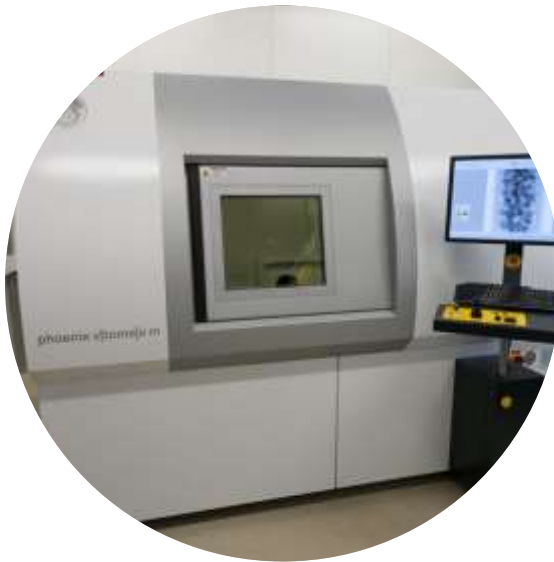


X-Ray Tomography

Gaining insight on the inside

23 March 2017, Remco Hamoen and Erik Esveld



Outlook

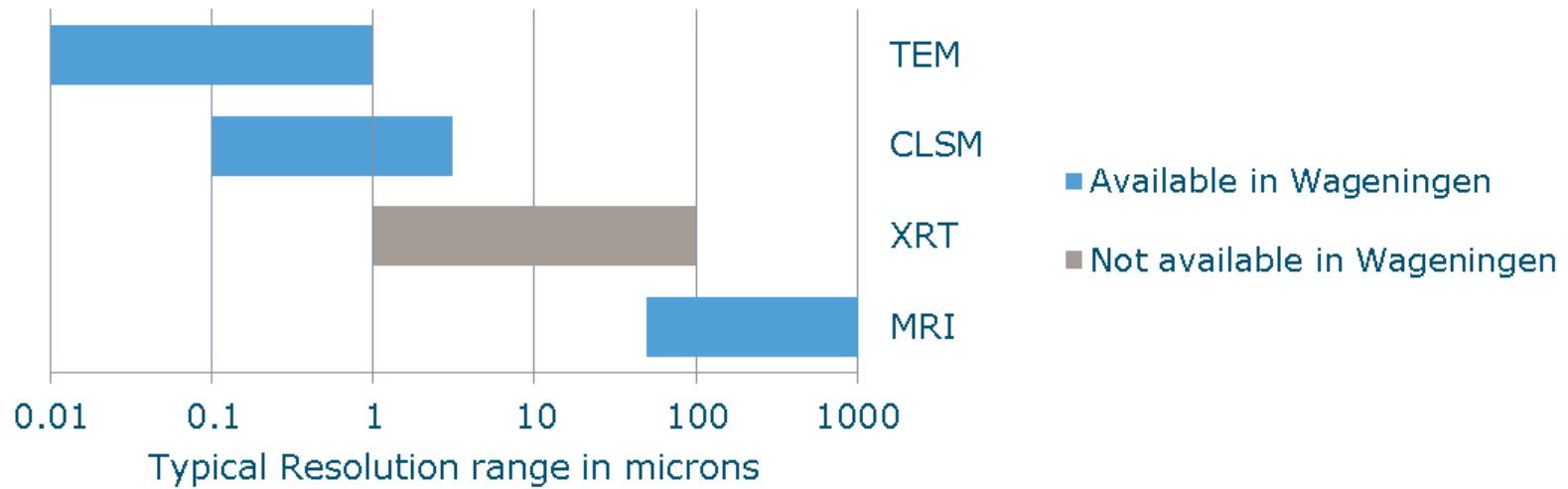
- XRT in a nut shell

- Focus areas
 - Soil, plant and root morphology
 - Food product structure
 - Physiology of animals (and humans)

- Discussion in smaller groups

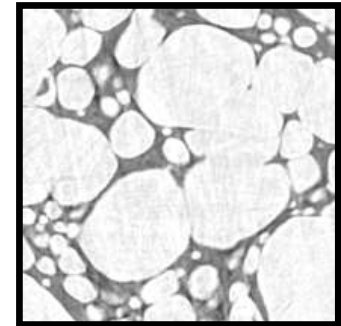
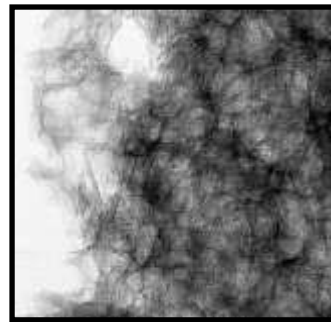
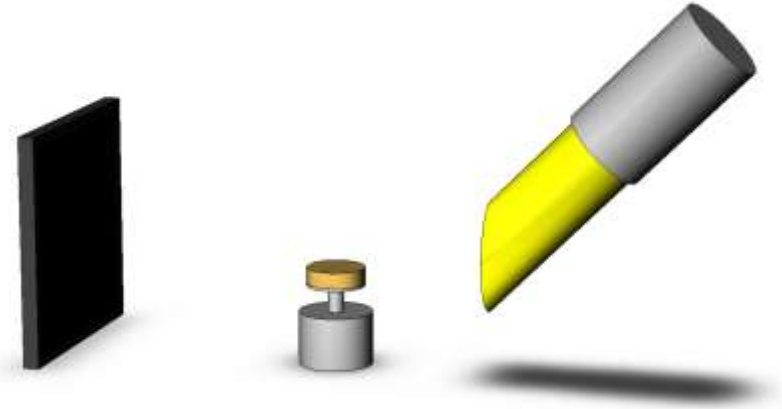
- Recap and closure

Imaging at WUR



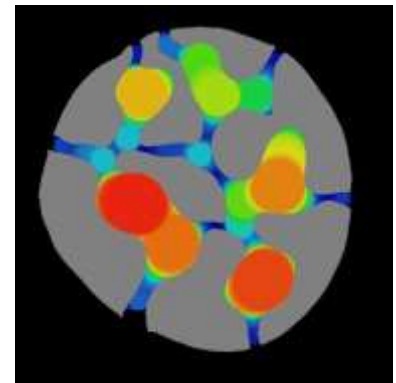
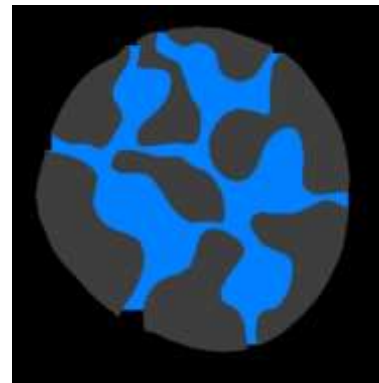
XRT in a Nut Shell

