



WELCOME

RIGAKU WEBINAR SERIES

X-RAY COMPUTED TOMOGRAPHY
FOR MATERIALS & LIFE SCIENCE

LIFE SCIENCE APPLICATIONS

IS STARTING NOW.



Presenter: Angela Criswell

Senior Scientist
Rigaku Americas Corporation



Host: Tom Concolino

Southeast Regional Account Manager
Rigaku Americas Corporation



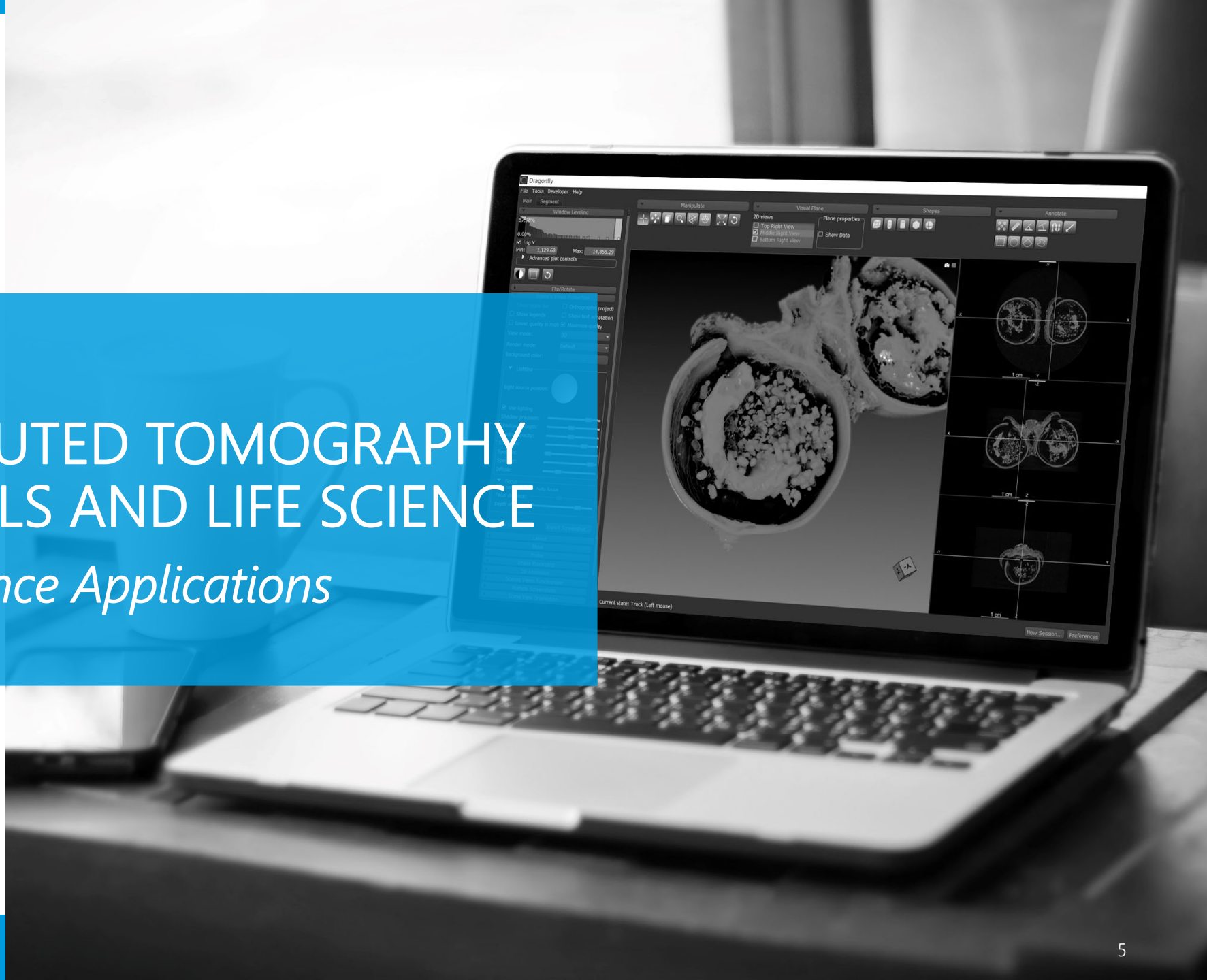
You can send us questions during the presentation.
They will be addressed at the end of the presentation.



A recording of this webinar will be available.
You will receive an email with a link to it tomorrow.

X-RAY COMPUTED TOMOGRAPHY FOR MATERIALS AND LIFE SCIENCE

Life Science Applications



Life science

a branch that deals with living organisms and life processes (Merriam-Webster)

medicine, biology, botany, archaeology and sometimes anthropology or sociology





You will learn:

- Sample Contrast
- CT Data Analysis
- Life Science Applications

X-RAY ABSORPTION

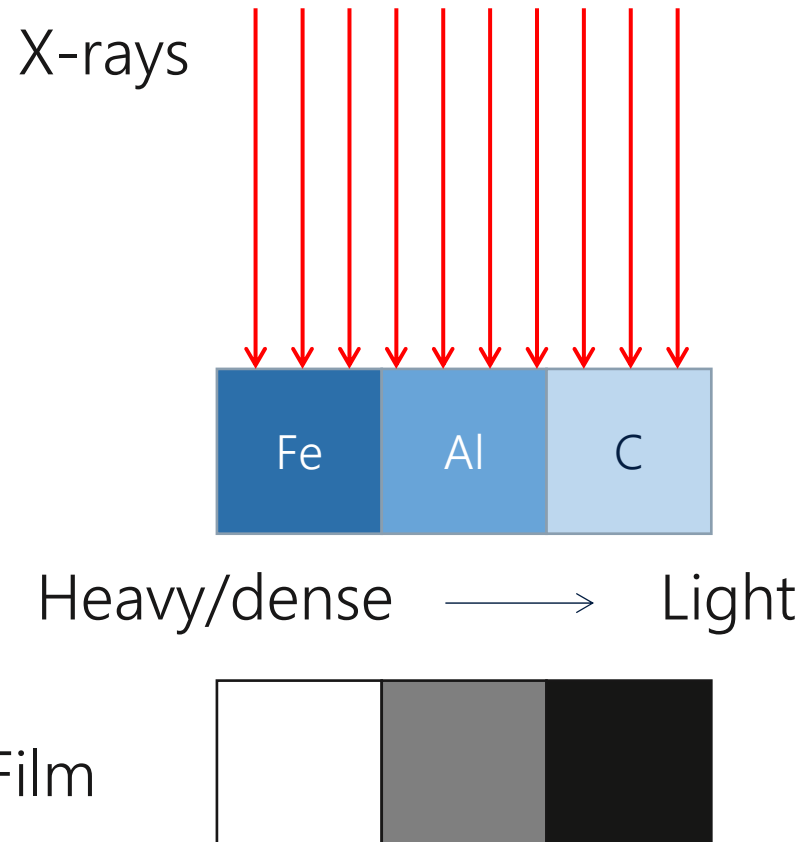
$$I_{measured} = I_{incident} e^{-\mu t}$$

$$\mu = \frac{\rho Z^4}{AE^3}$$

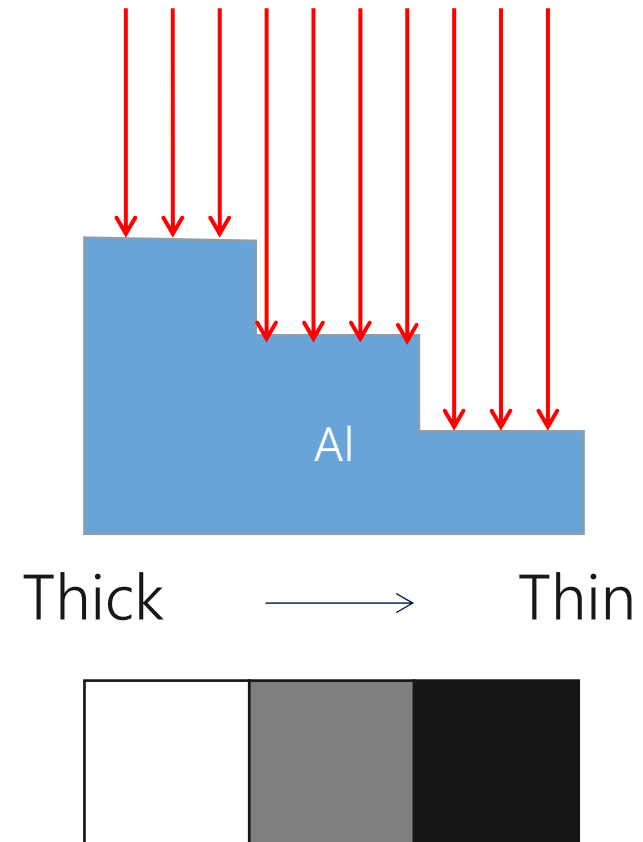
- X-ray absorption depends on:
 - Elemental composition
 - Density (ρ)
 - Atomic number (Z)
 - Atomic mass (A)
 - X-ray energy (E)
 - Sample thickness (t)



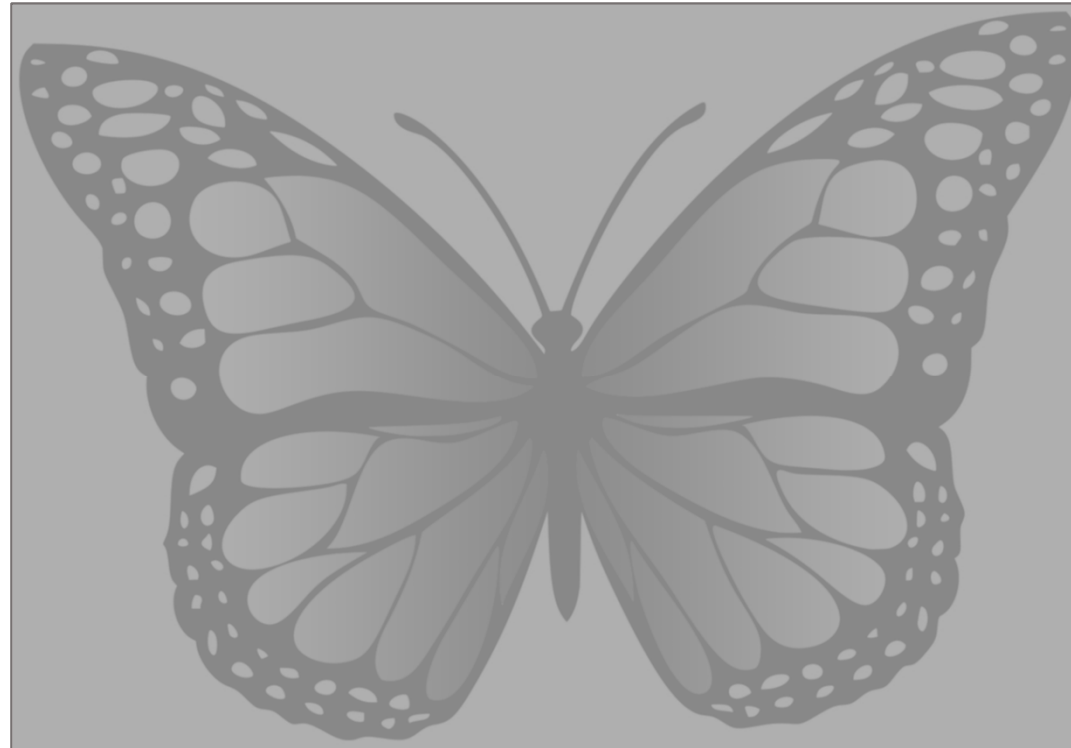
Elemental composition



Sample thickness



X-ray energy



Energy not optimal
Energy not optimal

Group→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
↓Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
Lanthanides			57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
Actinides			89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	

CONTRAST ENHANCEMENT

- Choice of X-ray energy
- Phase contrast imaging
- Phase retrieval
- Contrast agents

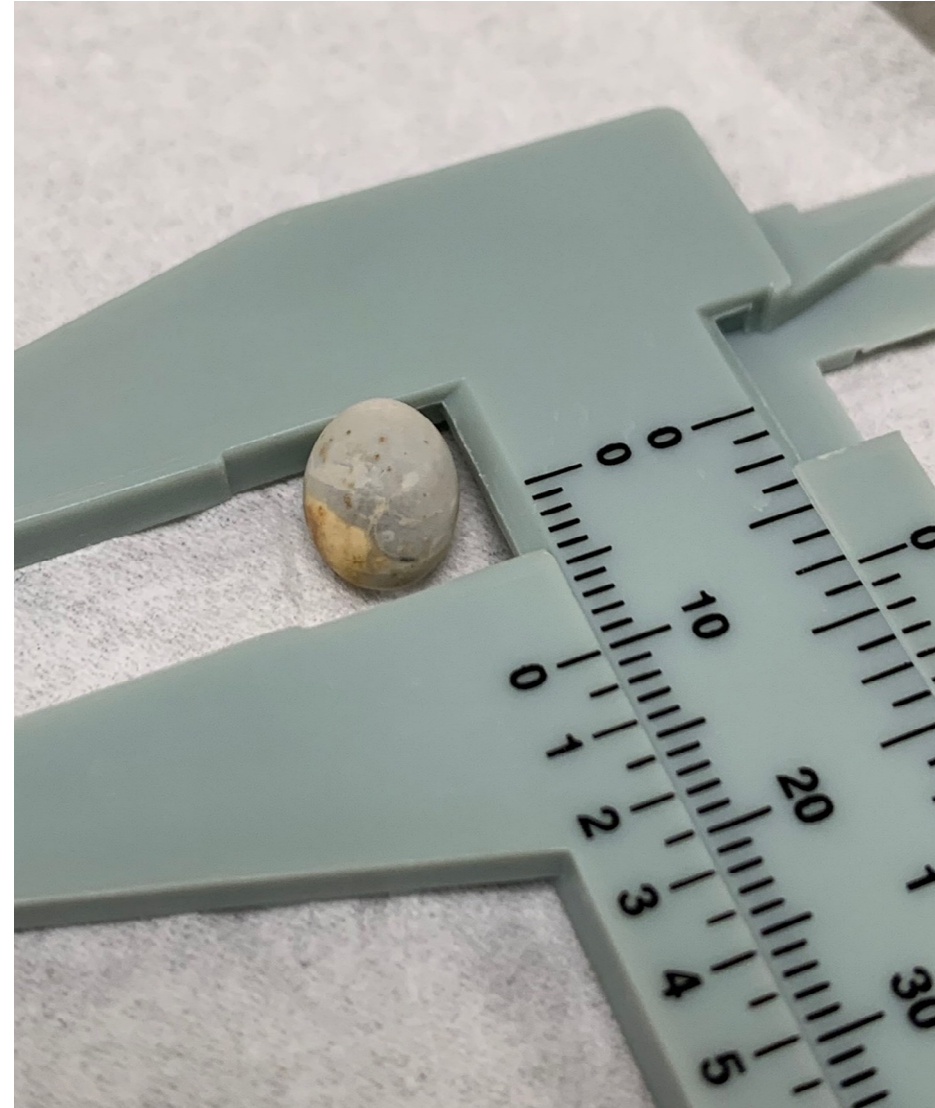


CHOICE OF X-RAY ENERGY



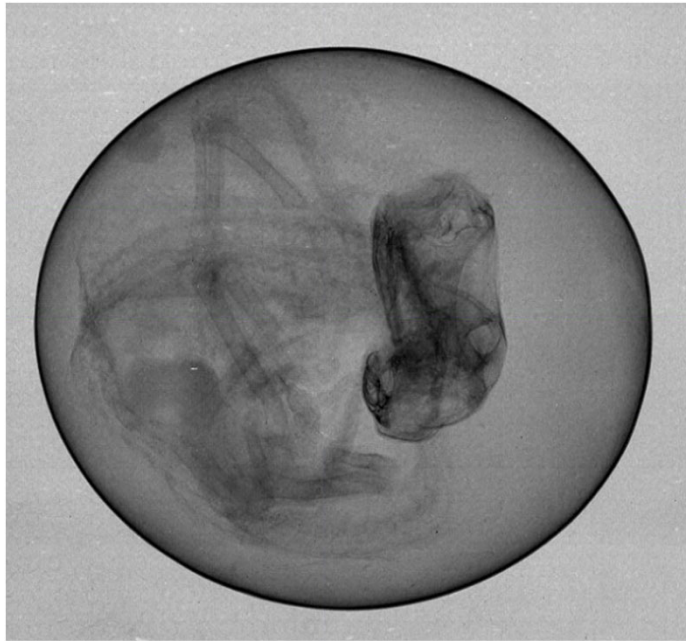
X-RAY ENERGY

- CT Lab HX (W target)

