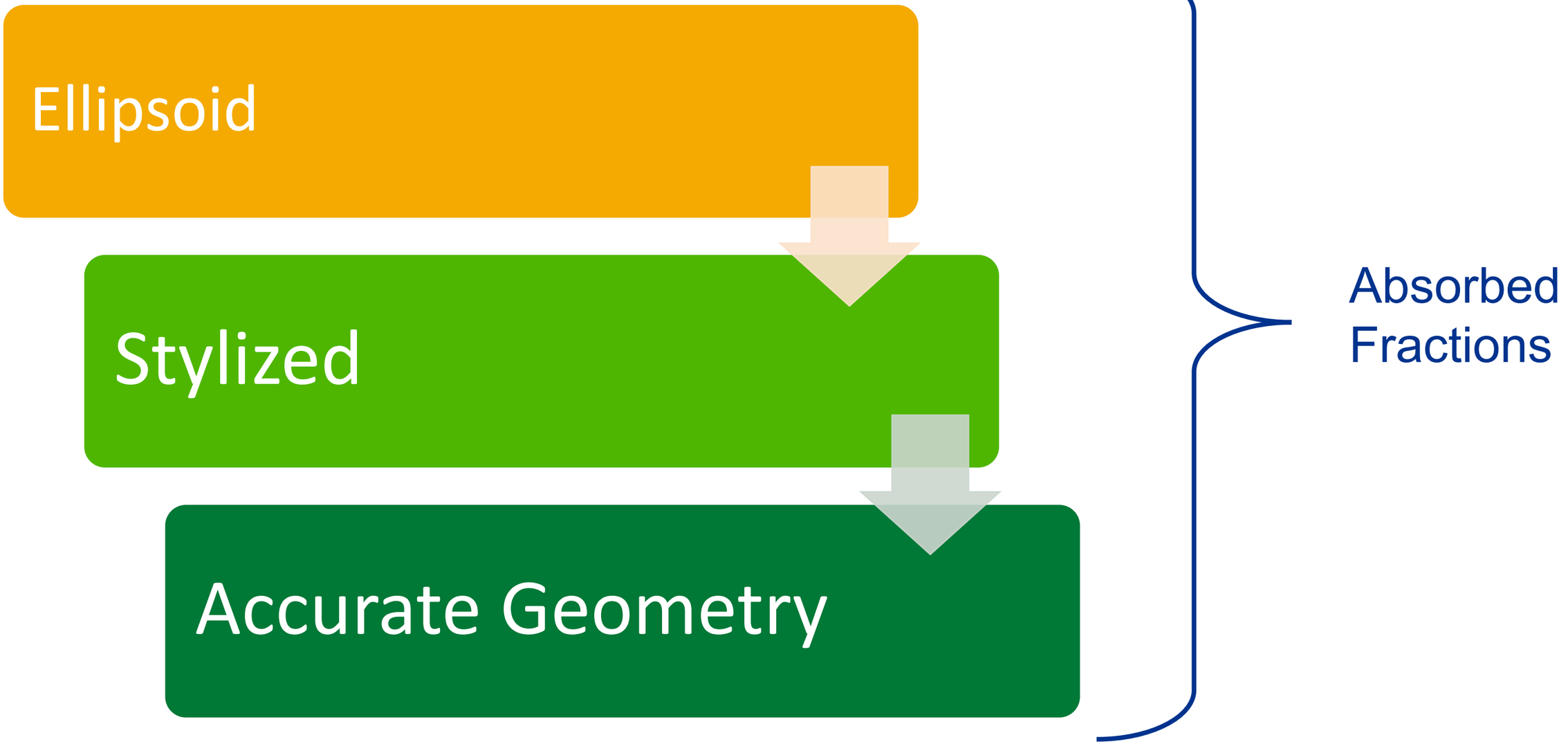
Biocentric - ICRP 108 (ICRP 2008)

- 12 Reference Animals and Plants (RAPs)
  - Population Health (Not Individual)

- Reference Animals and Plants were selected in order to be references which could be used for related species

- ICRP 108 present simple ellipsoid/geometric models for all the reference animals and plants
  - Homogenous distribution of radionuclides
  - Modelled composition of human tissue