- XRT (X-Ray Tomography)
- 1000-2000 X-Ray projections during a full 360° rotation
- Reconstruction of these image to a 3D grey scale dataset
- Selection (segmentation) of different parts of the scanned object
- Typical resolution 1/1000 of object size
- Maximum object size ~30cm



XRT in a Nut Shell

- Analysis of the object structure
 - Visualisations (3D and slices) and animations
 - Volumes and porosity
 - Surface area, shape factors
 - Bubble size distribution
 - Skeleton analysis
 - Wall thickness analysis



Soil and Root systems

Collaboration with ESG: Ingrid Lubbers & Rima Porre

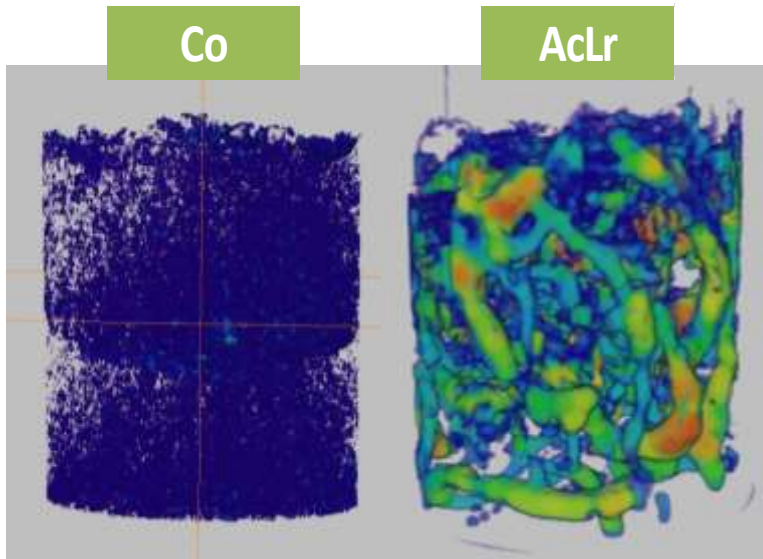
- Pathways for gas emission (N_2O) as function of mesofauna
- Correlation with air structure in soil
- Porosity
- Pore size distribution
- Mean pore size
- Volumetric air content

Monitoring N_2O fluxes for 70 days



Soil and Root systems

Results:

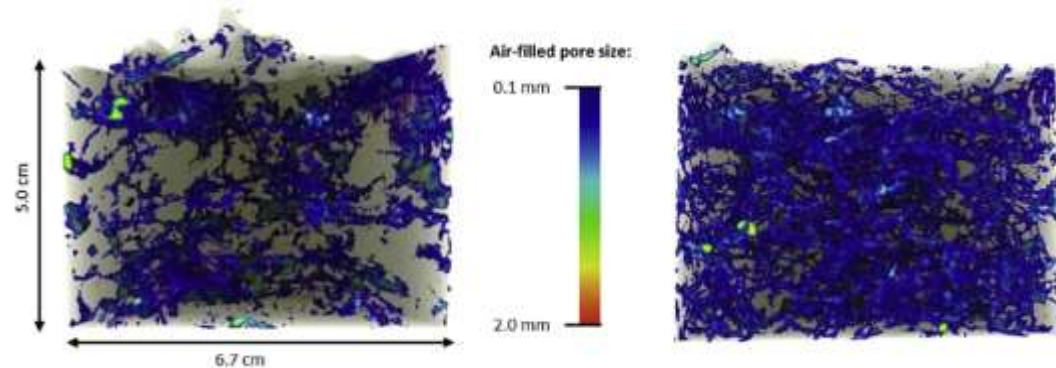


- Co: Control
- AcLr: Including earthworms

- Left: Control with hay
- Right: *Enchytraeus albidus*

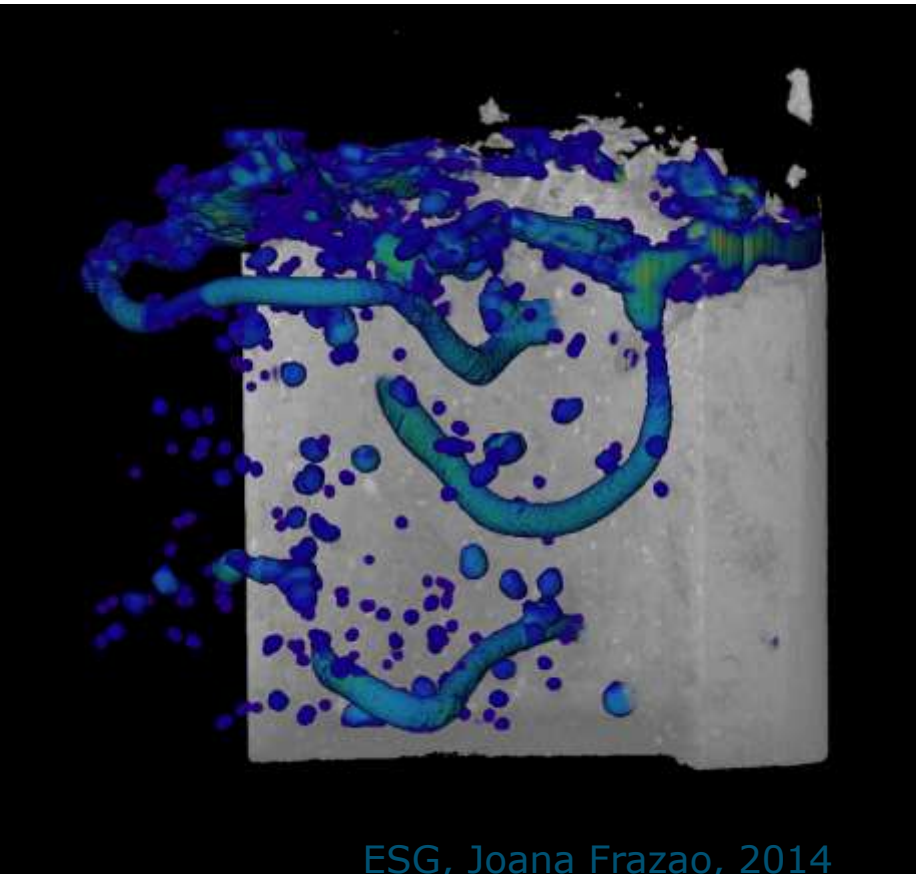


Porre, R. J., van Groenigen, J. W., De Deyn, G. B., de Goede, R. G., & Lubbers, I. M. (2016). Exploring the relationship between soil mesofauna, soil structure and N₂O emissions. *Soil Biology and Biochemistry*, 96, 55-64.