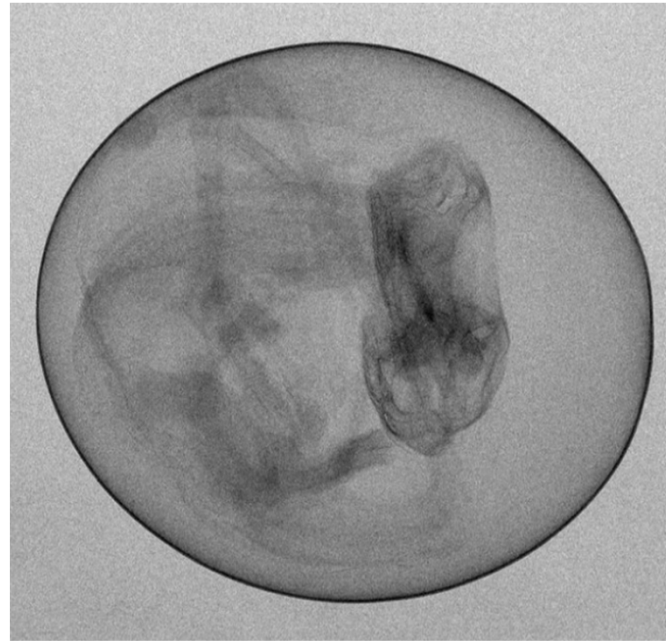


X-RAY ENERGY

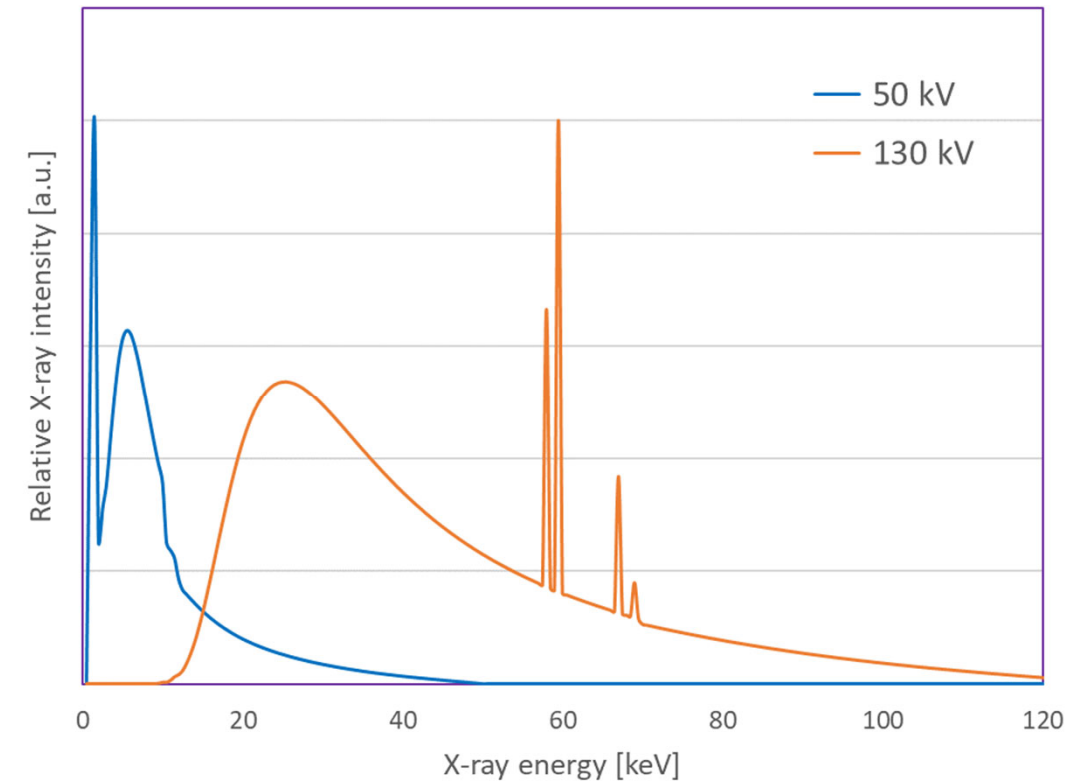
- CT Lab HX (W target, selectable applied voltage)



W target 50 kV

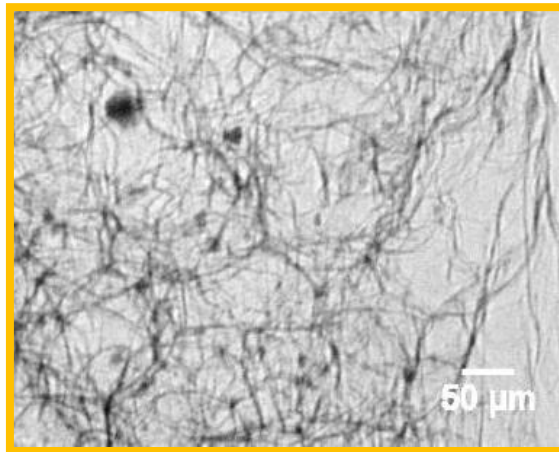
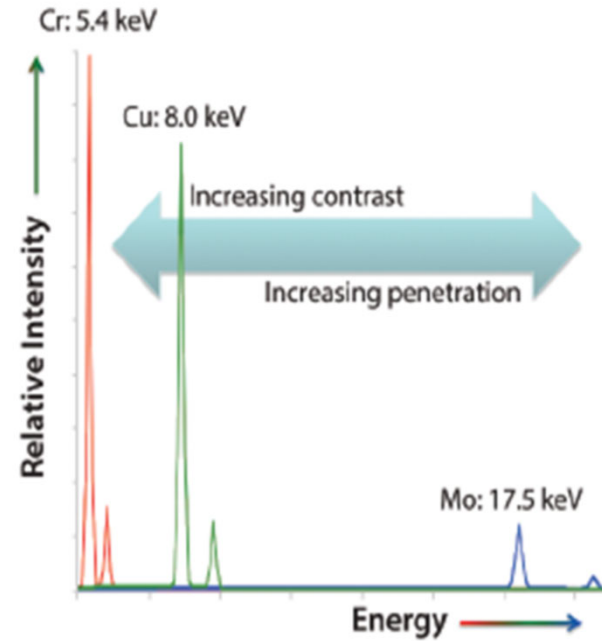


W target 130 kV

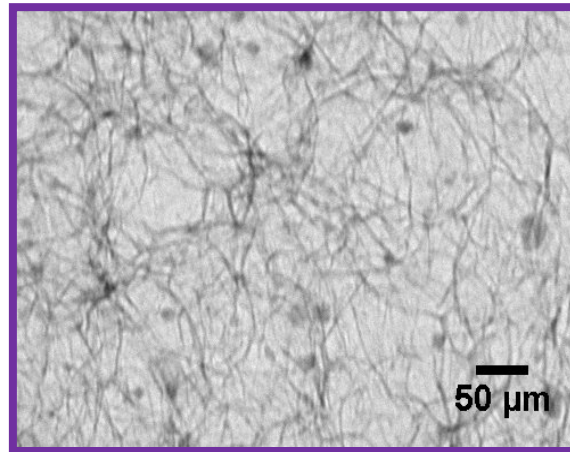


X-RAY ENERGY

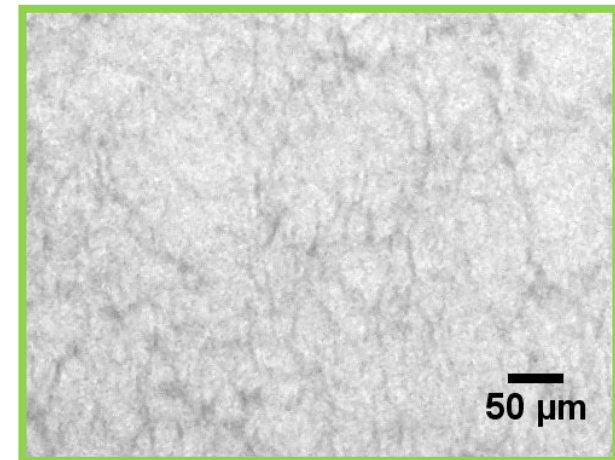
- nano3DX (selectable target)
 - Cr, Cu, Mo



Cr target 5.4 keV



Cu target 8 keV



Mo target 17 keV

PHASE CONTRAST IMAGING

PHASE CONTRAST IMAGING

- Takes advantage of phase change generated by refraction as X-rays pass through sample.



PHASE CONTRAST IMAGING

- Takes advantage of phase change generated by refraction as X-rays pass through sample.
- Enhances the visibility of the interfaces between soft tissues
 - "Edge enhancement"



PHASE CONTRAST IMAGING - RAT

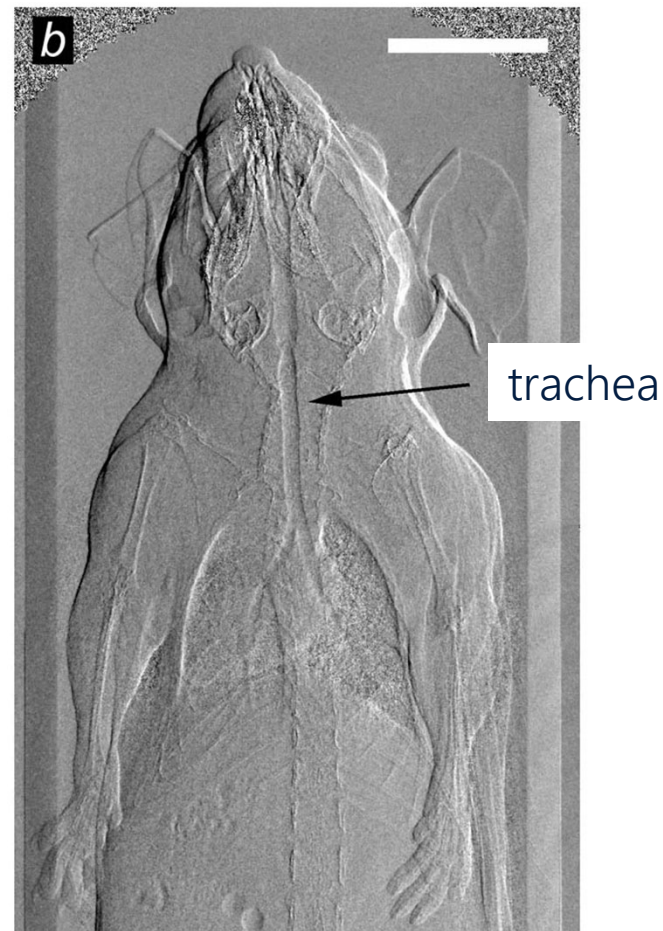


Image adapted from: Bech, M., Tapfer, A., Velroyen, A. *et al.* "In-vivo dark-field and phase-contrast X-ray imaging." *Sci Rep* 3, 3209 (2013).

PHASE RETRIEVAL

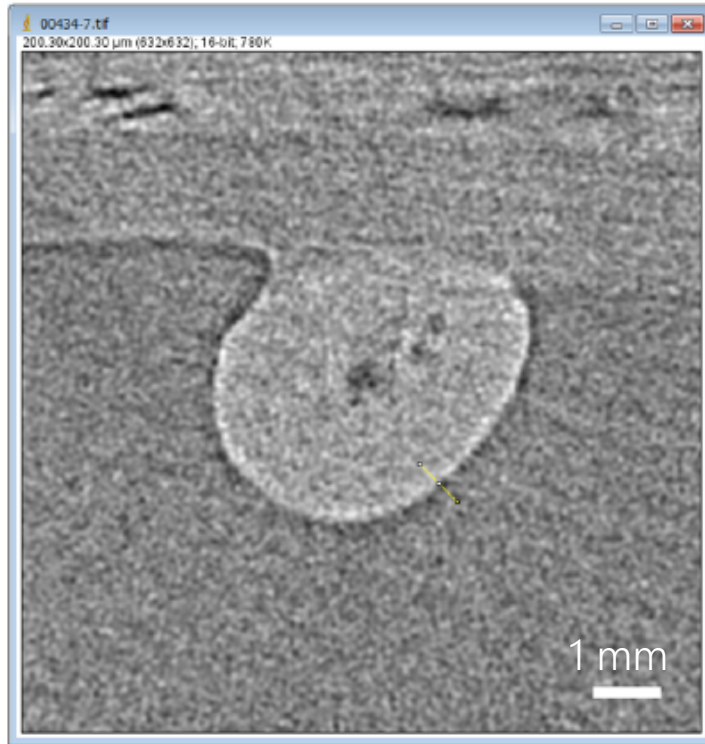
PHASE RETRIEVAL

- Inexpensive, as it does not require additional hardware

```
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function(b){this.element=a(b)};c.VERSION="3.
d=b.data("target");if(d||(d=b.attr("href"),d
("hide.bs.tab",{relatedTarget:b[0]}),g=a.Ev
){var h=a(d);this.activate(b.closest("li"),c
nown.bs.tab",relatedTarget:e[0]}))}}},c.pro
moveClass("active").end().find('[data-toggl
),h?(b[0].offsetWidth,b.addClass("in")):b.r
toggle="tab"]').attr("aria-expanded",!0),e&&
>.fade").length);g.length&&h?g.one("bsTran
a.fn.tab=b,a.fn.tab.Constructor=c,a.fn.tab
ent).on("click.bs.tab.data-api",[data-tog
tion b(b){return this.each(function(){var c
}))}var c=function(b,d){this.options=a.ext
checkPosition,this)).on("click.bs.affix.da
dOffset=null,this.checkPosition()};c.VERSION
a,b,c,d){var e=this.$target.scrollTop(),f=
affixed)return null!=c?!(e+this.unpin<=f.t
":null!=d&&i+j>a-d&&"bottom"},c.prototype
s("affix");var a=this.$target.scrollTop()
unction(){setTimeout(a.proxy(this.checkPos
this.options.offset,e=d.top,f=d.b
p(this.$element,
```

PHASE CONTRAST IMAGING - HAIR

Absorption (no treatment)



Absorption (denoise)



Phase retrieval

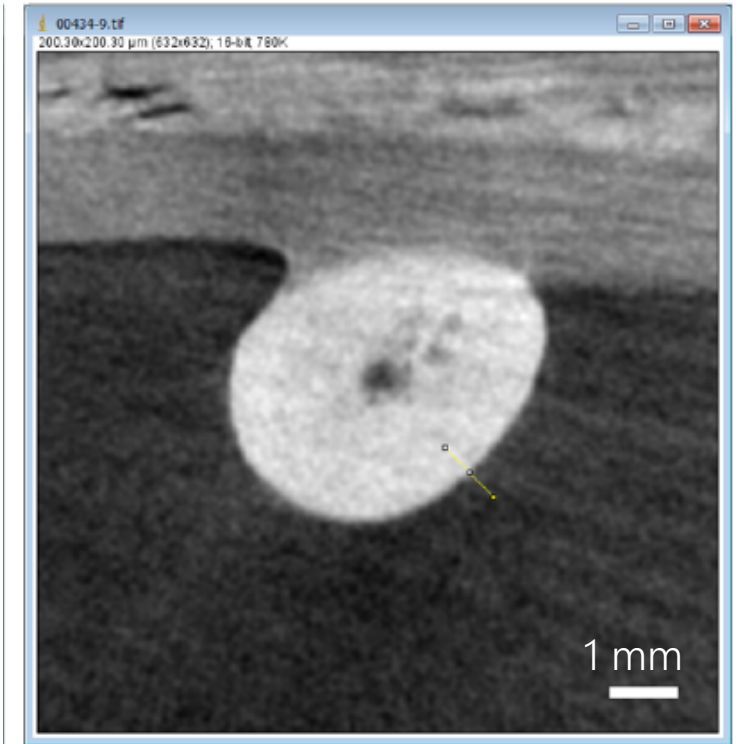
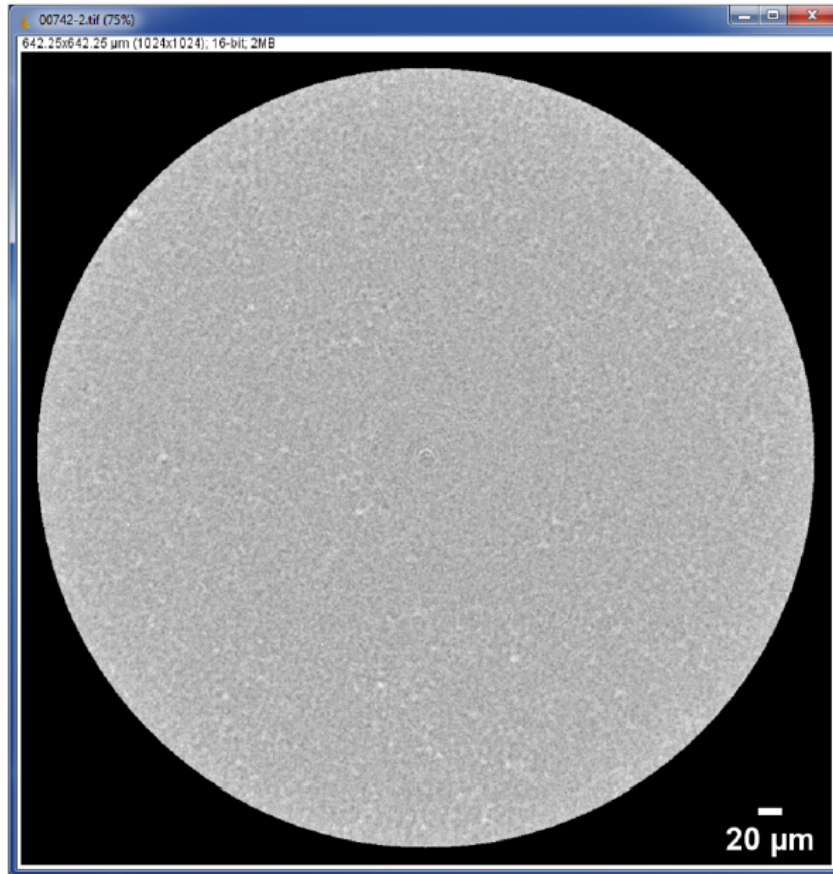


Image adapted from: Kunishima, N. "Application of the nano3DX X-ray microscope to biological specimens." *Rigaku Journal* **36**, 33 (2020).