Model Types: Non-Human Biota



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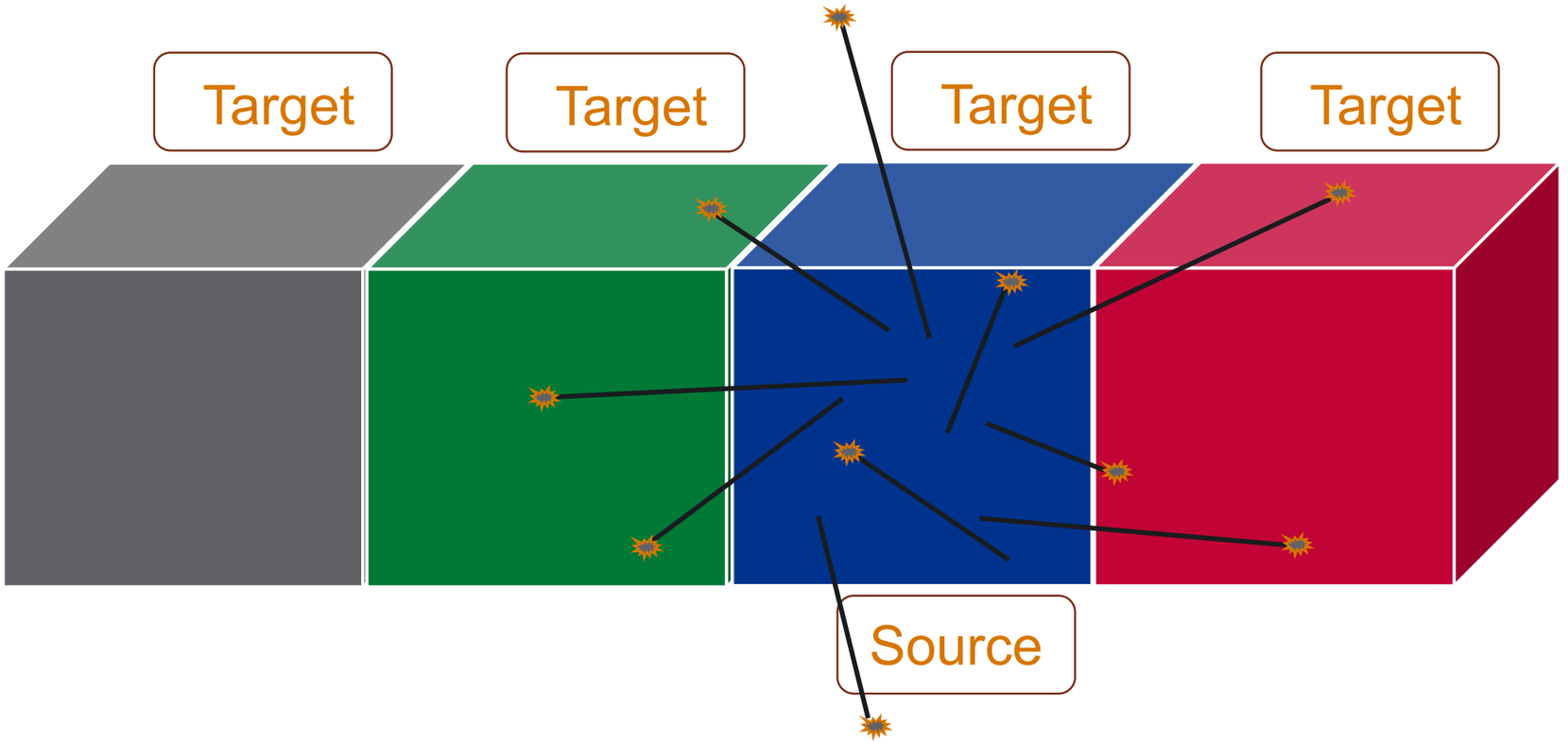
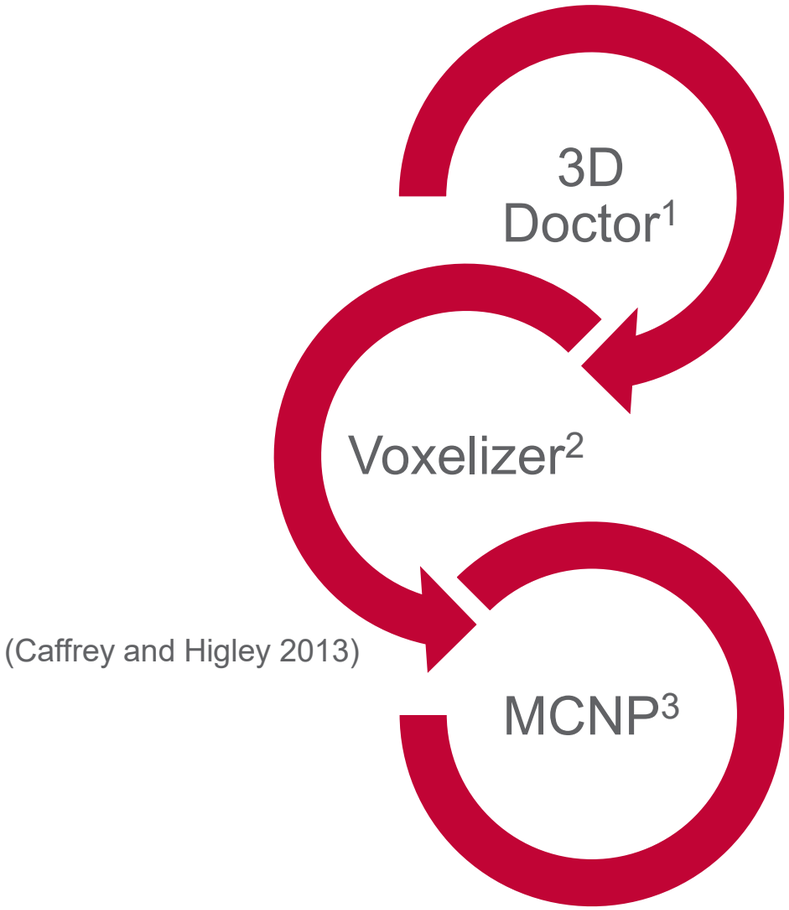
Absorbed Fractions