Soil and Root systems

Earth worm burrows



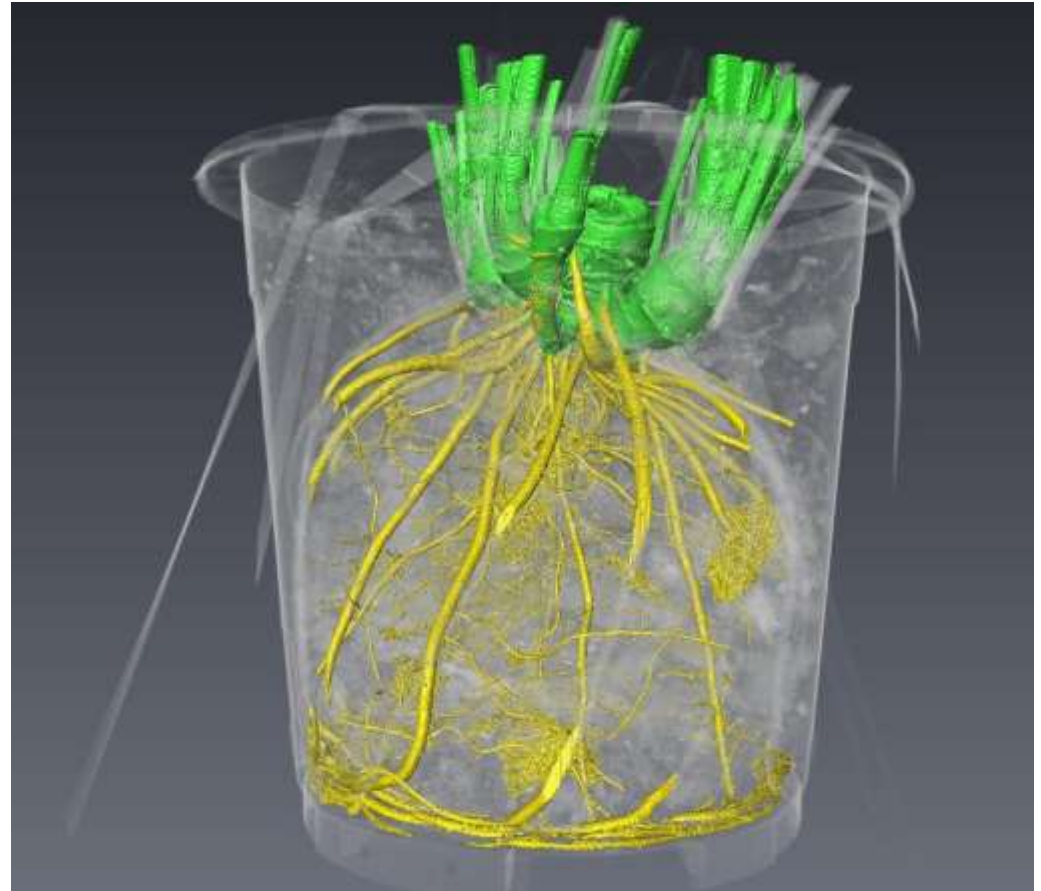
ESG, Joana Frazao, 2014

- Burrow length
- Burrow diameter

Soil and Root systems

Root morphology

- Non-destructive characterisation of root structure
- Roots can be identified despite denser soil surrounding
- However, contrast of root with water is a challenge.



Soil and Root systems

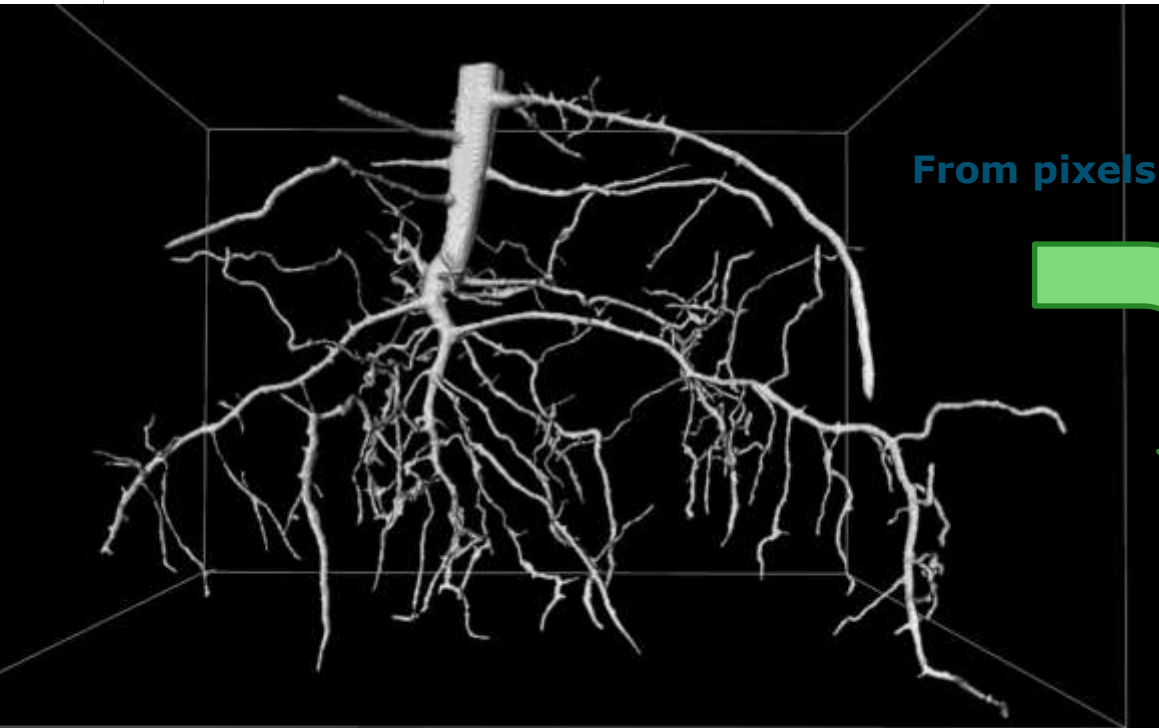
Visualizing roots with X-Ray

- **The capillary water of the Rockwool can drained in a matter of 10 minutes via a meter stack of wetted rockwool.**
- The result is a dramatically improved contrast for root detection.
- Water can be supplied again after a scanning, which enable to track the development of the same plants in time.