PHASE CONTRAST IMAGING – PANSY SEED

Absorption (no treatment)



Phase retrieval

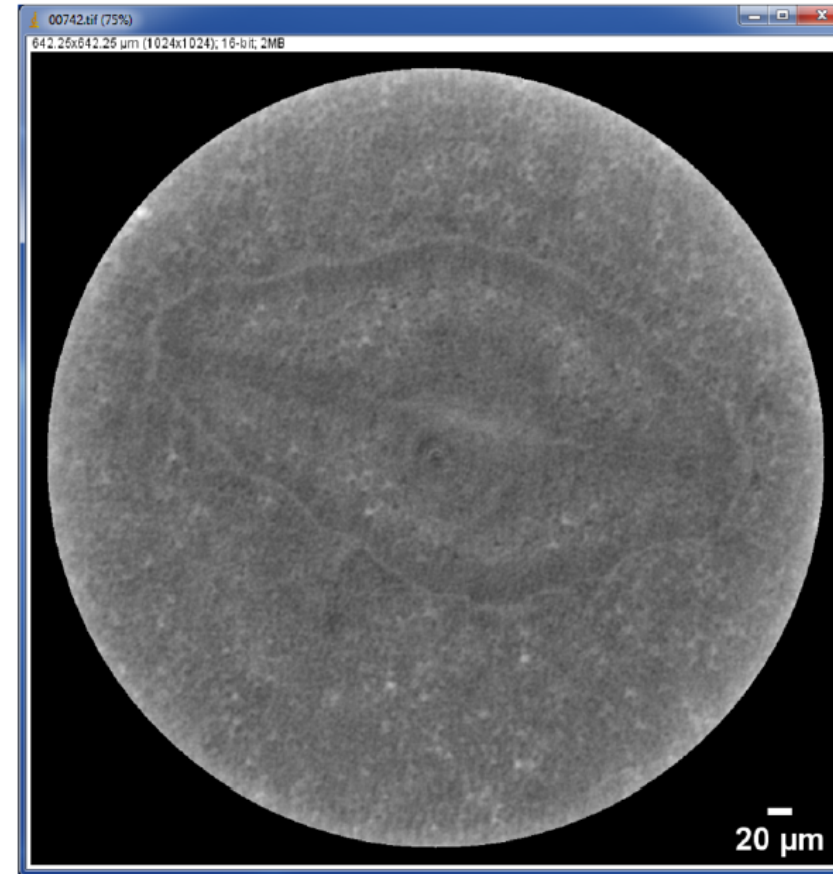


Image adapted from: Kunishima, N. "Application of the nano3DX X-ray microscope to biological specimens." *Rigaku Journal* **36**, 33 (2020).

CONTRAST AGENTS

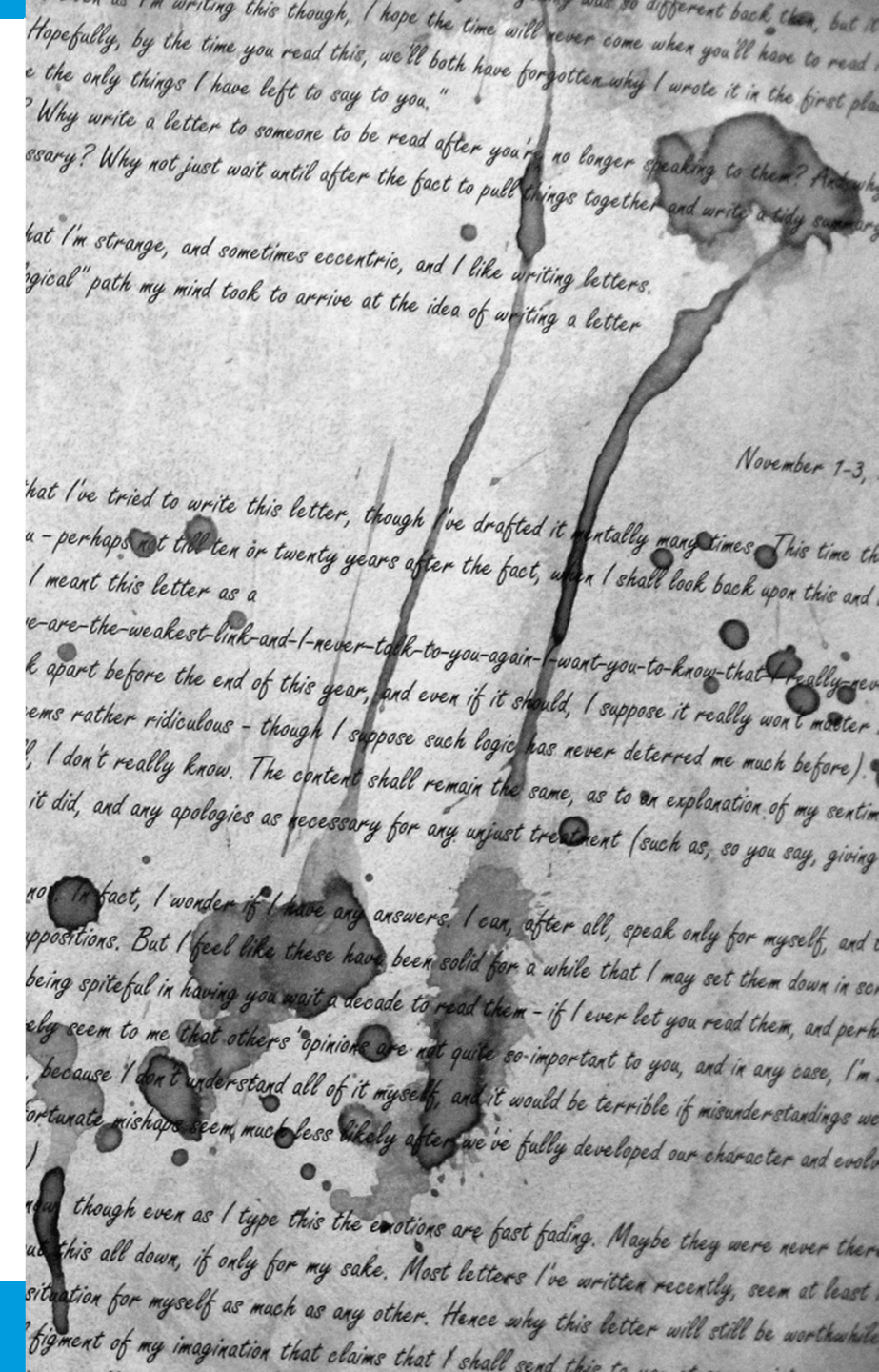
CONTRAST AGENTS

- Chemical tools
 - Heavy atom labels
 - Heavy atom stains



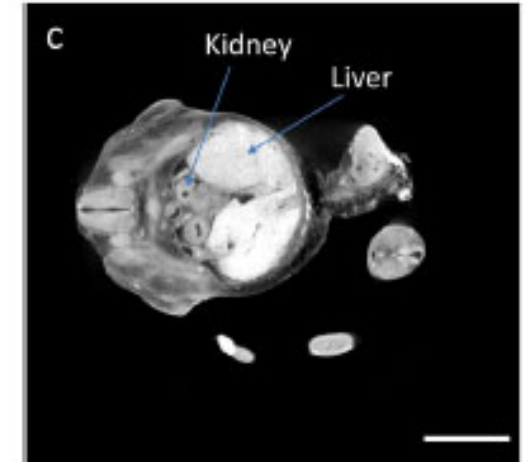
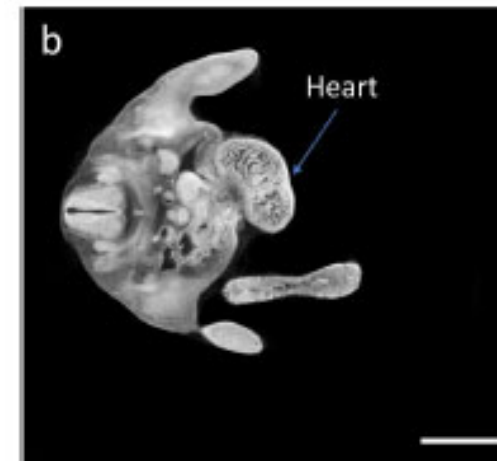
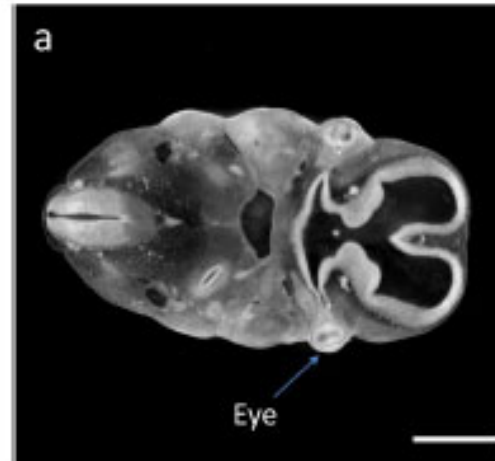
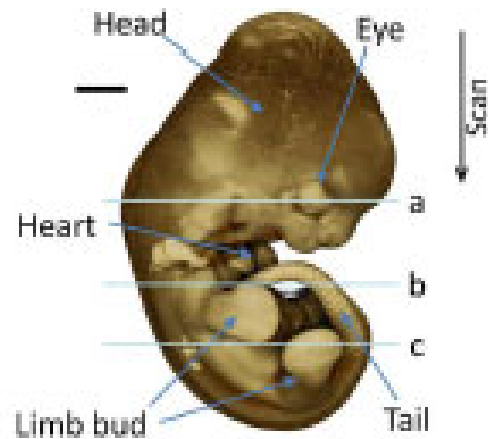
HEAVY ATOM STAINING

- Preservation
 - Fixation
- Staining
 - Stain time
 - Stain concentration
- Drying



CHEMICAL STAINING – MOUSE EMBRYO

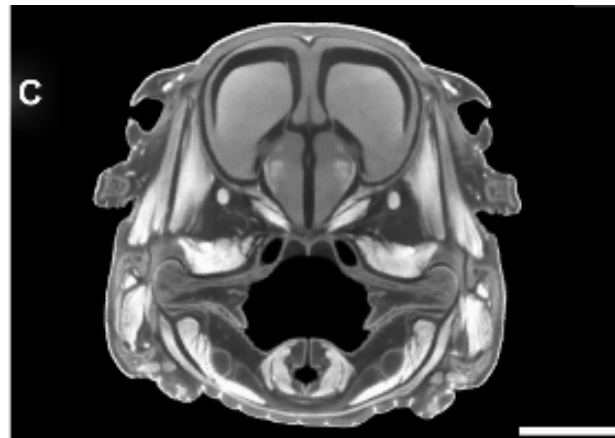
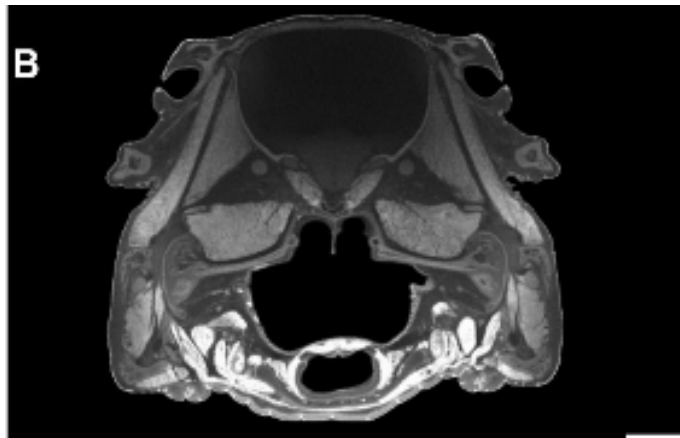
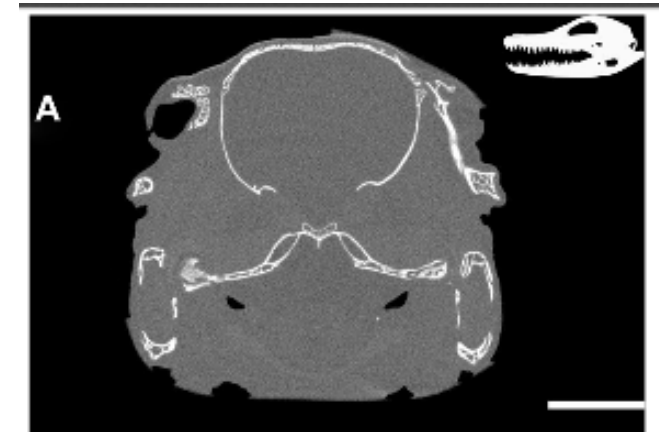
- Fixed in formaldehyde
- Staining with phosphotungstate solution



Images adapted from: Kunishima, N. "Application of the nano3DX X-ray microscope to biological specimens." *Rigaku Journal* **36**, 33 (2020).

CHEMICAL STAINING – ALLIGATOR

- Fixed in 10% buffered formalin
- Staining with Lugol's solution (iodine)

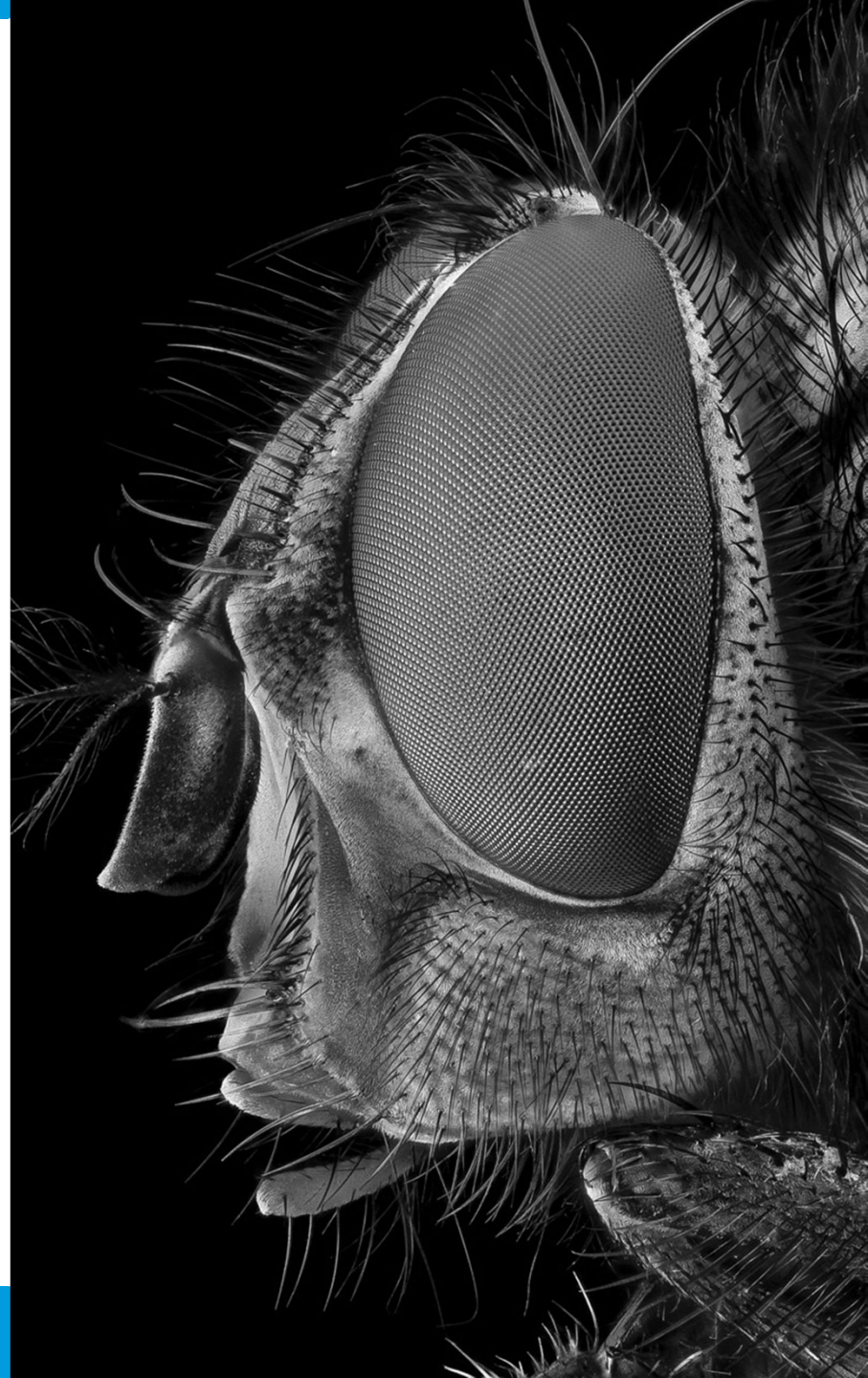


Images adapted from: Gignac, PM, Kley, NJ. "Iodine-Enhanced Micro-CT Imaging: Methodological Refinements for the Study of the Soft-Tissue Anatomy of Post-Embryonic Vertebrates." *J. Exp. Zool. (Mol. Dev. Evol.)* **322B**, 166 (2014).

CT DATA ANALYSIS

WHAT TYPES OF ANALYSES?