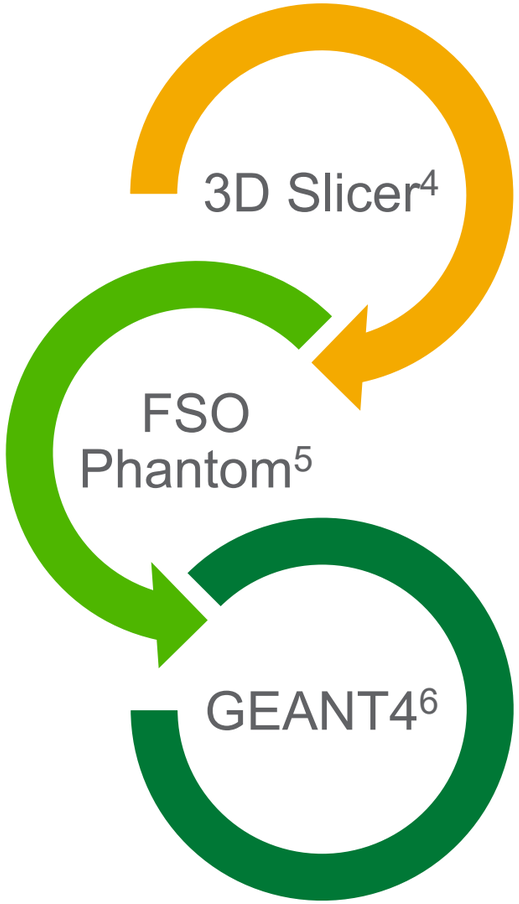


Two Model Development Pathways

Starting with Medical Imaging Scans of Organism



(Caffrey and Higley 2013)



(Condon 2019)

[1] Able Software Corp. 5 Appletree Lane, Lexington MA 02420. http://www.ablesw.com/3d-doctor/index.html.

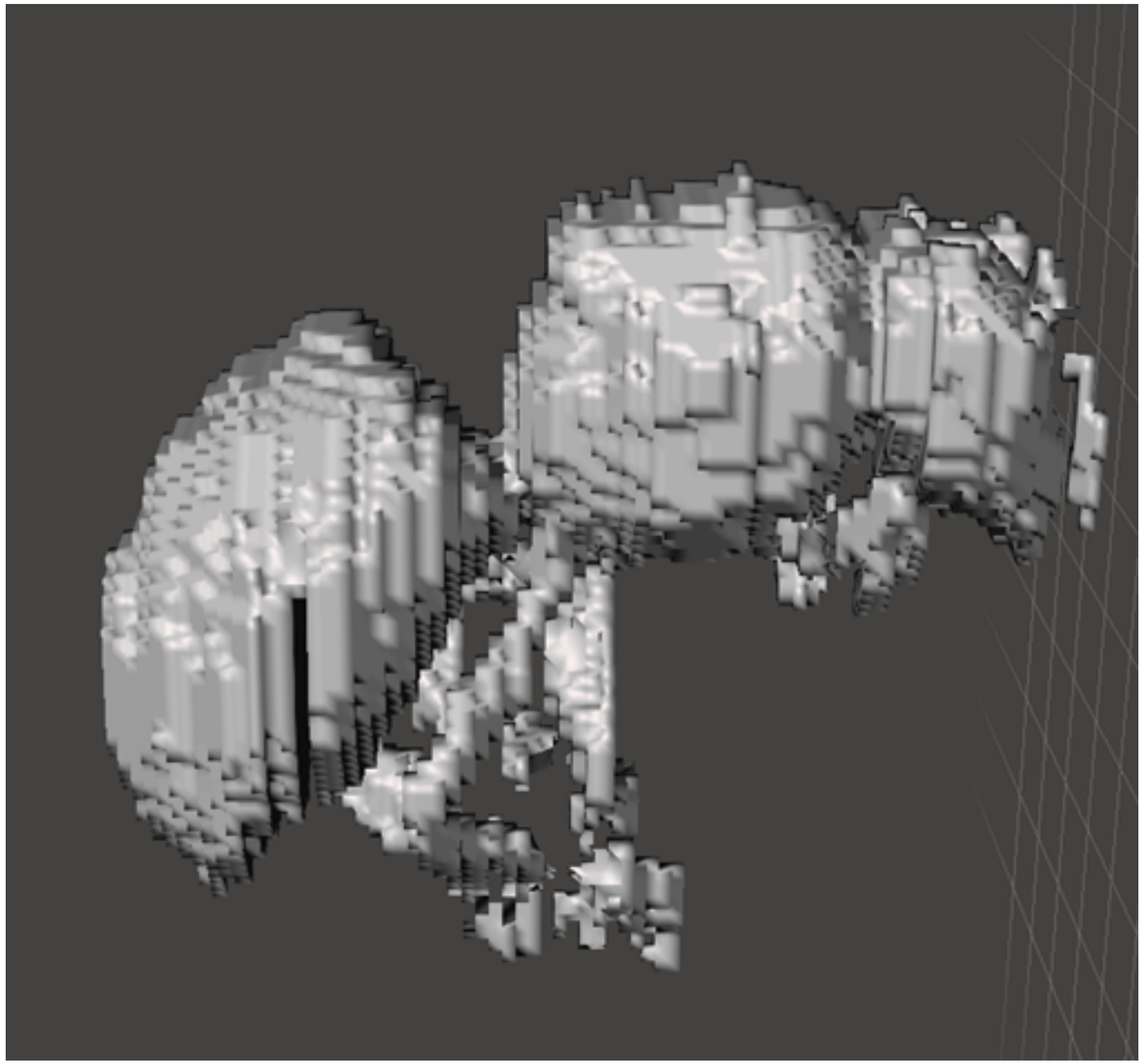
[2] Human Monitoring Laboratory, National Internal Radiation Assessment Section, Radiation Protection Bureau, 775 Brookfield Road PL6302D, Ottawa, Ontario K1A 1C1, Canada