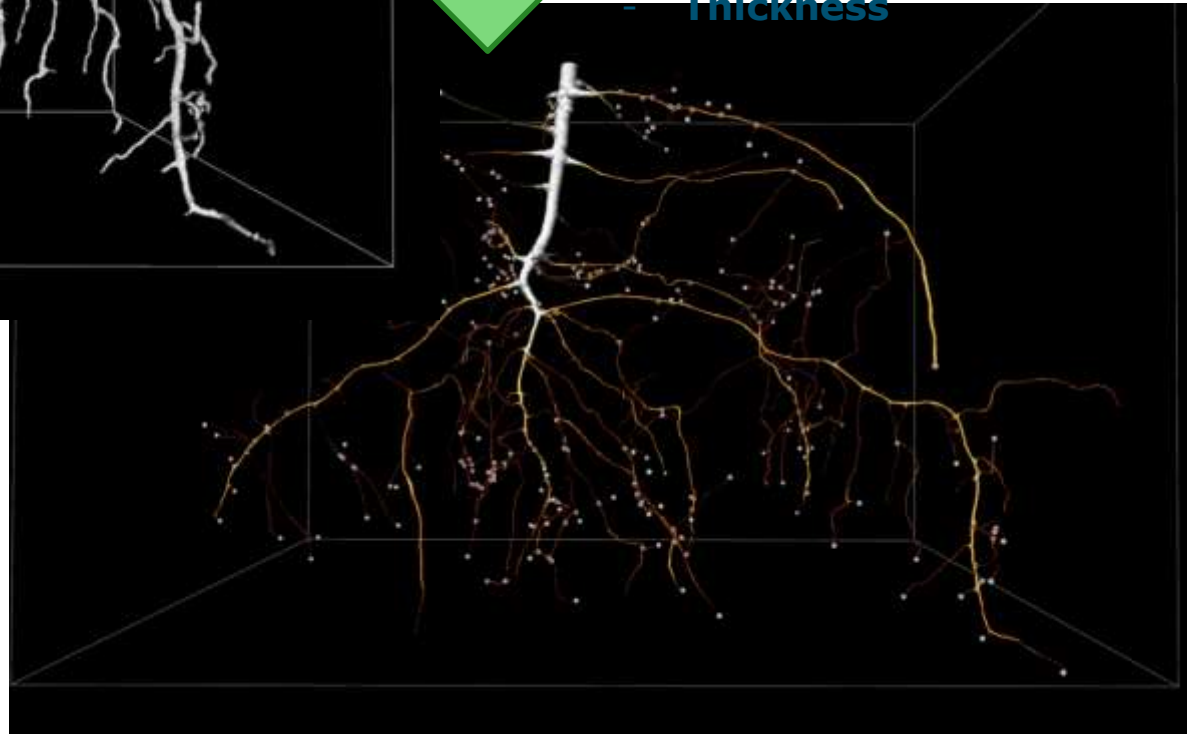
seedling grown in rockwool

Soil and Root systems



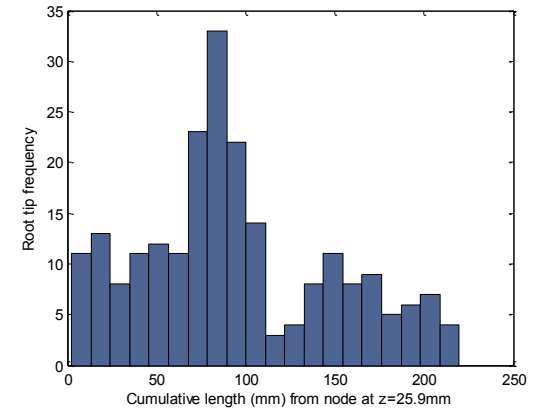
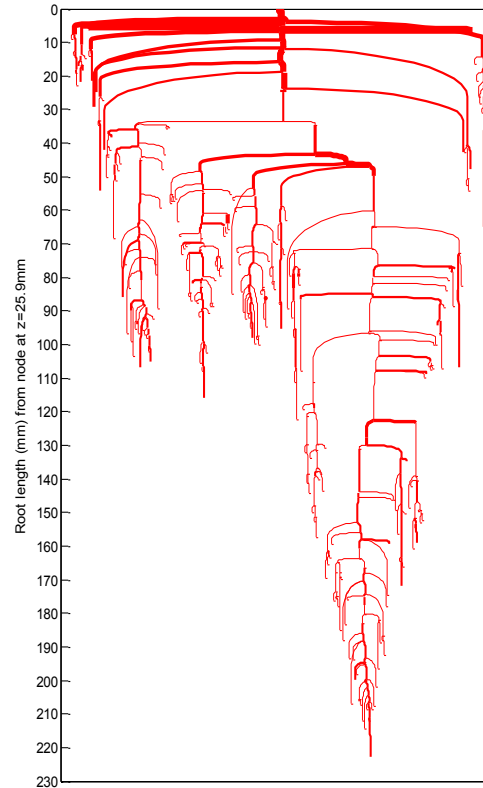
To skeleton:

- Nodes (x,y,z)
- Segments
- Points (x,y,z)
- Thickness



Soil and Root systems

Number of Segments	501
Mean Radius	0.22 mm
Total Volume	578 mm ³
Total Length	2090 mm