- Taxonomic and anatomic study
- Development studies
- Whole animal phenotyping
- Parasite pathology
- Respiration function
- Time-course studies



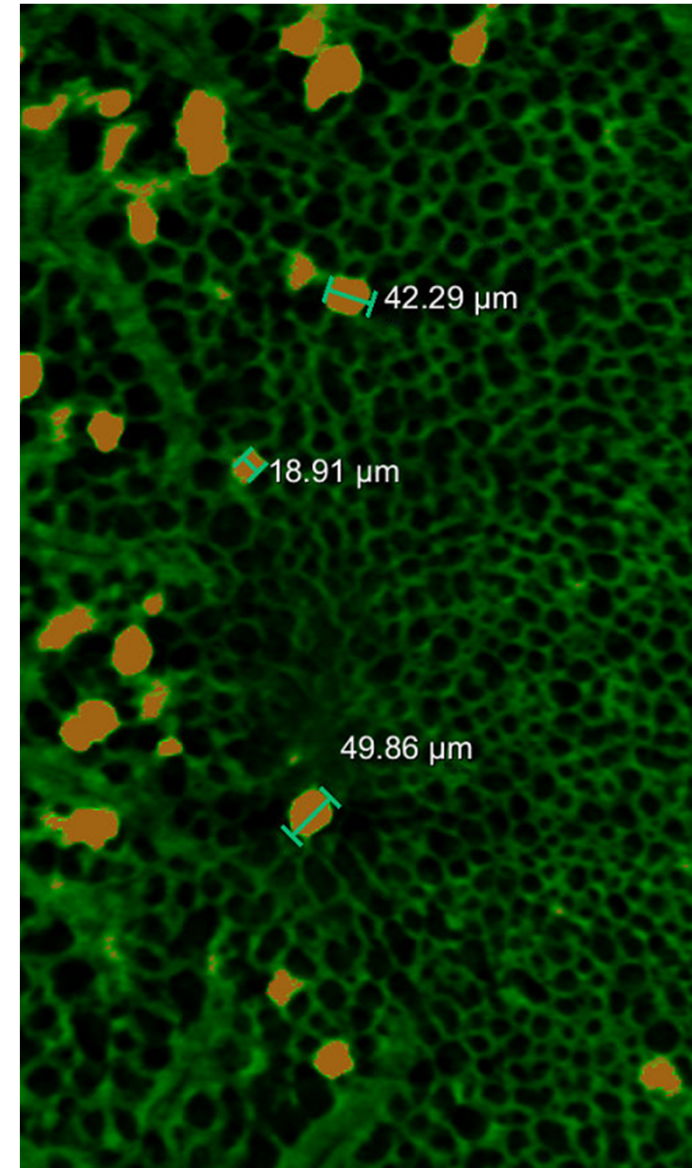
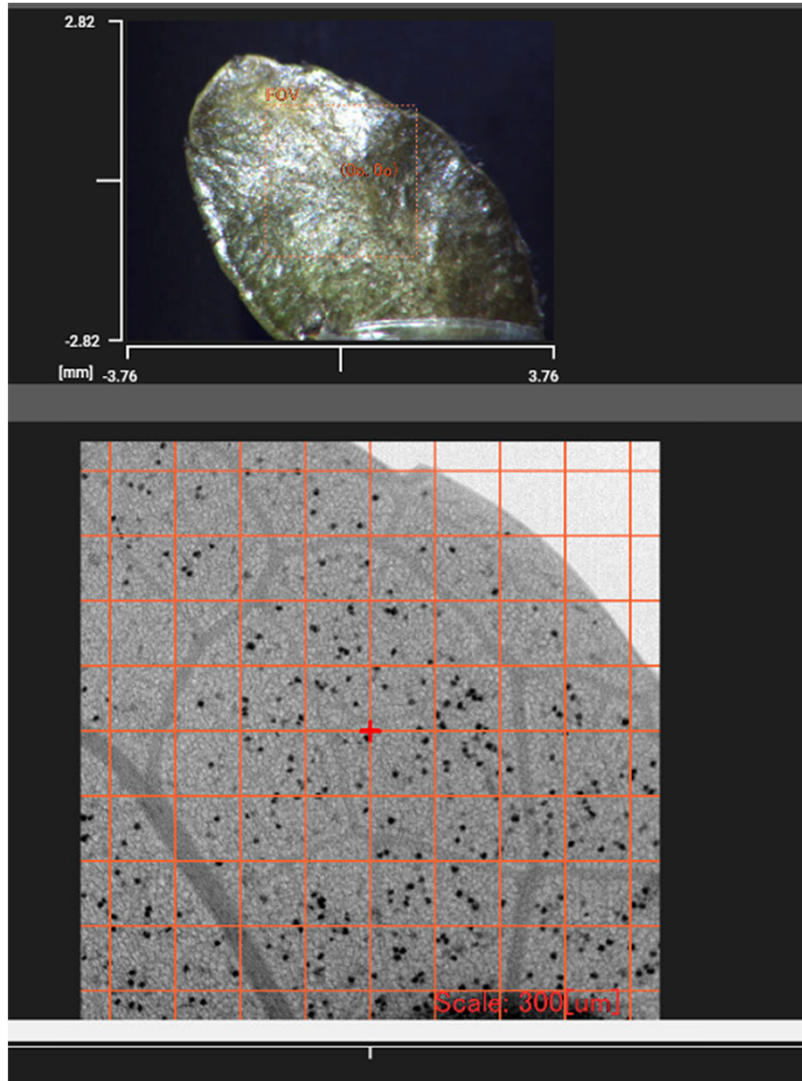
WHAT ARE THE CHALLENGES?

DATA ANALYSIS CHALLENGES

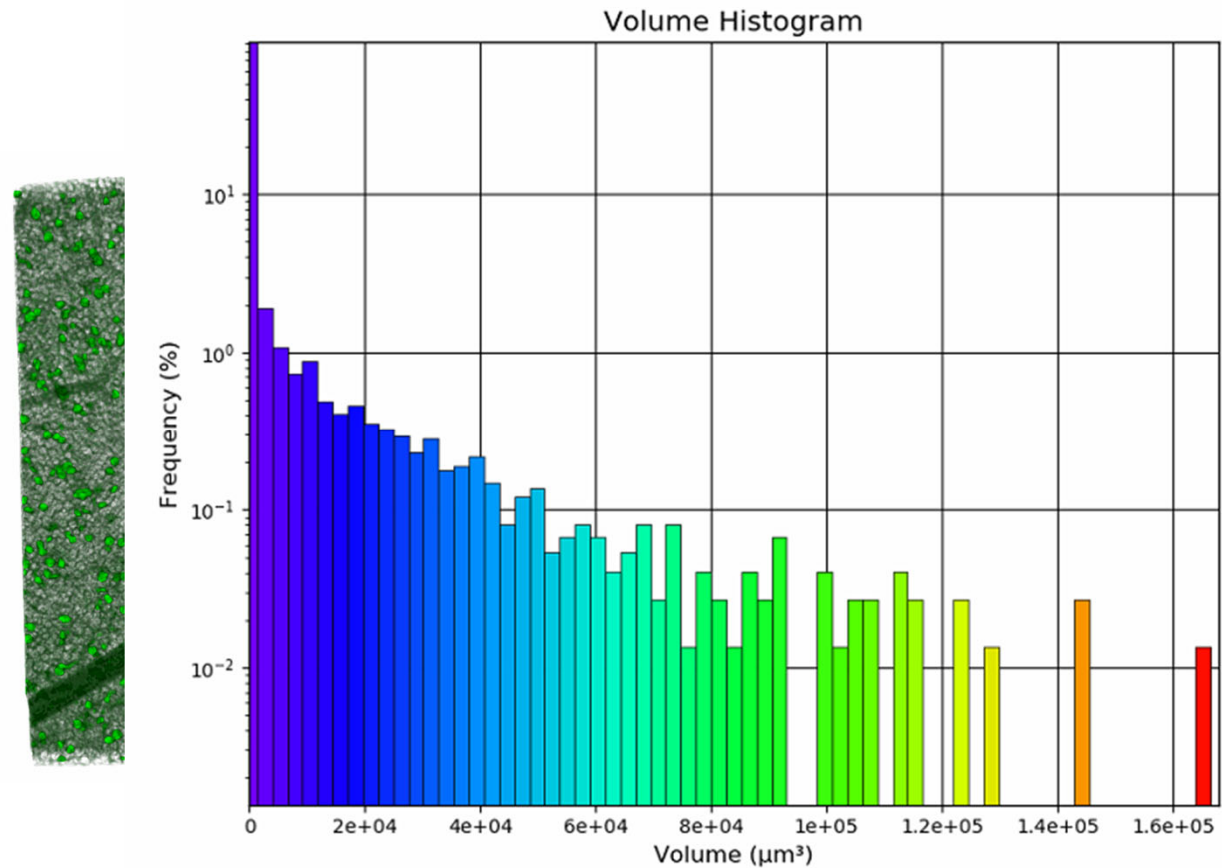
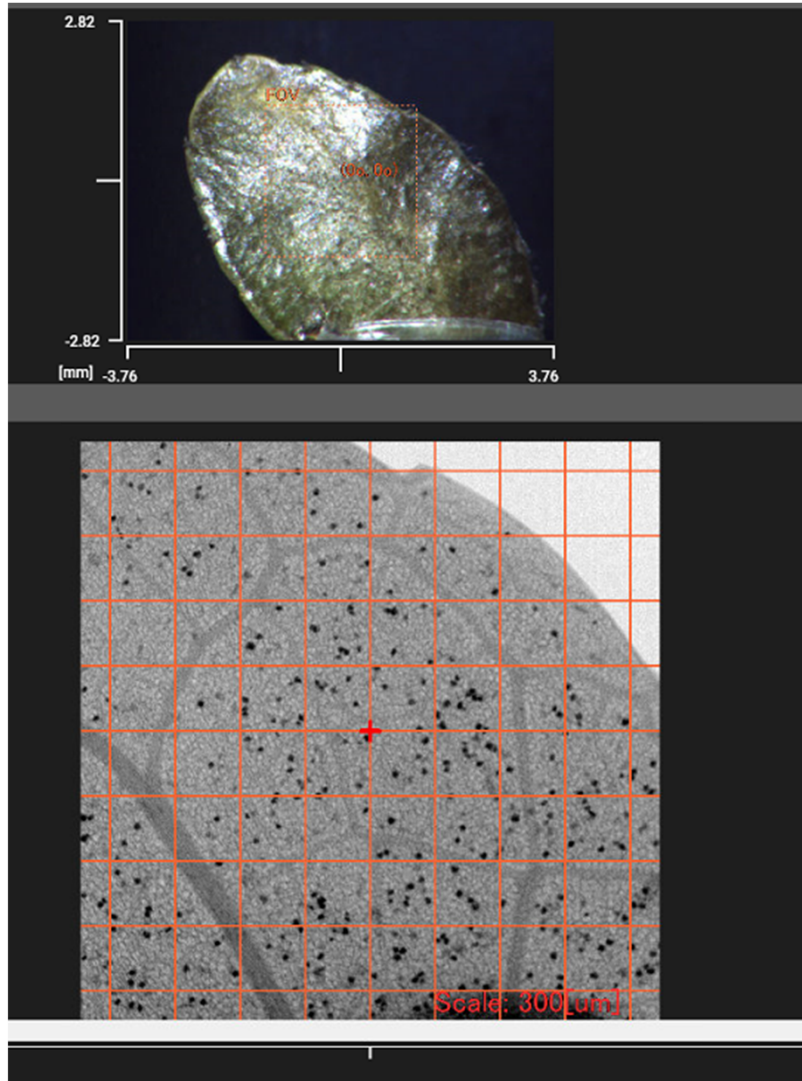
- Quantification
- Segmentation



QUANTITATIVE ANALYSES



QUANTITATIVE ANALYSES

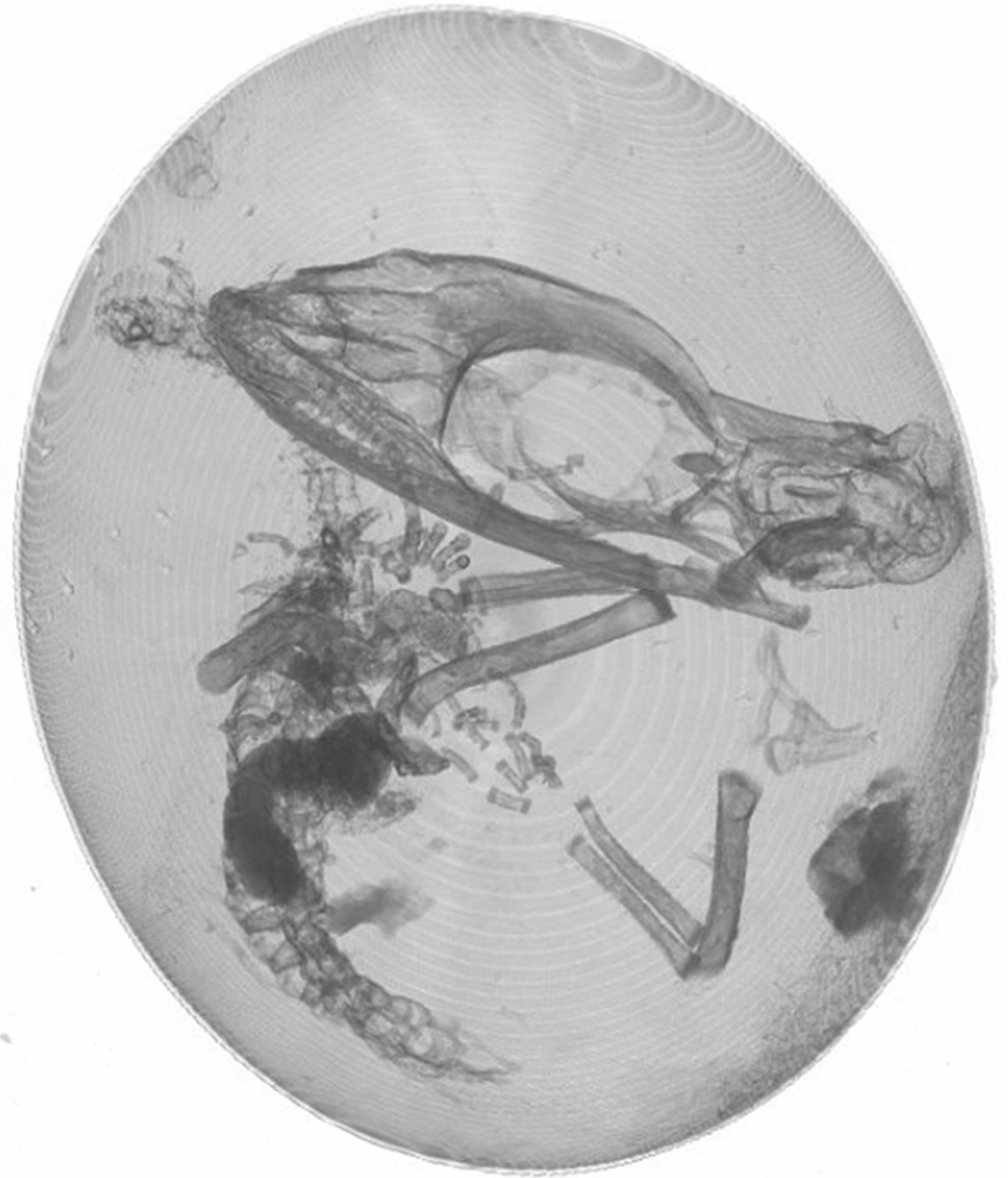


QUANTITATIVE ANALYSIS

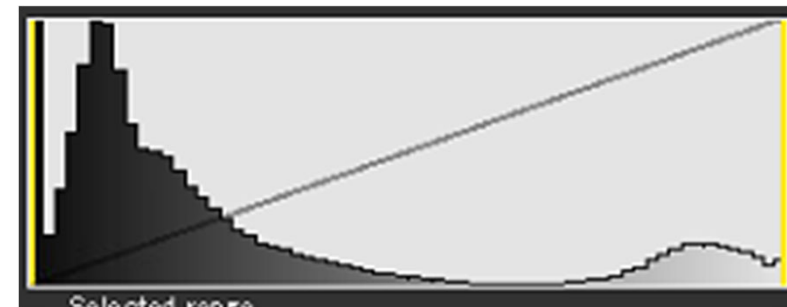
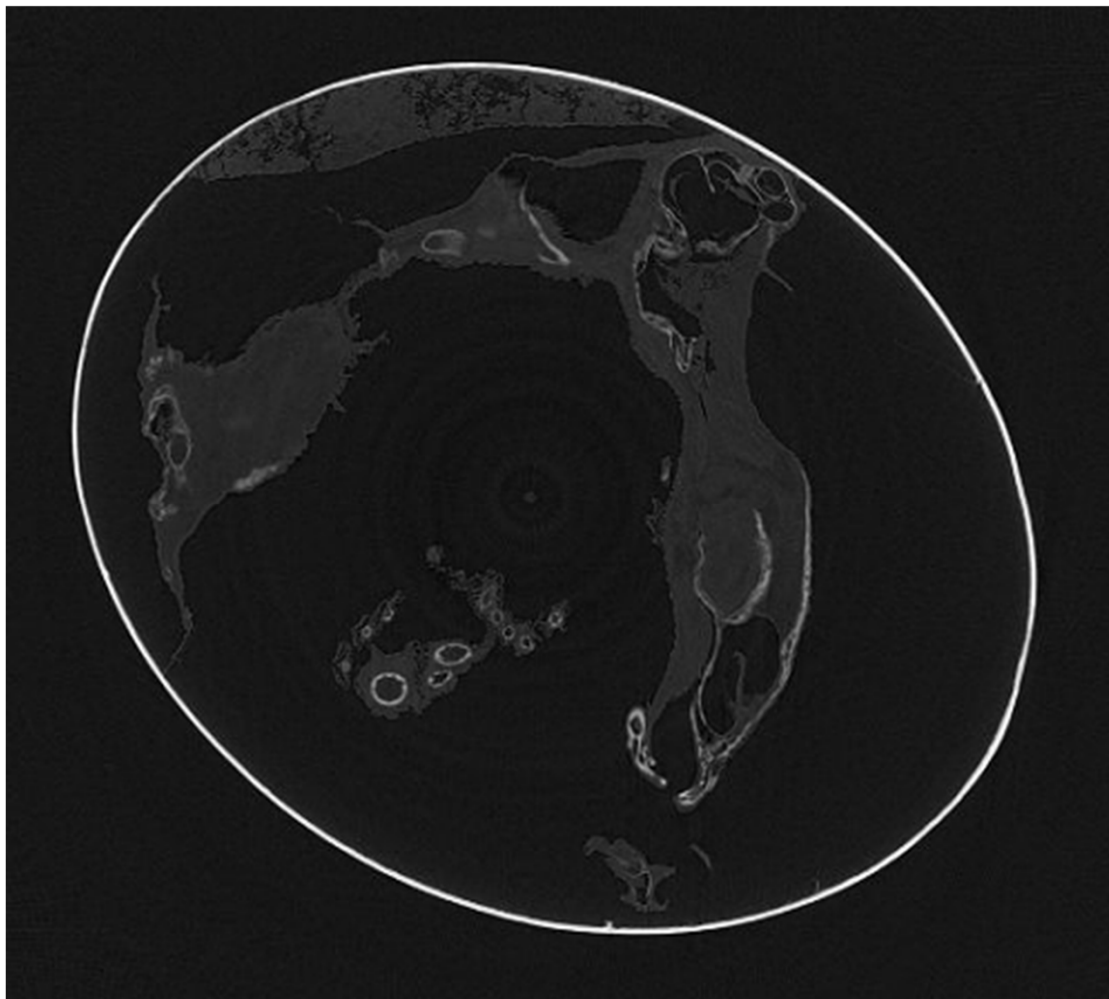
- Volumetric analysis
 - Volume percentage
 - Volume distribution
- Porosity
- Branching