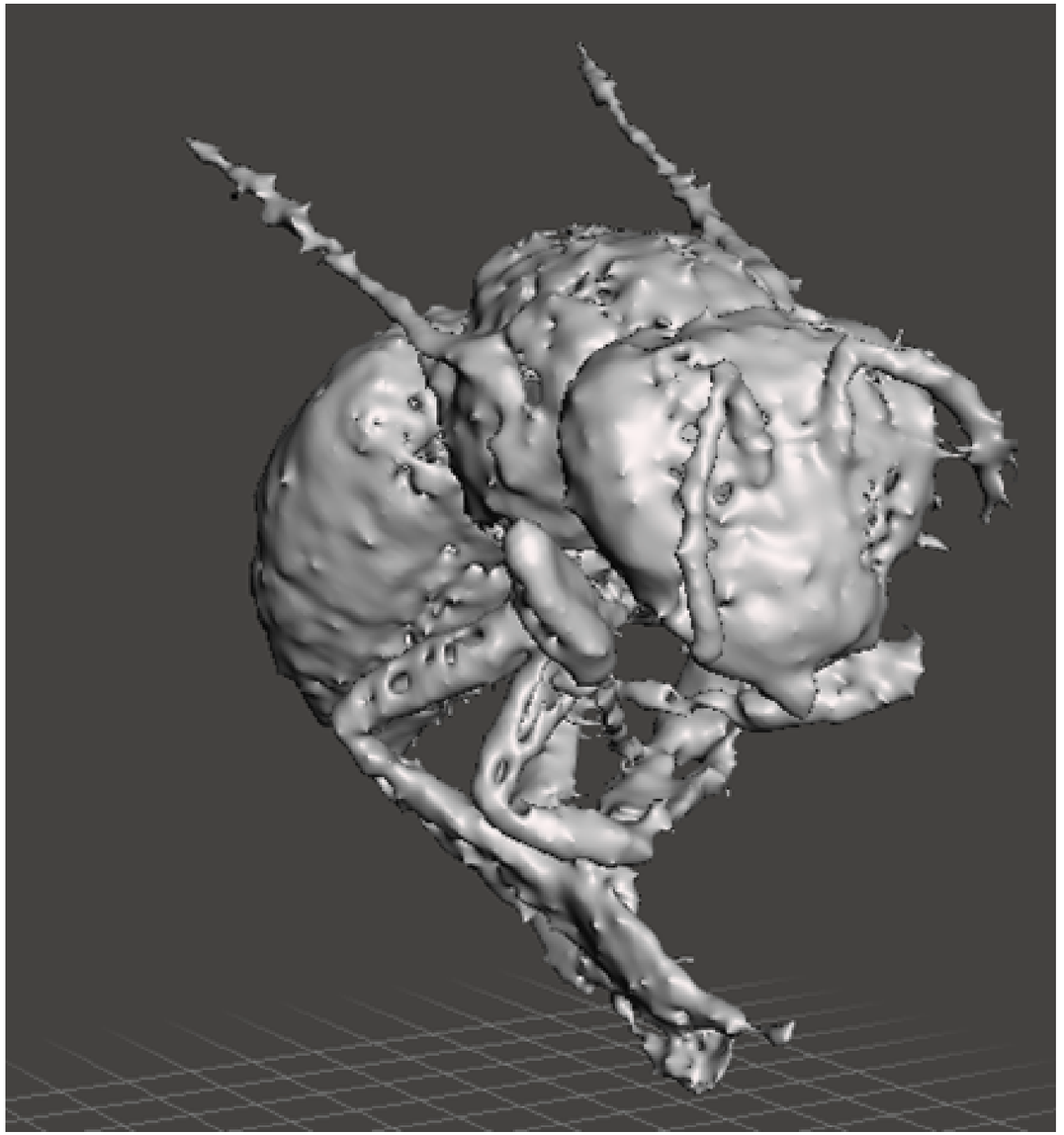
3 Triad National Security, LLC. Manager and Operator of Los Alamos National Laboratory

[4] Fedorov A., Beichel R., Kalpathy-Cramer J., Finet J., Fillion-Robin J-C., Pujol S., Bauer C., Jennings D., Fennessy F.M., Sonka M., Buatti J., Aylward S.R., Miller J.V., Pieper S., Kikinis R. 3D Slicer as an Image Computing Platform for the Quantitative Imaging Network. Magn Reson Imaging. 2012 Nov;30(9):1323-41. PMID: 22770690. PMCID: PMC3466397.

[5] Code by Delvan Neville, Oregon State University

[6] GEANT4: A Simulation Tool, CERN. https://geant4.web.cern.ch/





Images curtesy of Delvan Neville, Oregon State University

ICRP Reference Animals and Plants (ICRP 2008)

- Deer
- Rat
- Duck
- Frog
- Trout
- Flatfish
- Bee
- Crab
- Earthworm
- Pine Tree
- Wild Grass
- Brown Seaweed

Accurate Geometric Models Developed

Voxel Phantom Crab (Caffrey and Higley 2013)

Public Domain Photograph: U.S. Fish and Wildlife Service

- Investigate complex geometry and composition model compared to simplified ICRP 108 model
- Electrons can act as penetrating radiation in small organisms, contrary to how we conduct human dosimetry (Caffrey and Higley 2013)
- Results vary significantly with changing organ mass and density

Voxel Phantom Trout

(Ruedig, Caffrey et al. 2014)