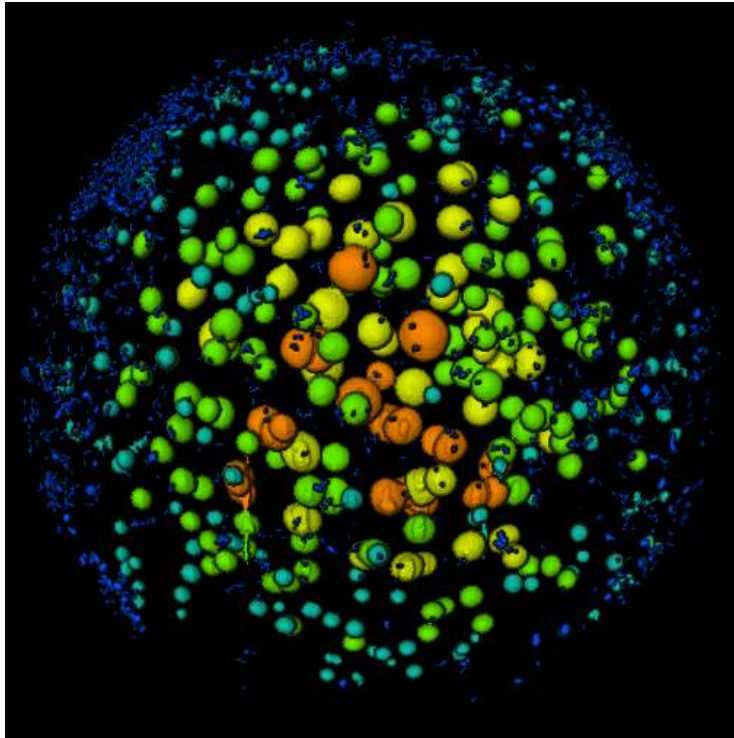
Dimensional properties

Tree view hierarchy with length

Graph data analysis

Food Products

Cheese analysis



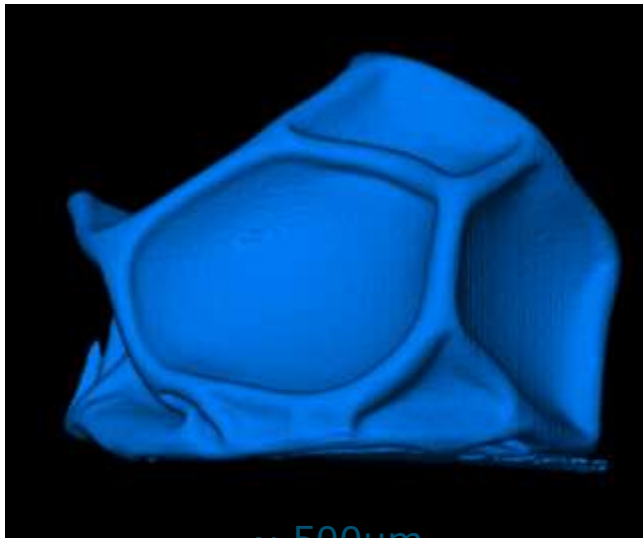
CSK, 2015

- Scanned in 4 sections and merged
- Pore size distribution
- Pore size vs. distance to the outer surface

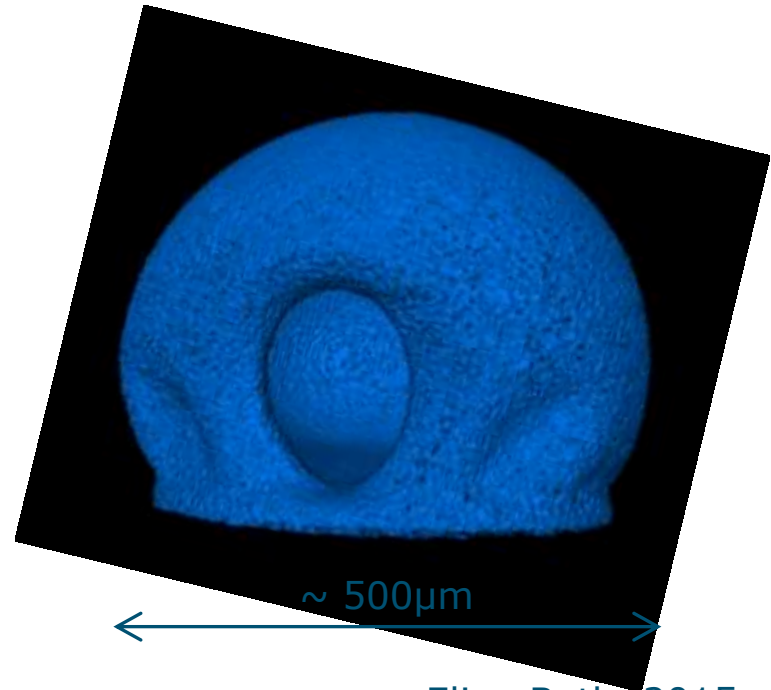


Food Products

Morphology development during (spray) drying



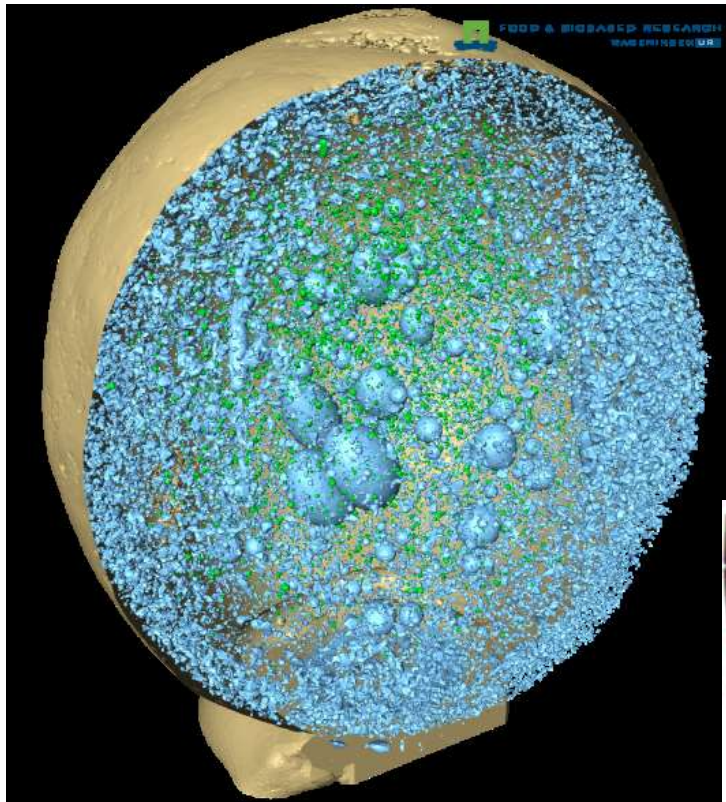
~ 500µm



~ 500µm

Eline Both, 2015

Food Products



- Visualisation of:
 - Air bubbles (blue)
 - Salt crystals (green)