SEGMENTATION

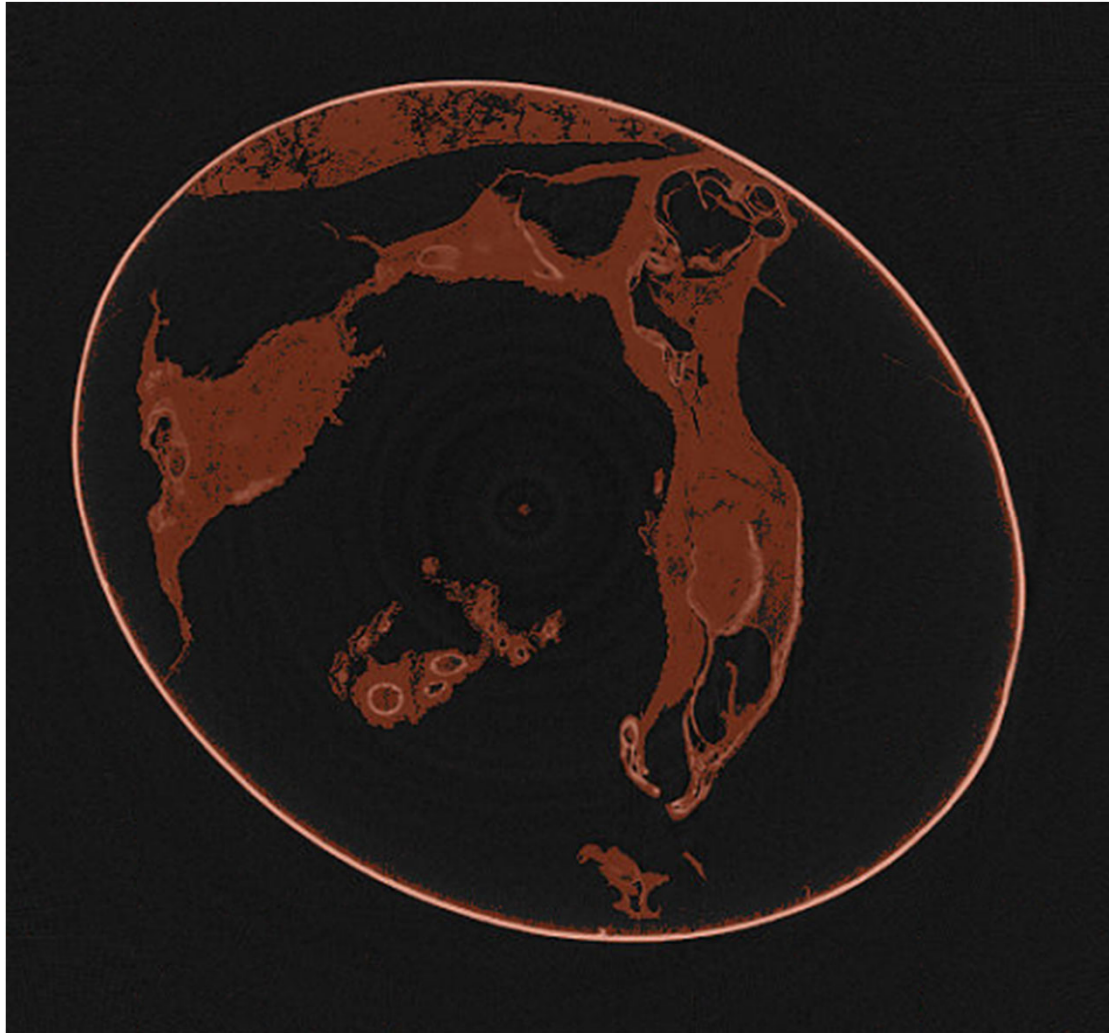
- Assign every voxel to a ROI
 - Time consuming
 - Can be difficult



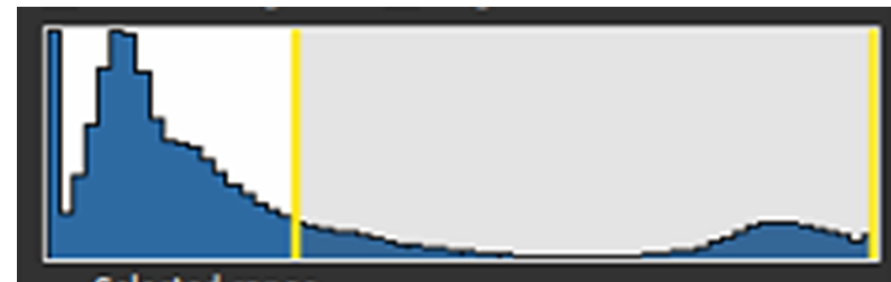
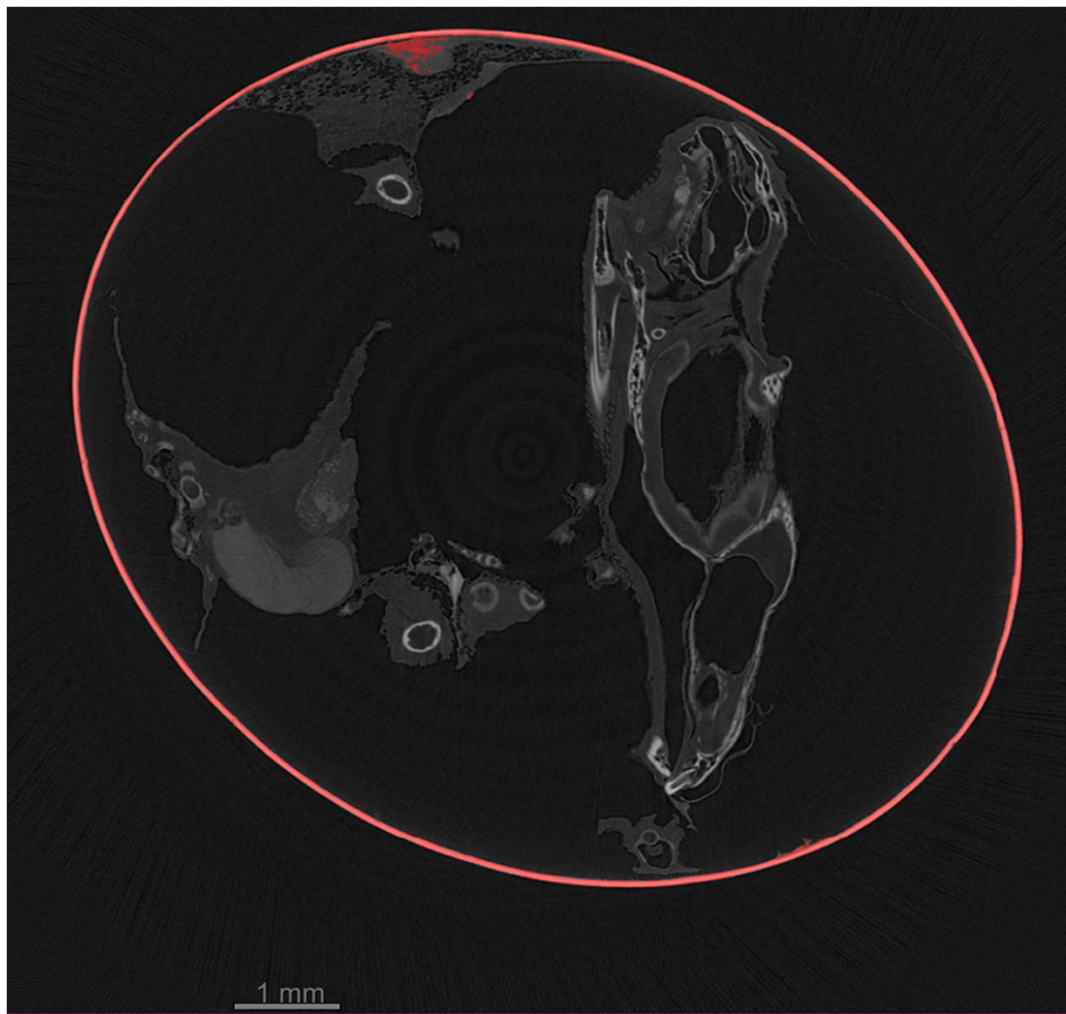
SEGMENTATION



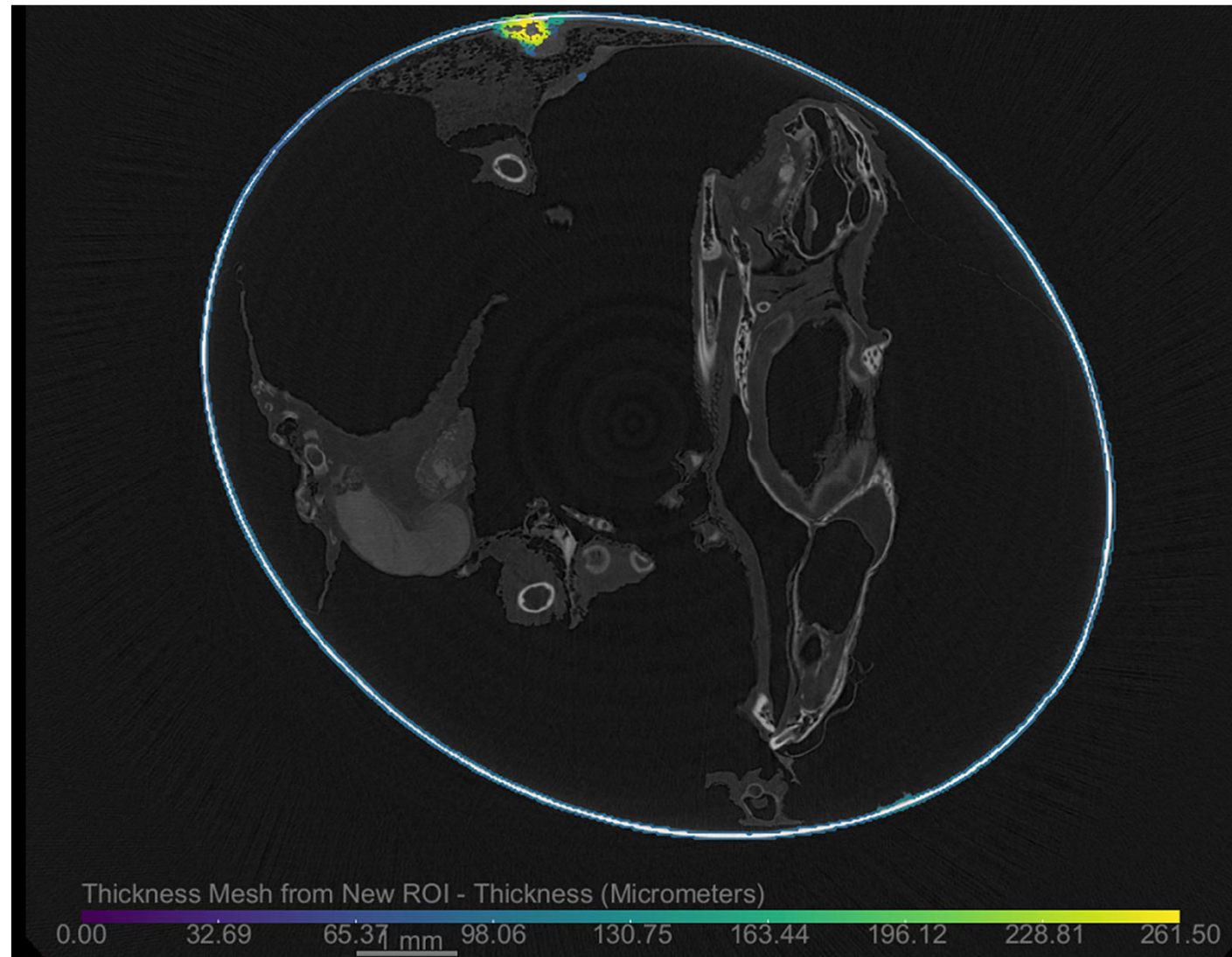
SEGMENTATION



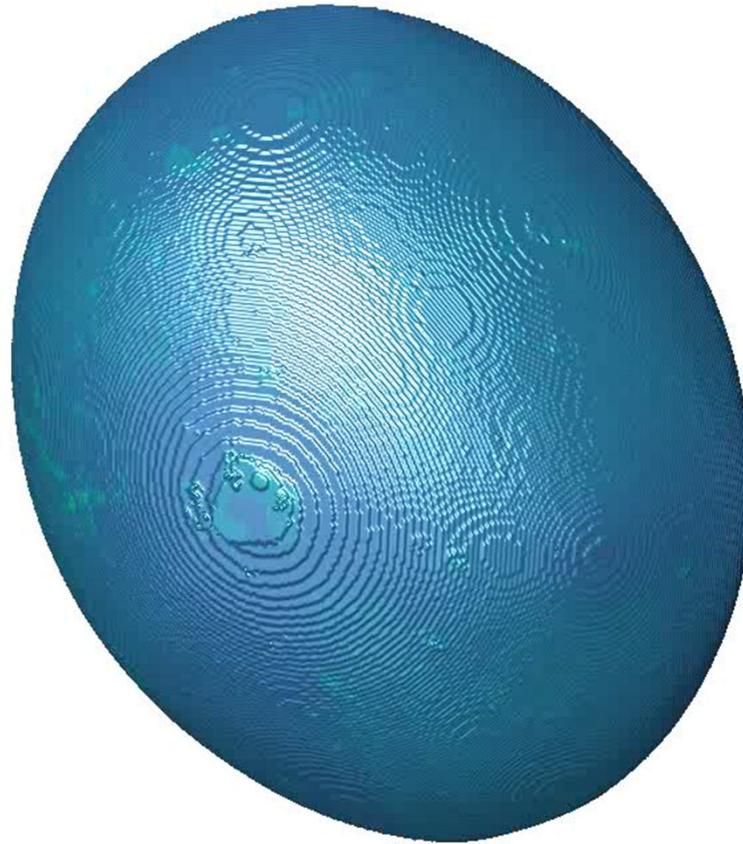
SEGMENTATION



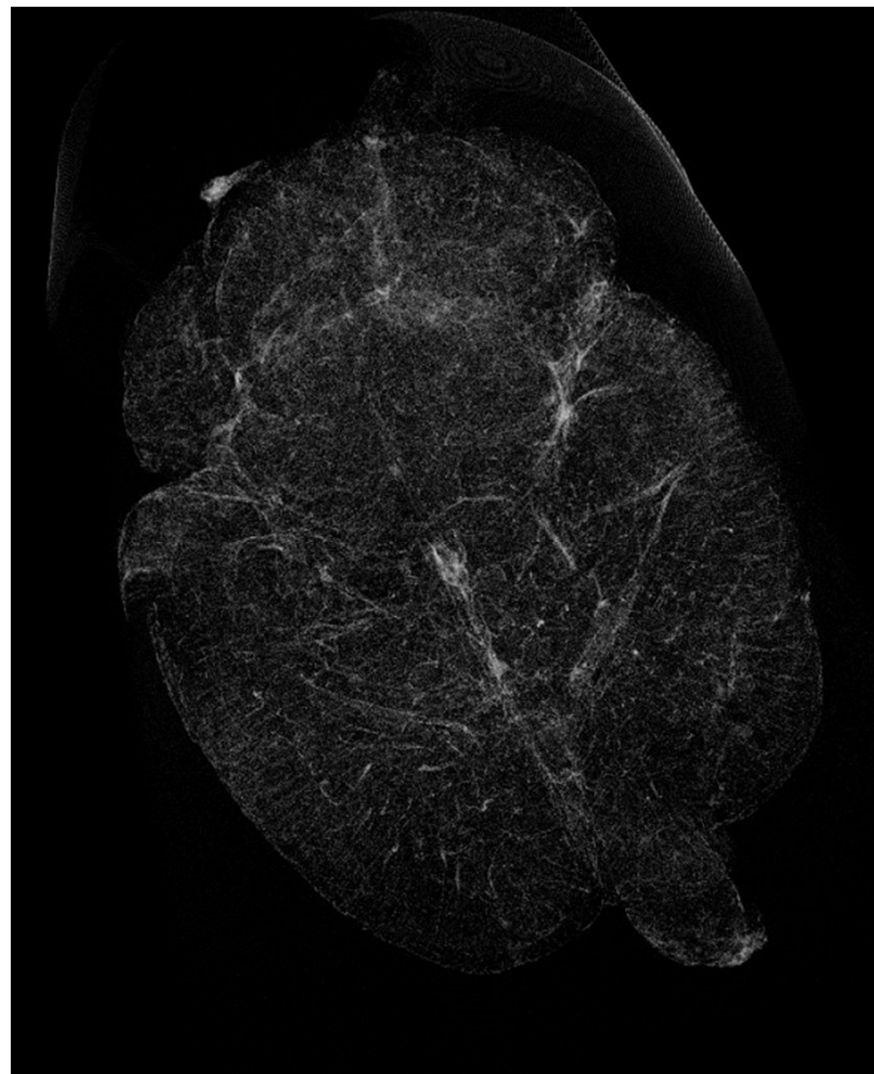
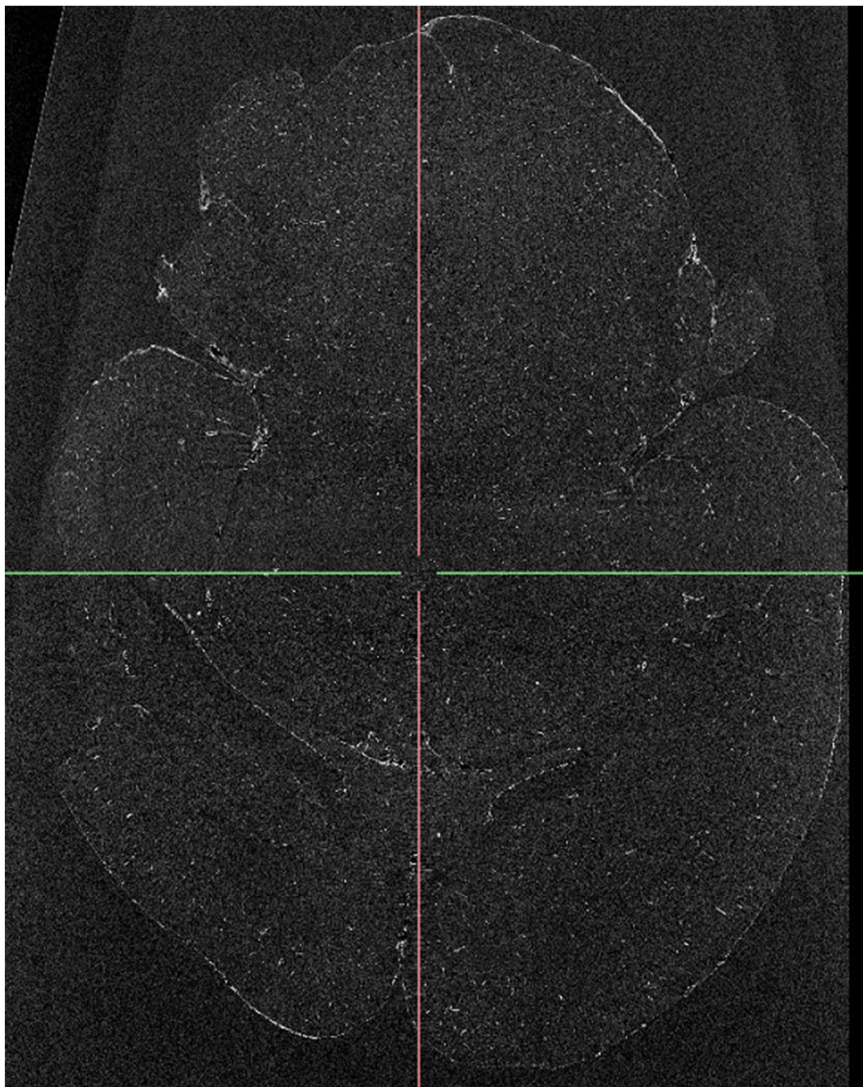
THICKNESS MESH OF EGG SHELL