- Developed to compare accurate geometry and density with more simplified geometry
- Determined that there was generally good agreement (within a factor of 2-3) for absorbed fractions from ICRP 108 compared with the voxel phantom results (Ruedig, Caffrey et al. 2014)
- Voxel phantom models should be used for dose response estimates

Public Domain Photograph: U.S. Fish and Wildlife Service, Eric Engbretson

Voxel Phantom Model of Rabbit (Caffrey, Johansen et al. 2016)

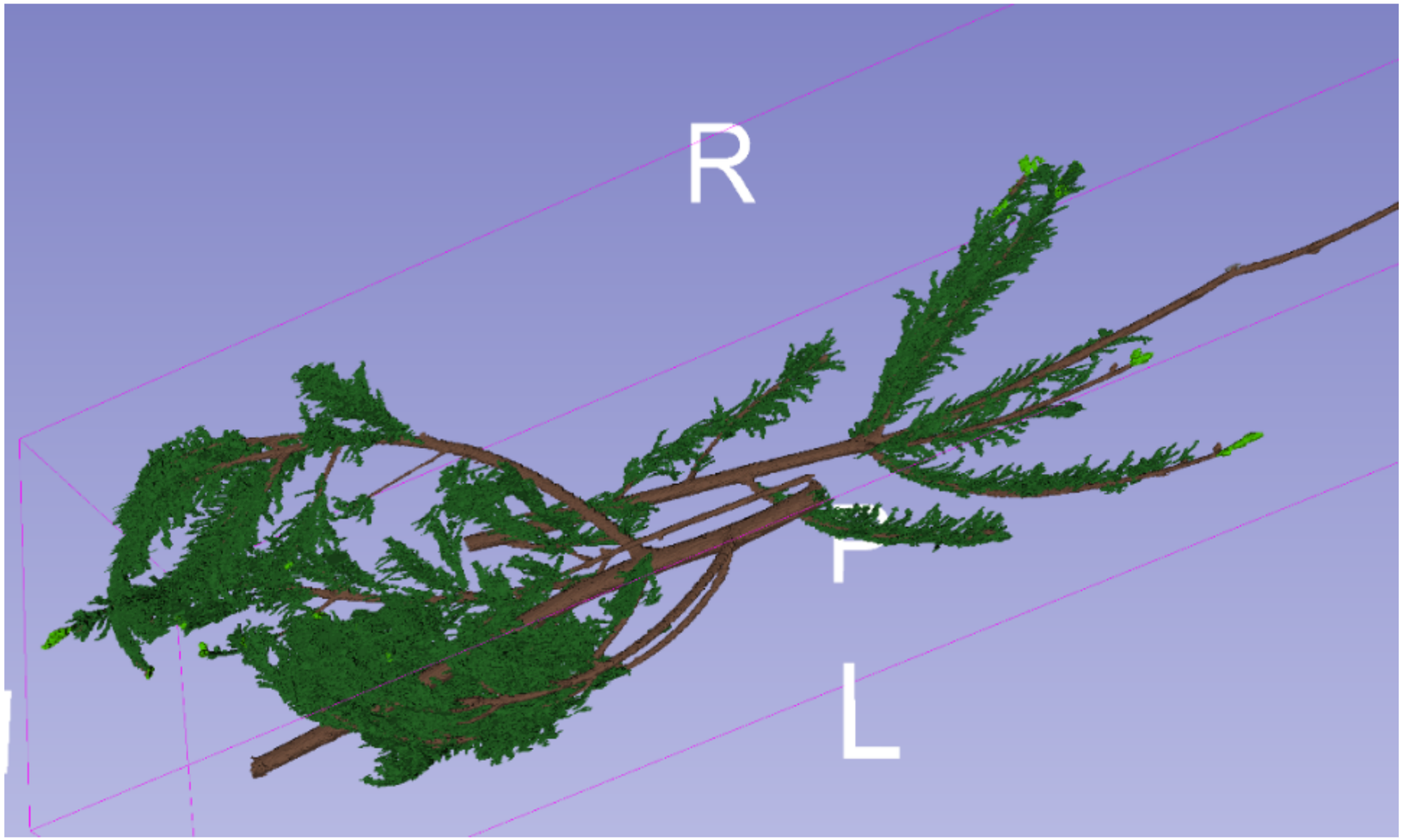
Public Domain Photograph

- Modelling accurate geometry and composition for absorbed fractions
- Hot particle modelling in lungs for different sized particles in different anatomical sections

Surface Mesh Sectional Models of Pine Tree

(Condon 2019)

- Surface Mesh Models of
  - Branch with Needles
  - Roots
  - Trunk
  - Large Branch
- Accurate composition and geometry compared to ICRP 108 ellipsoid model