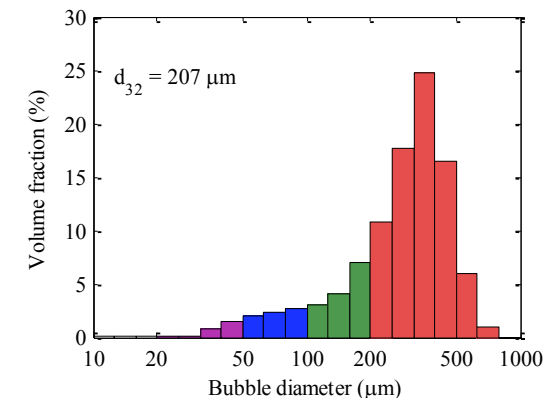
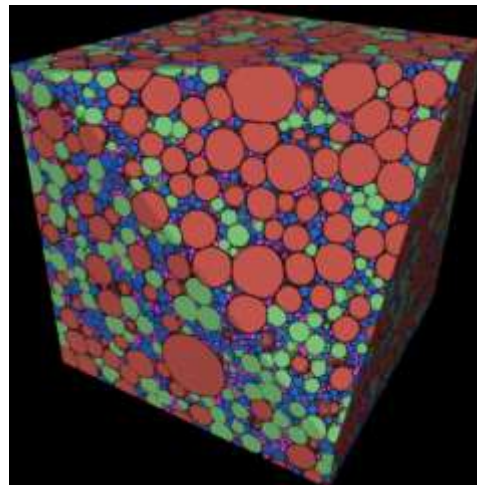
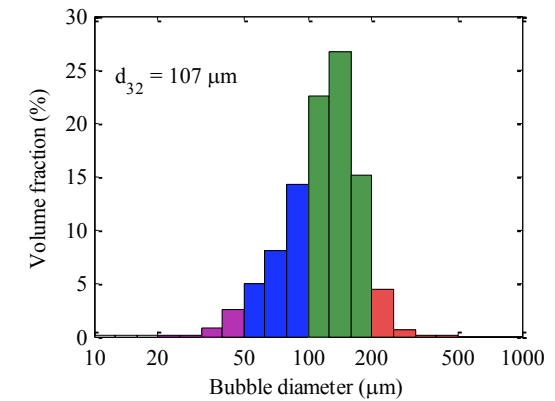
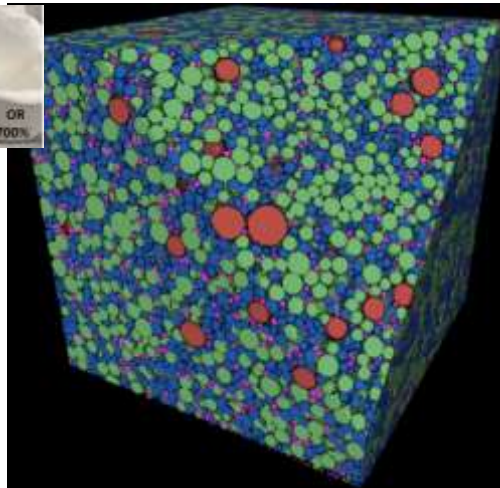


Food Products

Structure of foams as function of time



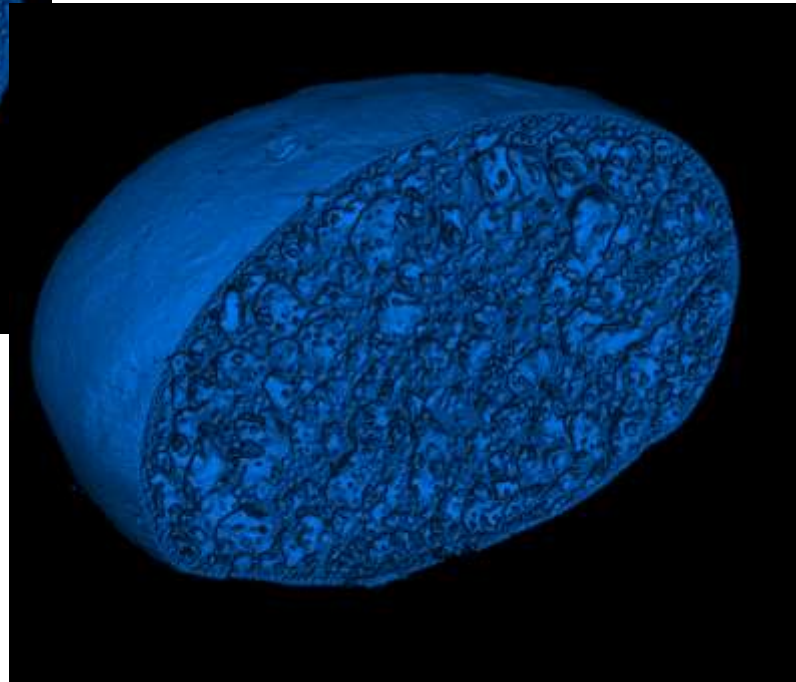
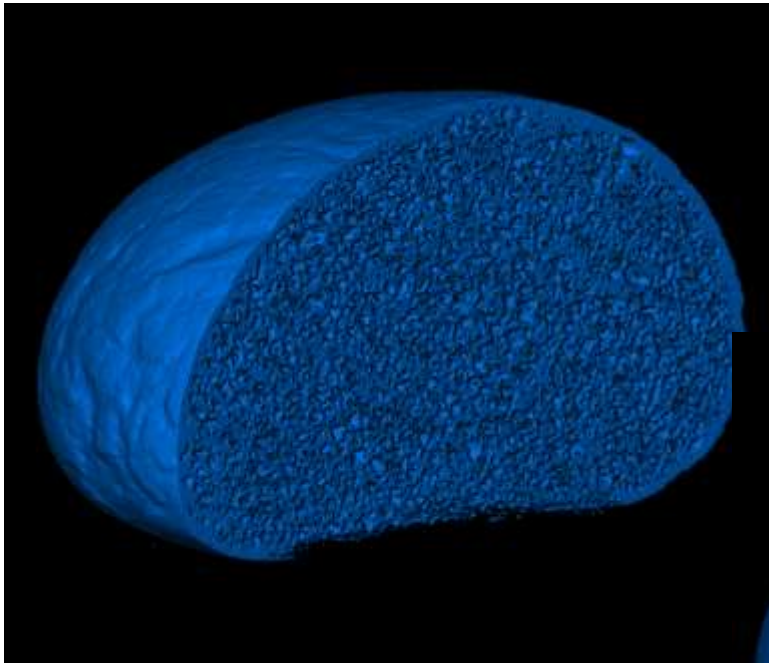
- Sugar syrup based bakery foam changes over time as reflected in bubble size histogram after 1 and 4 days.
- Foams are a challenge to image due to material movements.