THICKNESS MESH OF EGG SHELL



SEGMENTATION – MOUSE BRAIN



LET'S LOOK AT SOME EXAMPLES

ANT LEG

- nano3DX



GREEN ANOLE

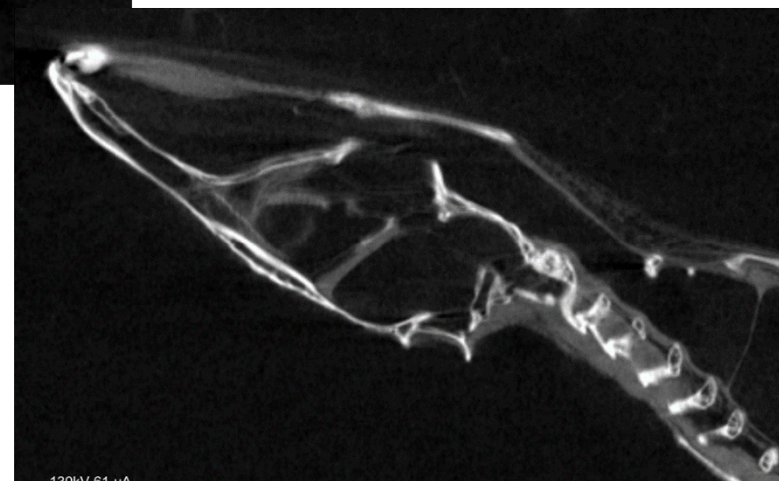
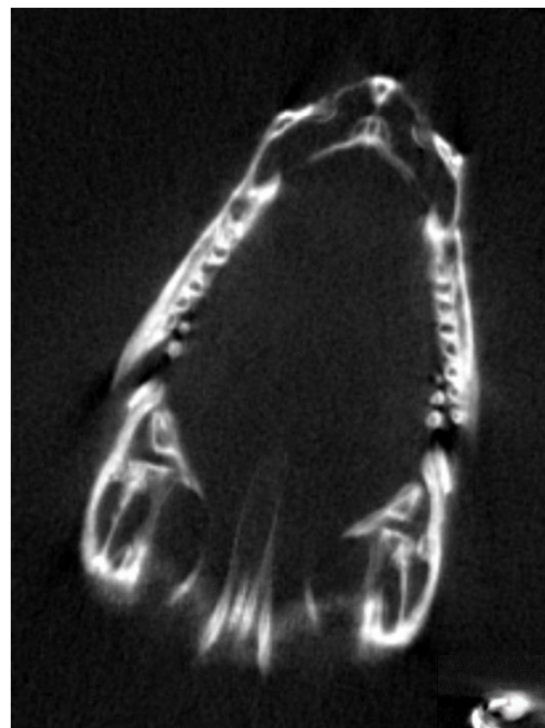
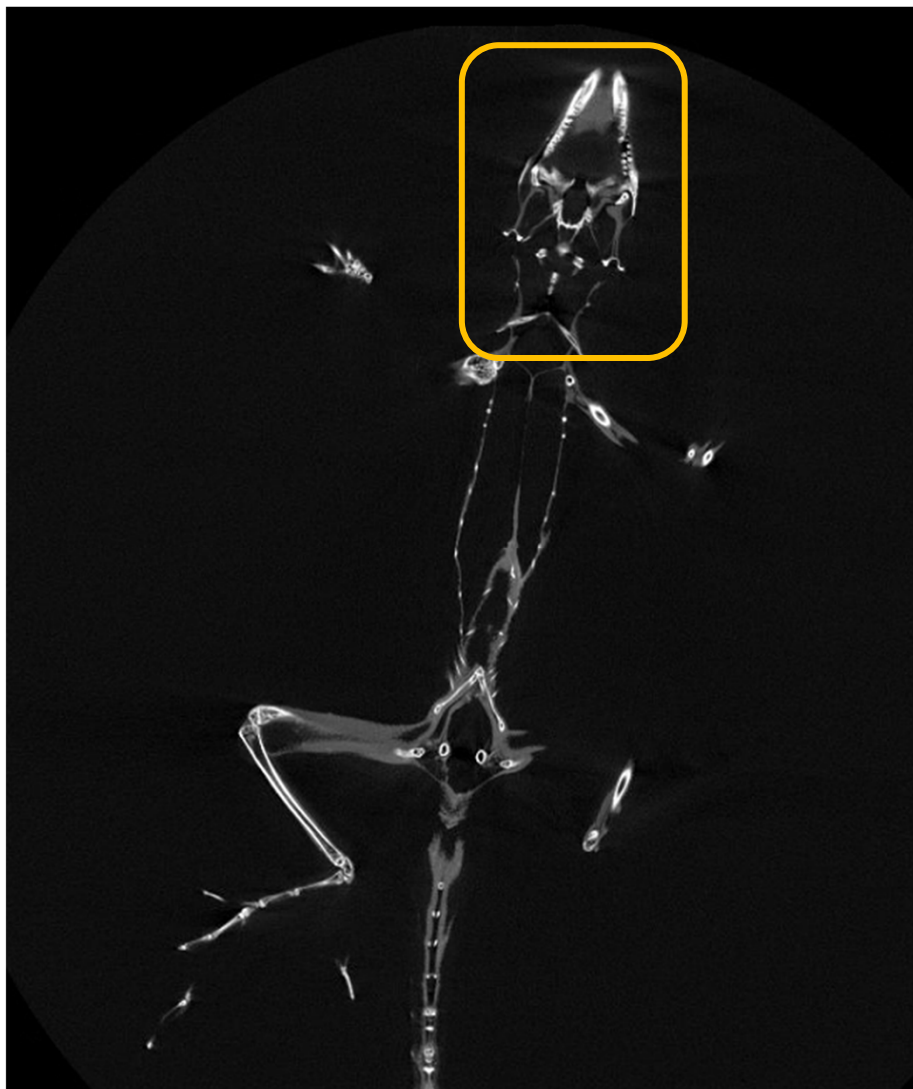


GREEN ANOLE

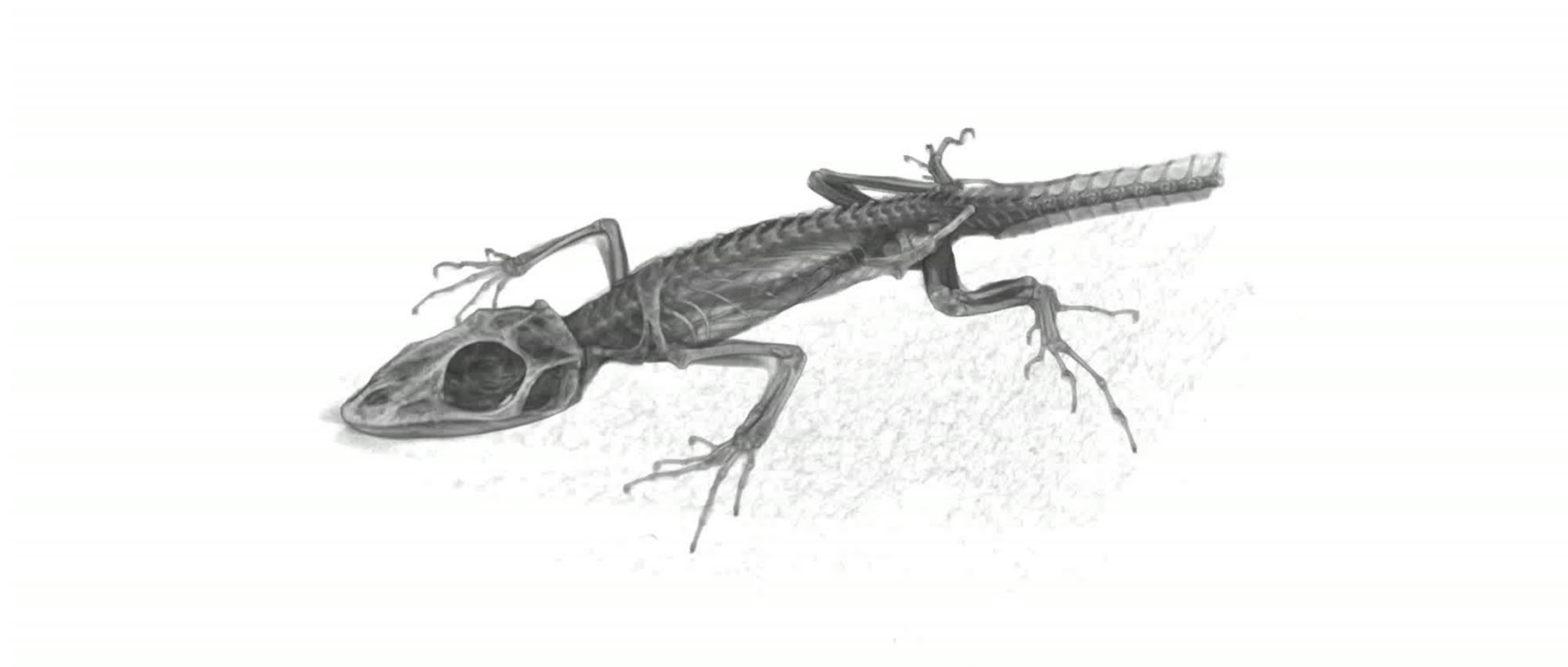
- Collected with the CT Lab GX
- Gantry geometry