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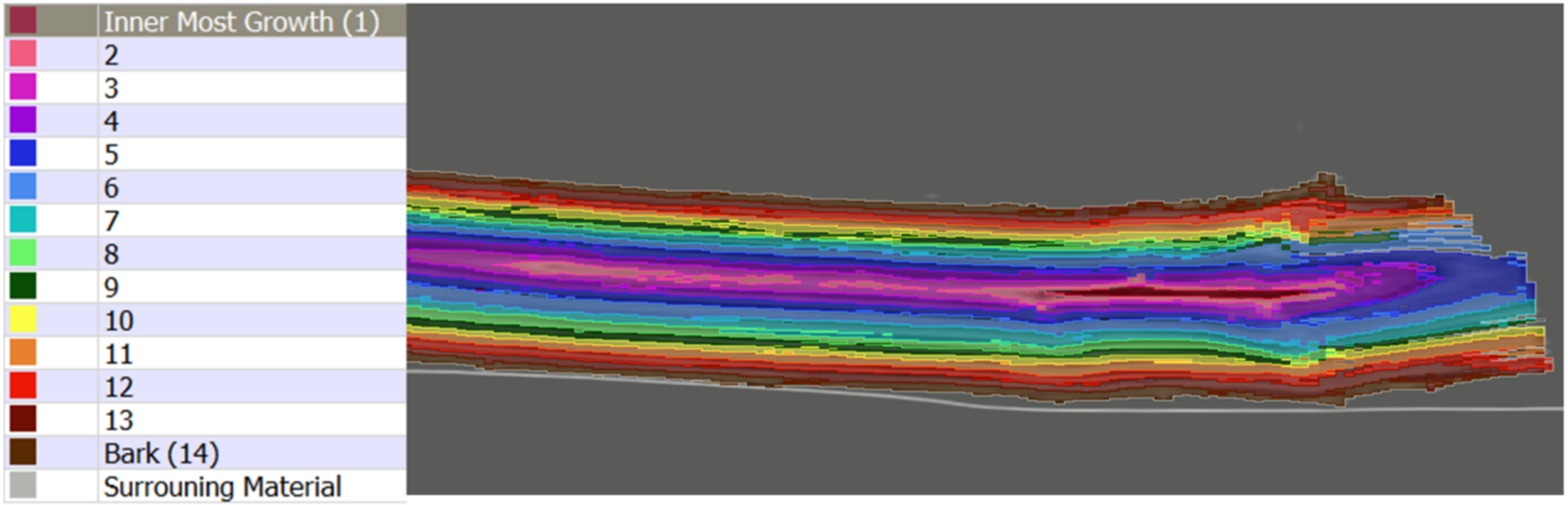