Food Products

Dough and bread

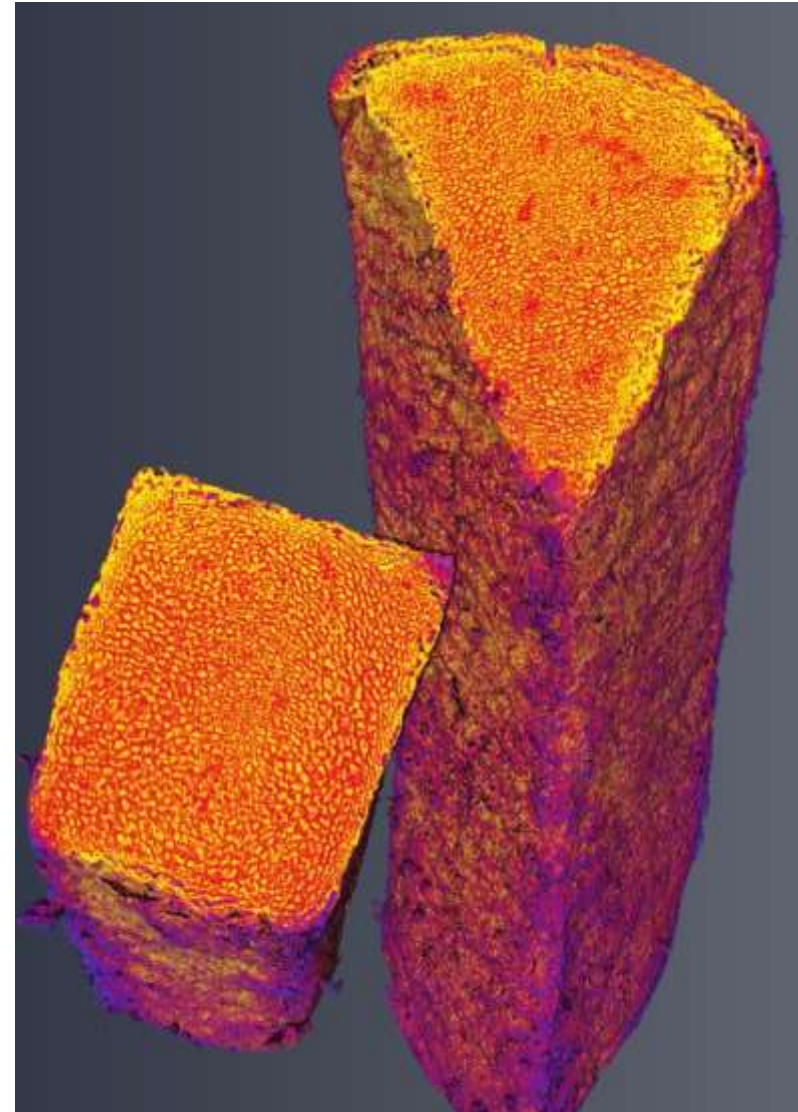
- CO₂ production over time (proofing)
- Air distribution
- Cell connections
- Wall thickness



Food Products

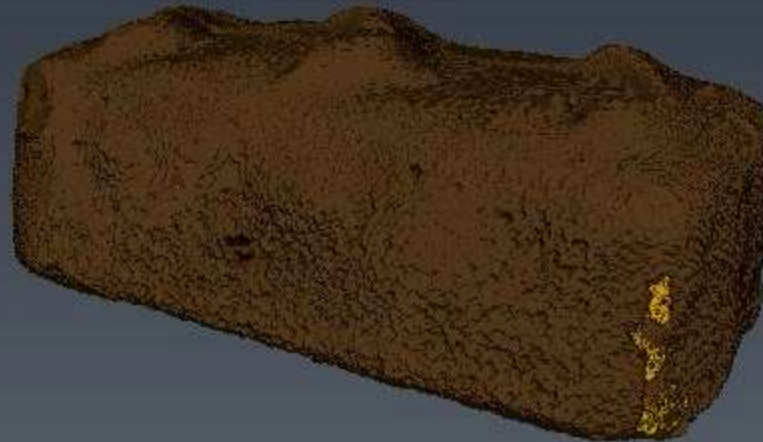
XRT of frozen tissue, imaging ice structure

- Peltier active cooling of isolated sample holder
- Ice is less dense than unfrozen remainder
- Clear observation ice morphology
- Example:
 - par fried frozen potato



Food Products

Chocolate bar

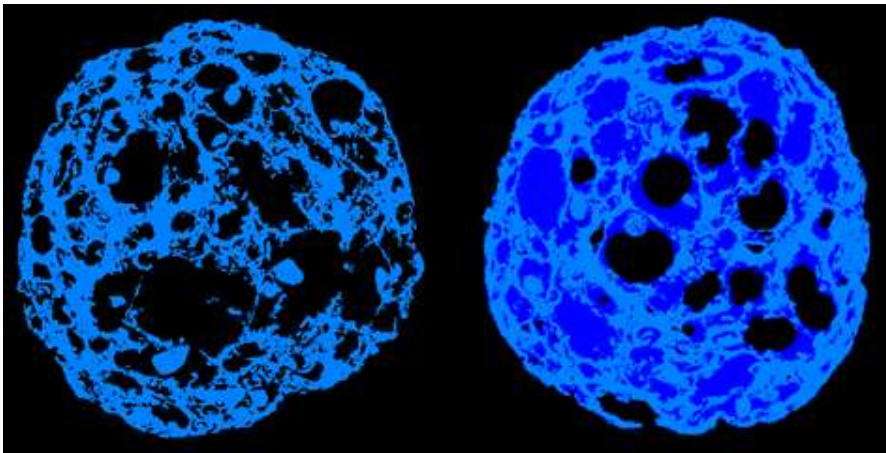


Feed Products

Fish feed pellet (expanded extrusion product)



- Oil absorption during vacuum coating
- Depends on:
 - Vacuum pressure
 - Connections between pores and outer surface