GREEN ANOLE

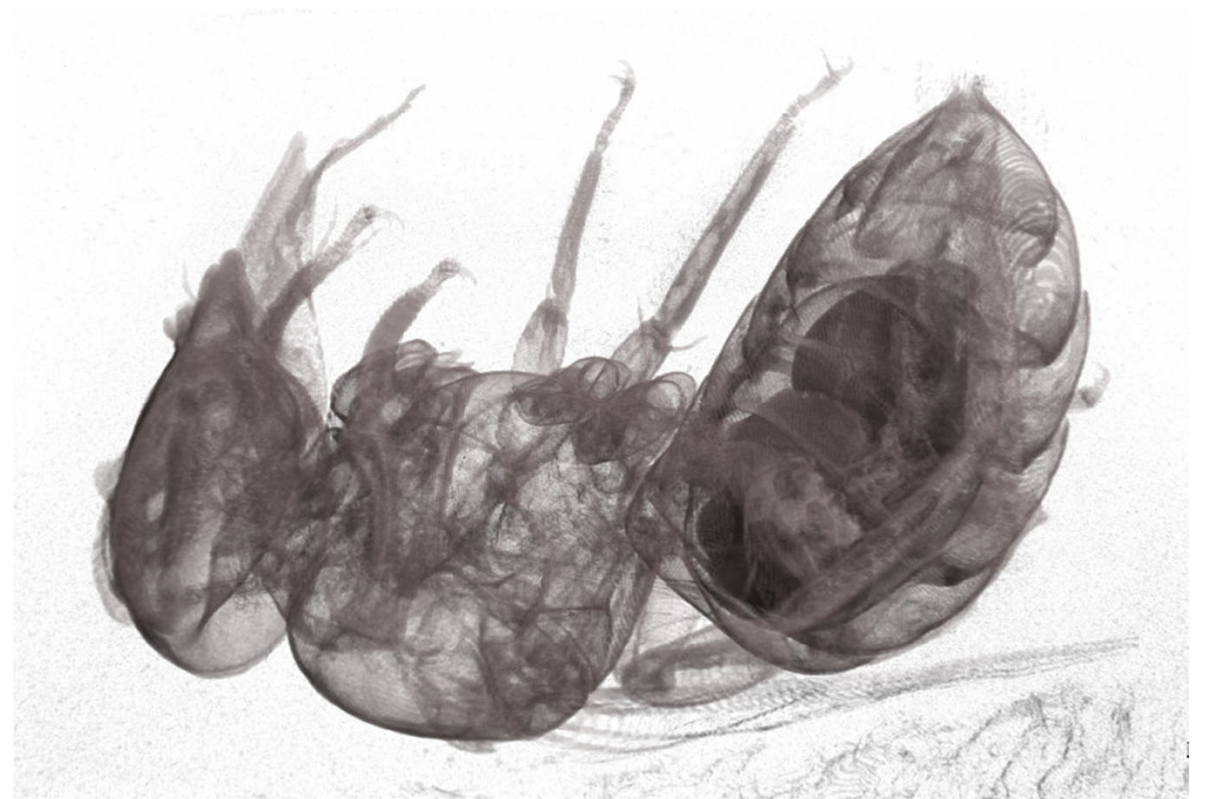


GREEN ANOLE



BEE & BEE LEG

- CT Lab HX, nano3DX



CT Lab HX

BEE & BEE LEG

- CT Lab HX, nano3DX



BEE & BEE LEG

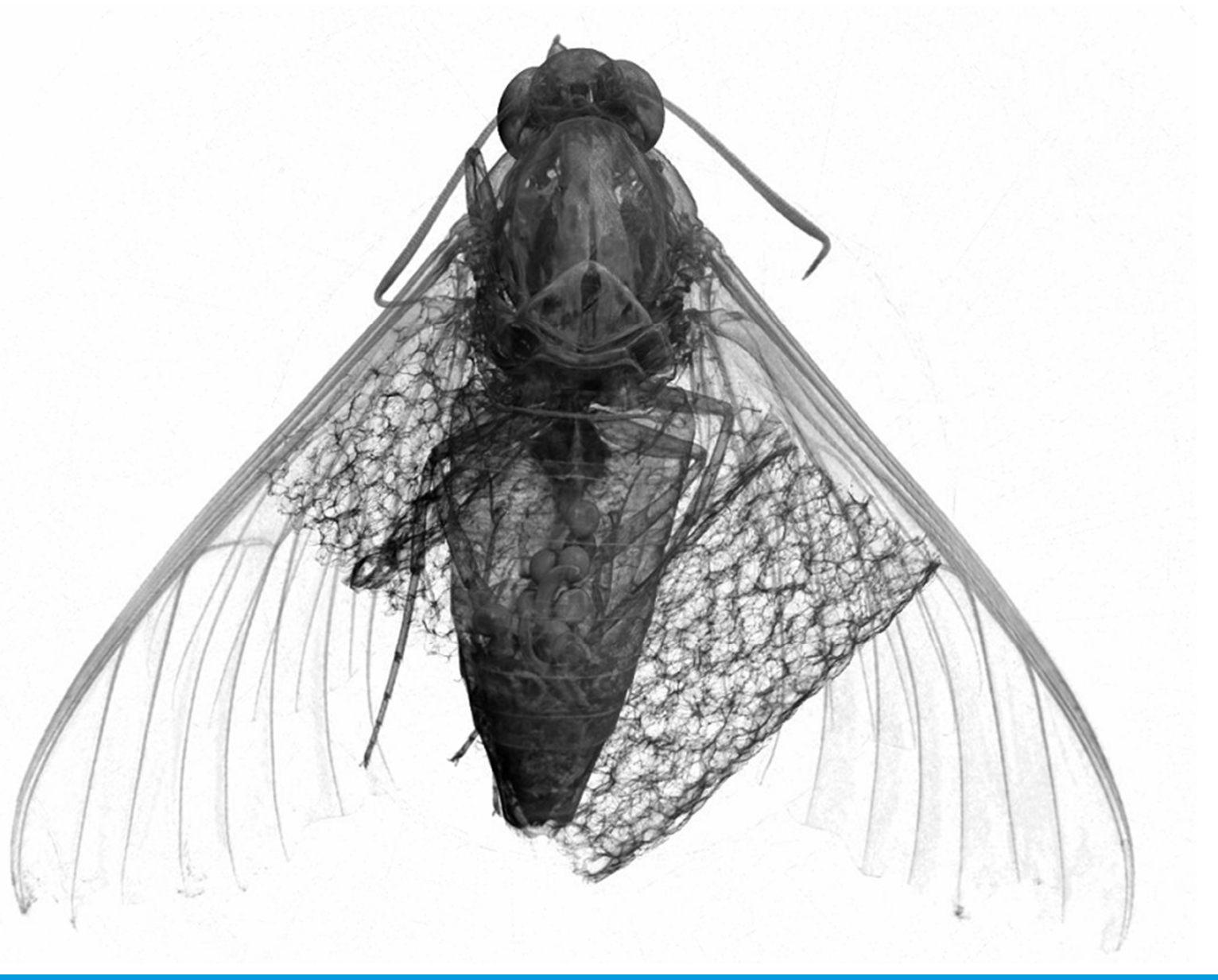
- CT Lab HX, nano3DX



nano3DX

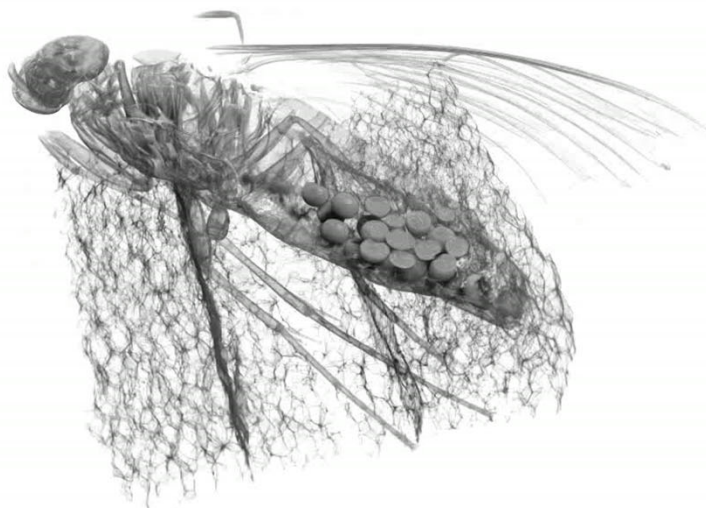
INSECT - MOTH

- CT Lab HX



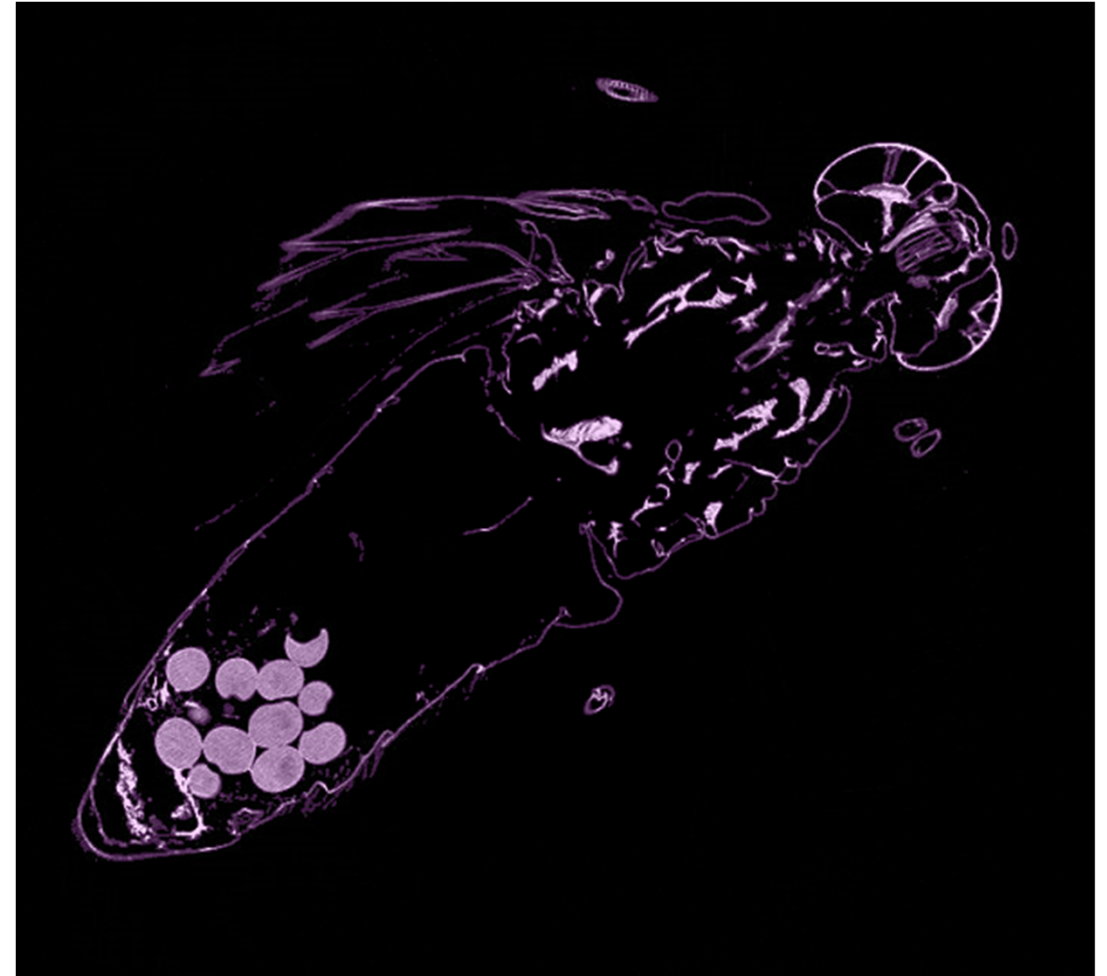
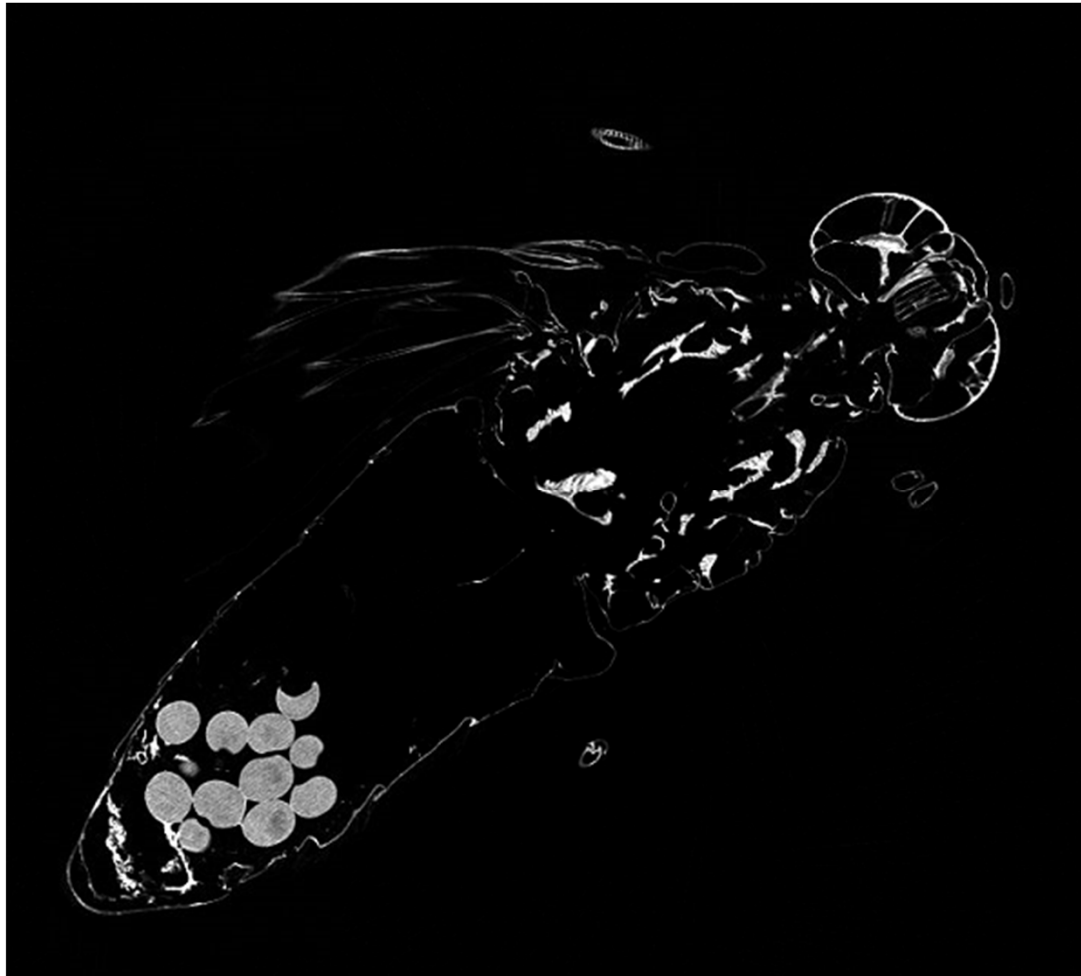
INSECT - MOTH

- CT Lab HX



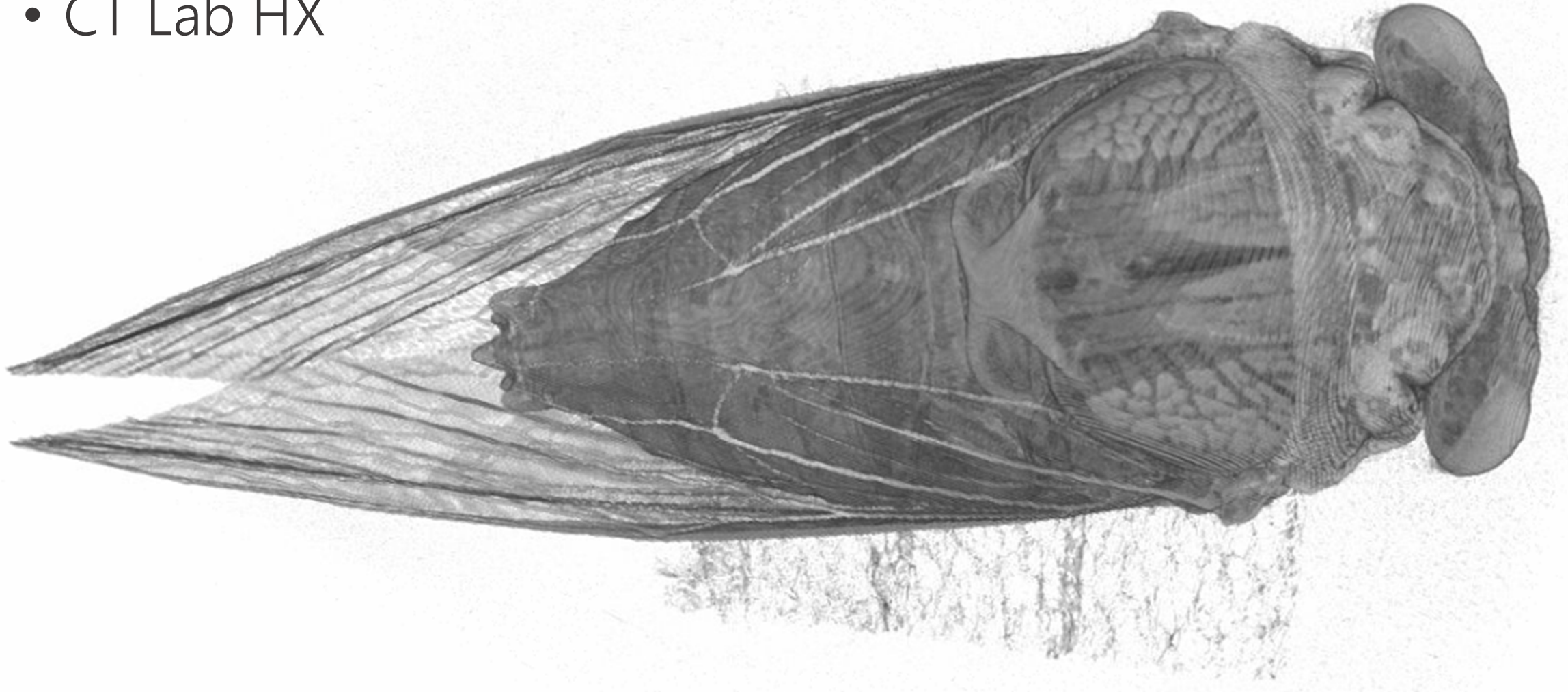
INSECT - MOTH

- CT Lab HX



INSECTS - CICADA

- CT Lab HX



INSECTS - CICADA

- CT Lab HX



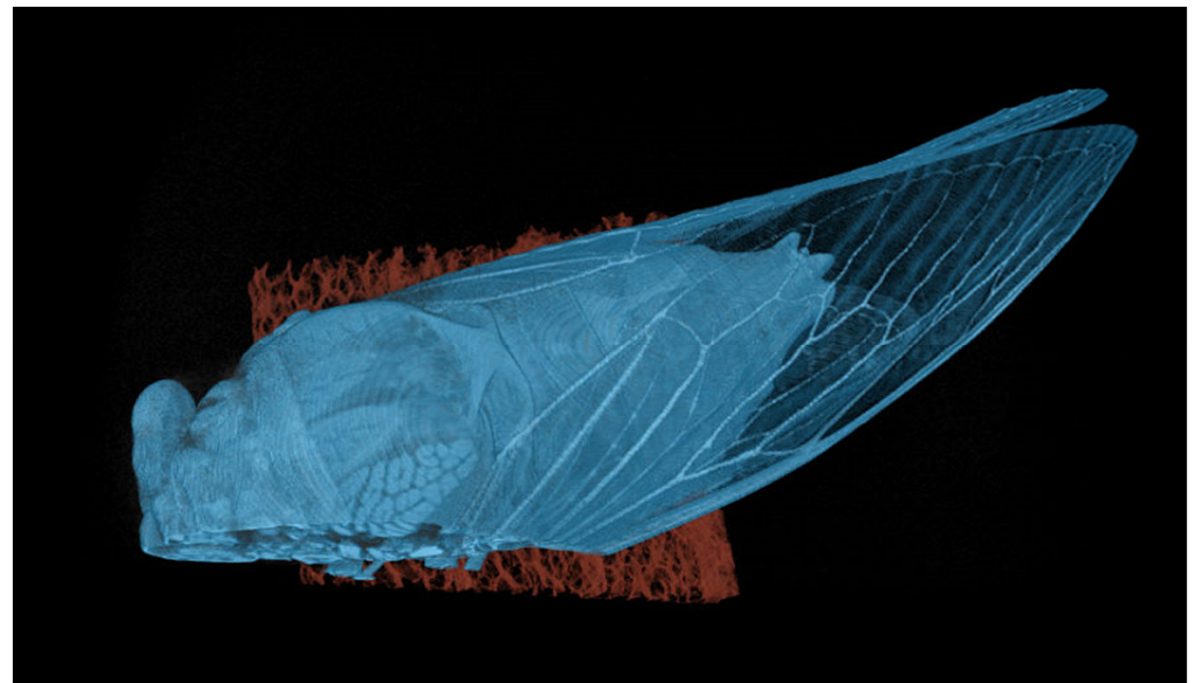
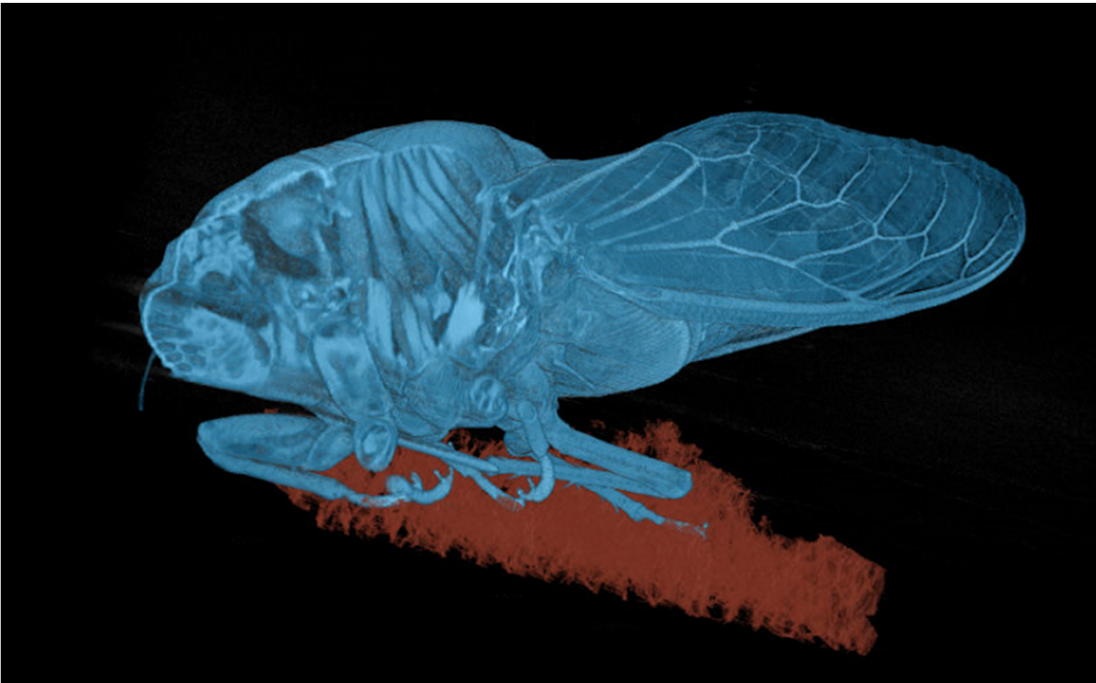
INSECTS - CICADA