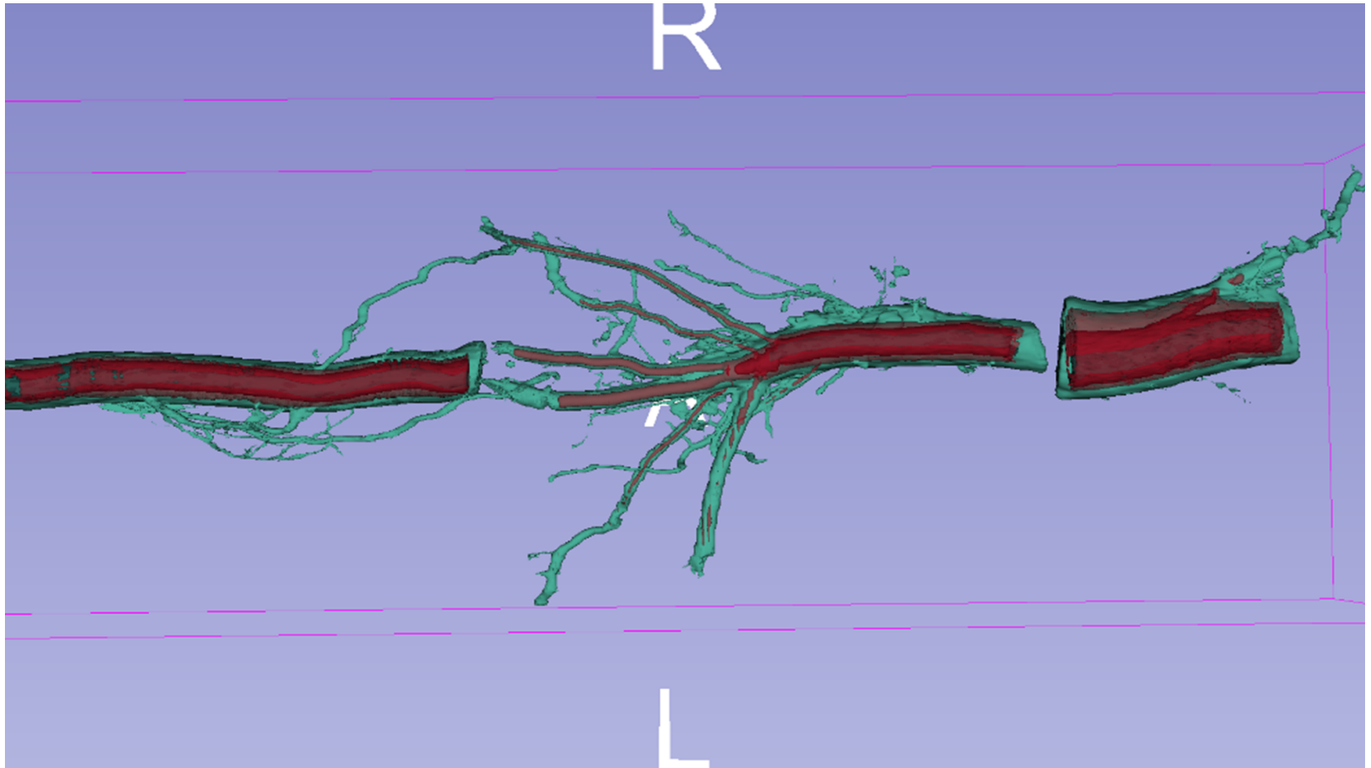
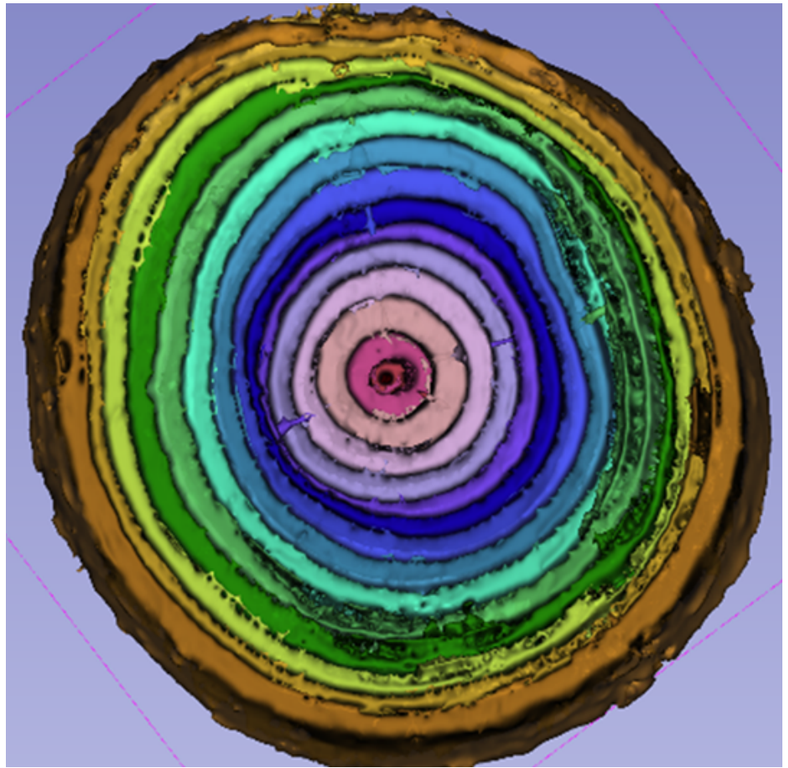
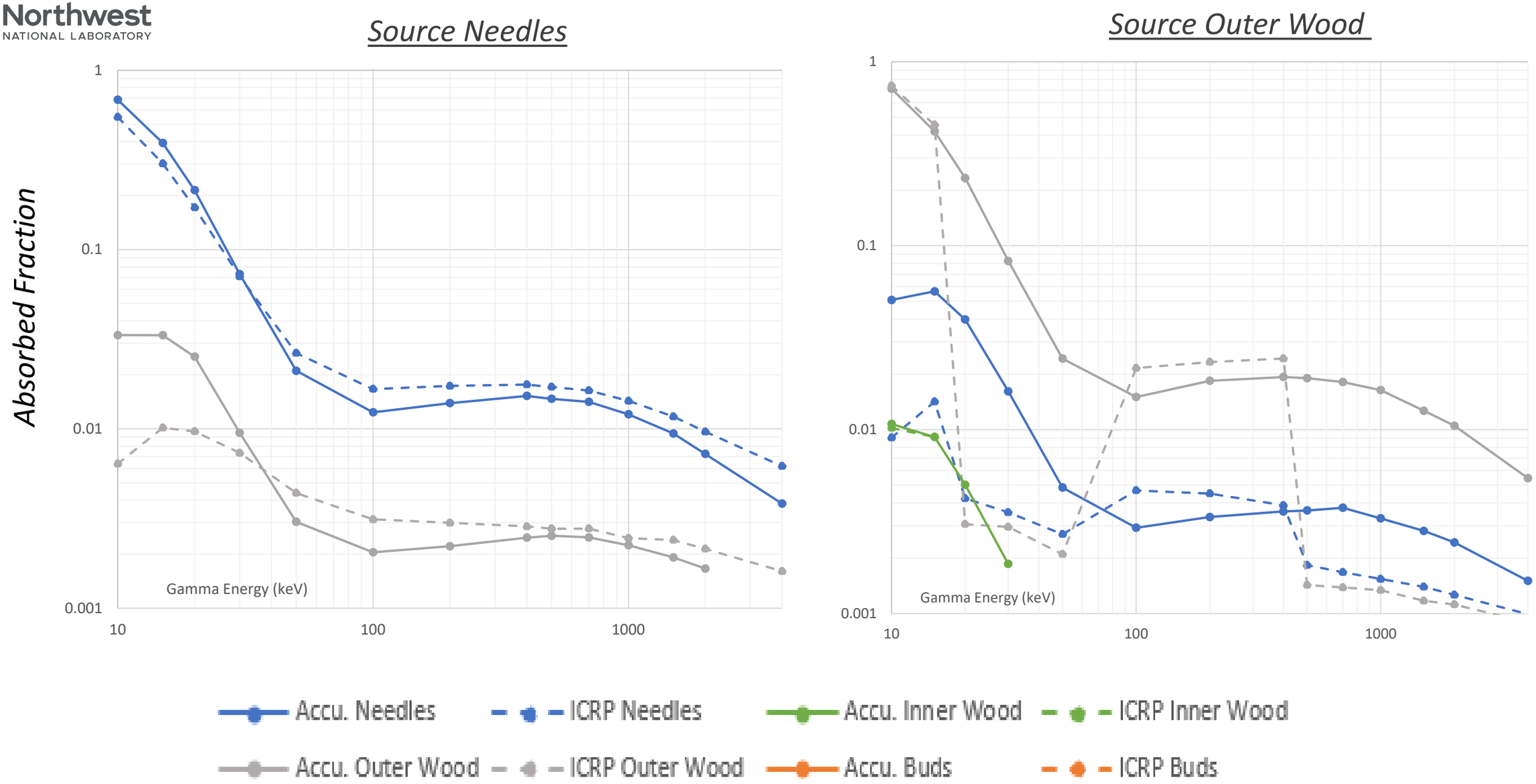