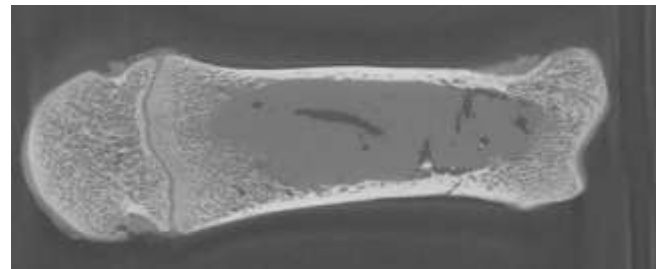
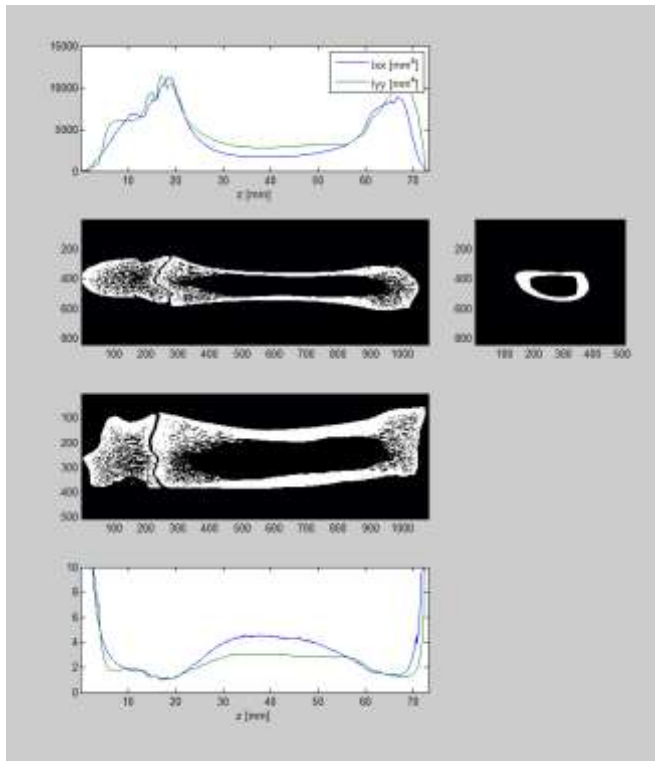
Animals and Humans

- We can't scan human people, nor living animals.
For 2 reasons:
 1. We cannot guarantee radiation safety
 2. They must not be able to move during the scan

- But ...
 - With the available software we are able to import several file formats such as DICOM
 - Medical CT and MRI scans can be analysed

Animals

Correlating bone structure to bone strength measurements on pork.

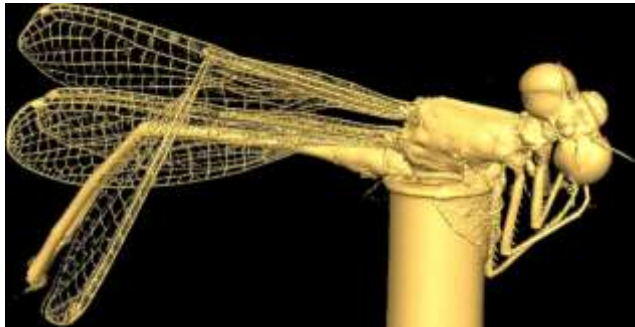


ASG, Paul Bikker, 2013

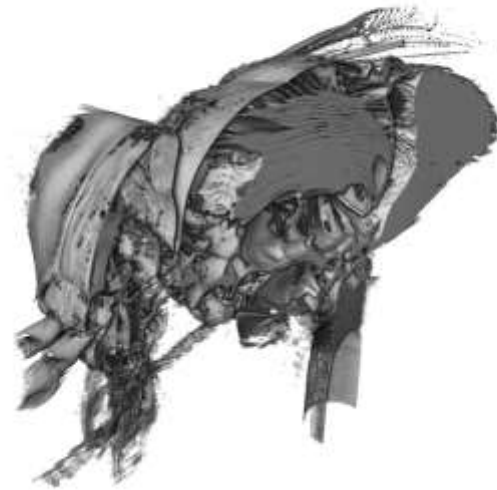
Animals

Insects (demonstration objects)

- dragonfly

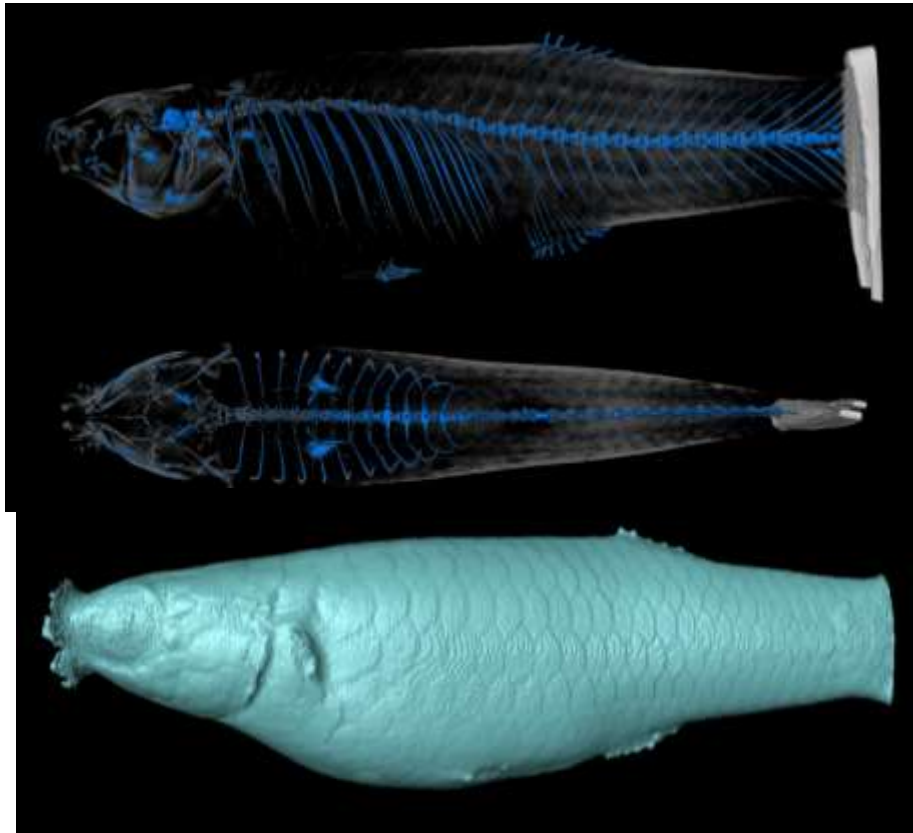


- fly



Animals

Fish (*Poeciliopsis gracilis*)



ASG & RUG, Elsa Quicazan, 2015

- Drag production of livebearing fish at different reproductive stages
- The 3D model was printed and tested in a flow tunnel

<https://www.youtube.com/watch?v=Plu6sXoHHzQ>

How does it work in practice

- The XRT is owned by WUR, so it's yours too
- You have access to it
- We are ready to facilitate you!
- Contact us before the project starts
- Assist you with proposal writing
 - Preferred above adding the method during the project

- 3 posters with questions
- Write your answers on the posters
it's preferred if you leave your name
- Put an post-it near answers if you are also interested in that answer

How can XRT contribute to your research project?



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