Small Branch Sectional Model Absorbed Fractions for Example Source-Target Pairings (Condon 2019)



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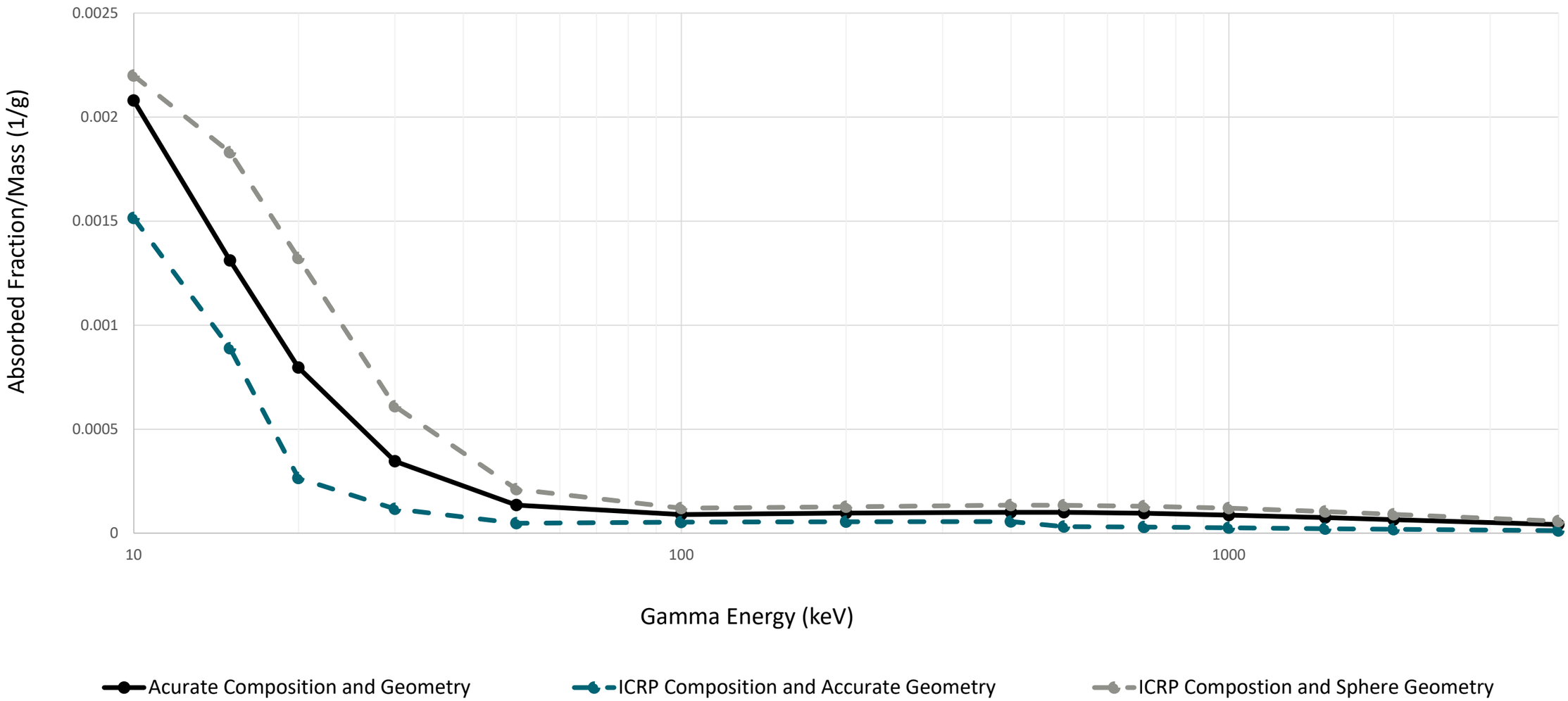
Accurate Composition and Geometry, ICRP Composition and Accurate Geometry, ICRP 108 Composition and Sphere for Small Branch Sectional Model Divided by Mass (Condon 2019)



Reference Tree Discussion: (Condon 2019)

From all 4 Models and Multiple Modelling Scenarios:

- Simplified geometric models were not consistently conservative for all sectional models compared to more physiological accurate scenarios and models
- Simplified ellipsoid models were conservative for Cs-137 dose comparisons when working from similar concentration ratios
- Working from full ICRP assumptions underestimated doses for all models when compared to results using more accurate geometry, composition, and concentration ratios

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Conclusions

- End points of interest (anthropocentric vs. biocentric): ellipsoidal and simplified models may be appropriate for demonstrating regulatory compliance but not for remediation decisions (Ruedig, Beresford et al. 2015)

- Accurate geometric modelling is being utilized to determine strengths and limitations of simplified ICRP 108 models (Caffrey and Higley 2013, Ruedig, Caffrey et al. 2014, Caffrey, Johansen et al. 2016, Condon 2019)

- Accurate dose response relationships are critical:

  - Underestimate dose – overestimate dose response

  - Overestimate dose – underestimate dose response

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- Ruedig, E., et al. (2014). "Monte Carlo derived absorbed fractions for a voxelized model of Oncorhynchus mykiss, a rainbow trout." Radiation and Environmental Biophysics **53**(3): 581-587.

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Thank you