- CT Lab HX



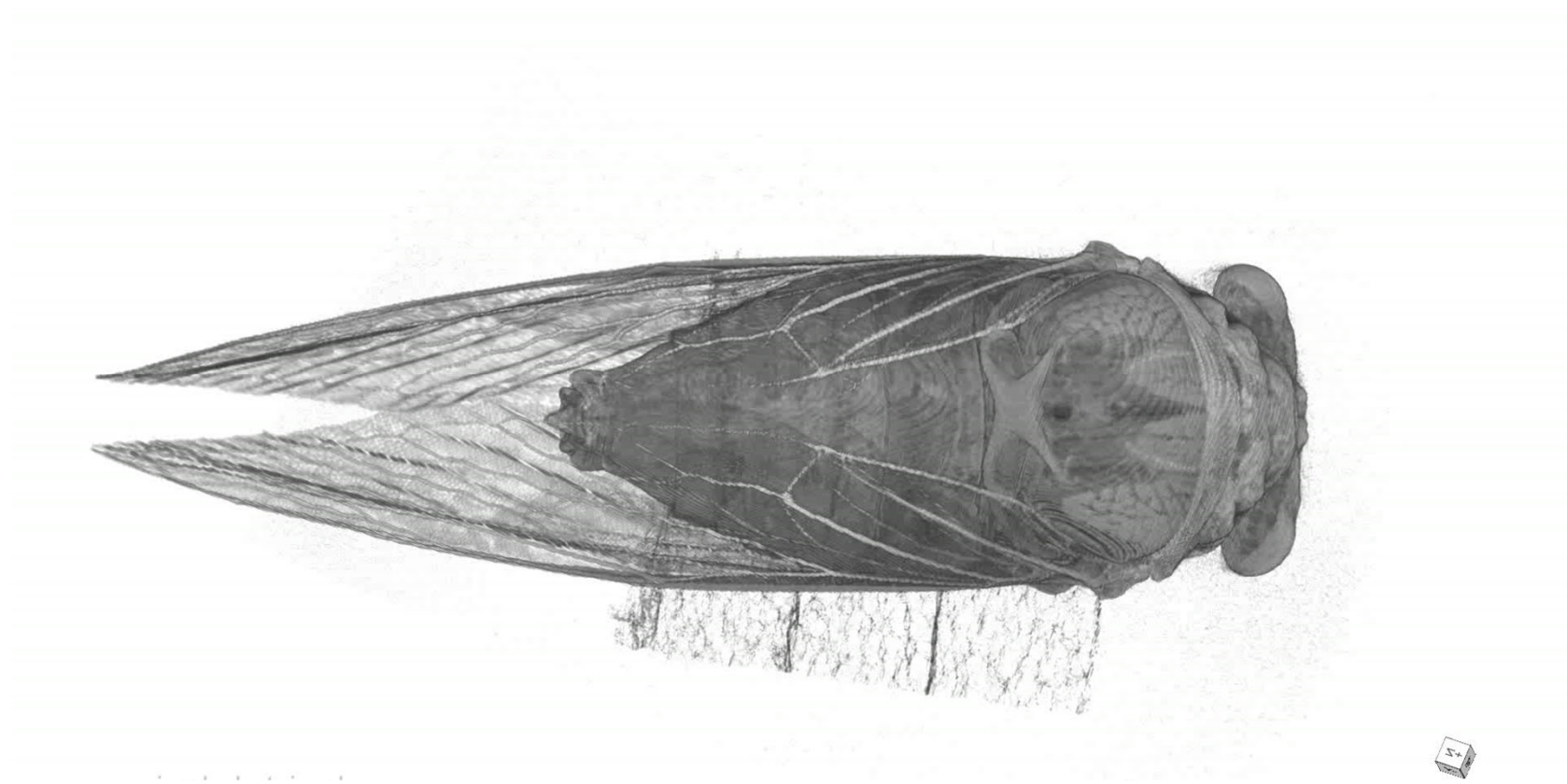
INSECTS - CICADA

- CT Lab HX



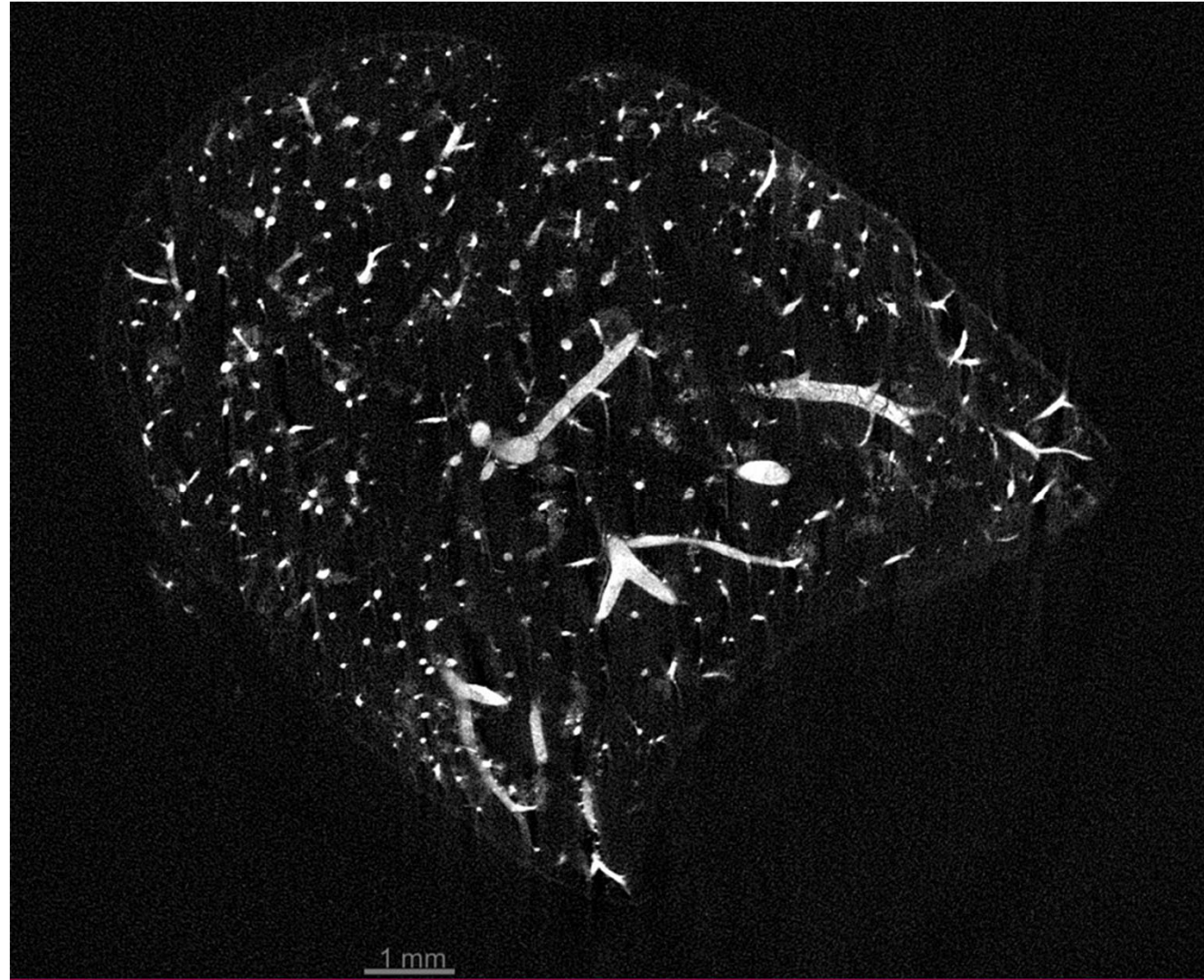
INSECTS - CICADA

- CT Lab HX



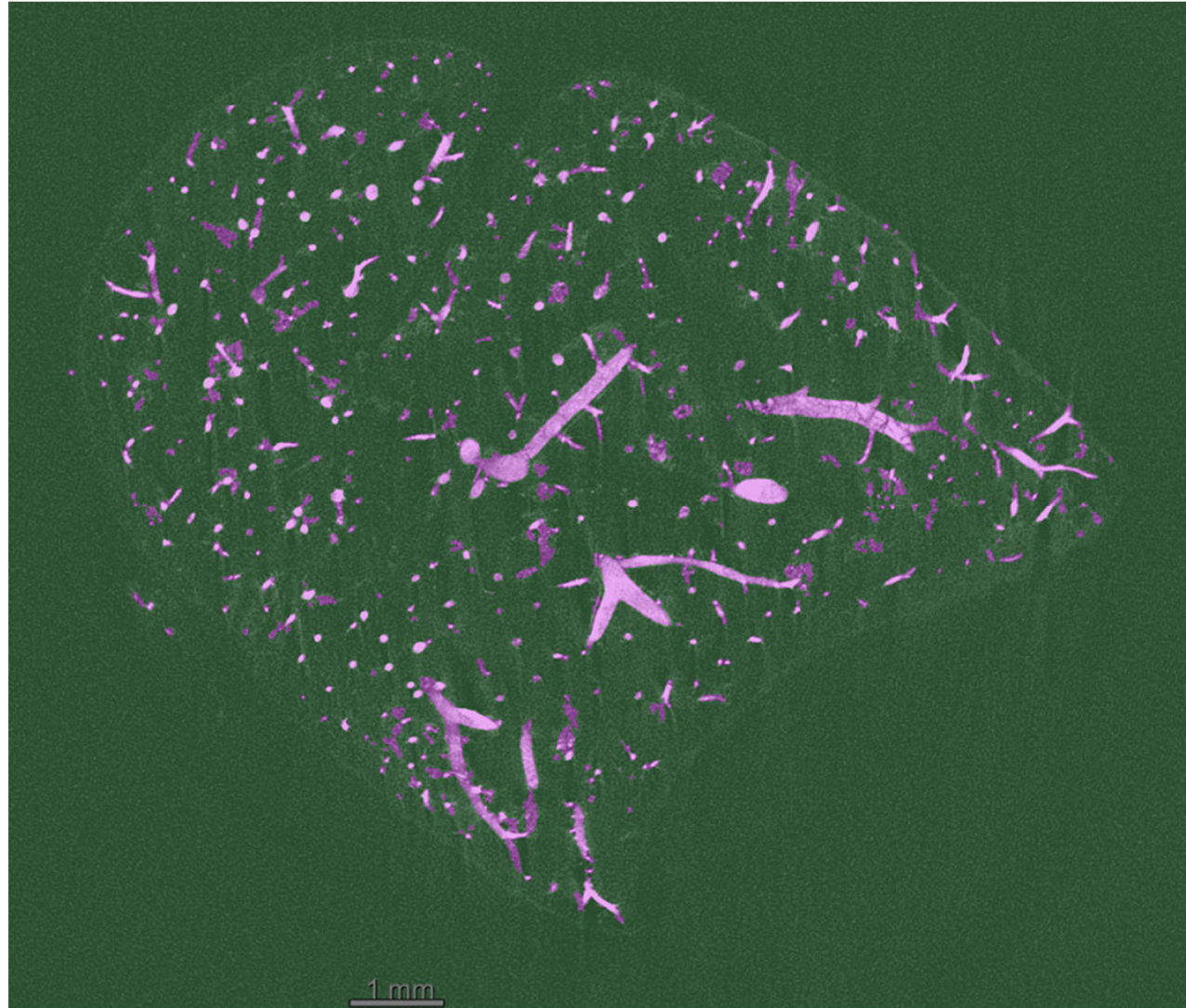
MOUSE LIVER

- nano3DX



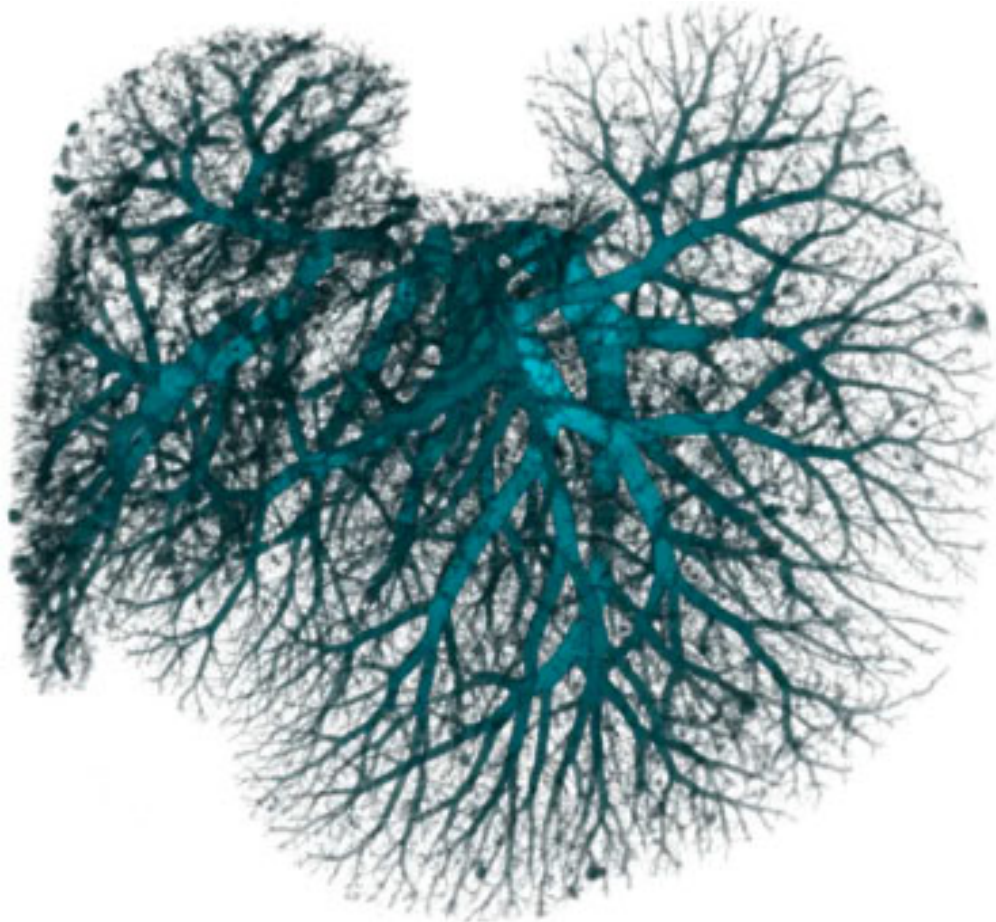
MOUSE LIVER

- nano3DX

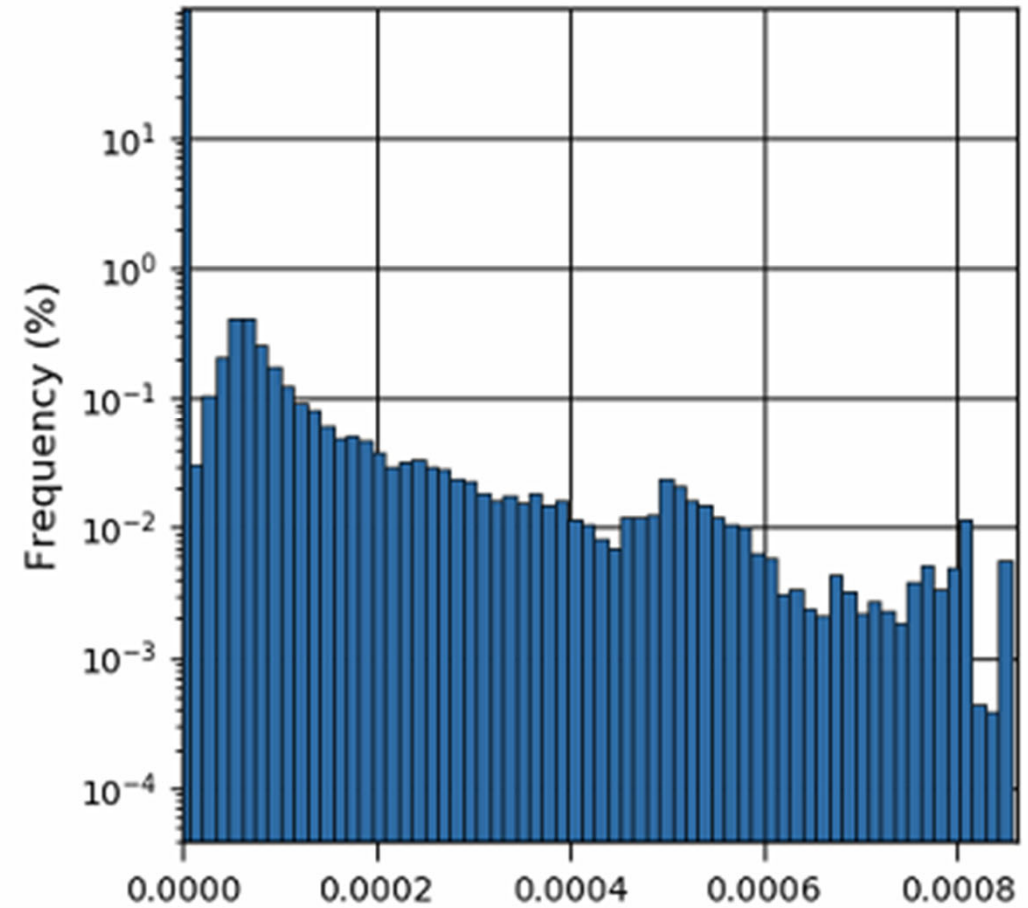


MOUSE LIVER

- nano3DX

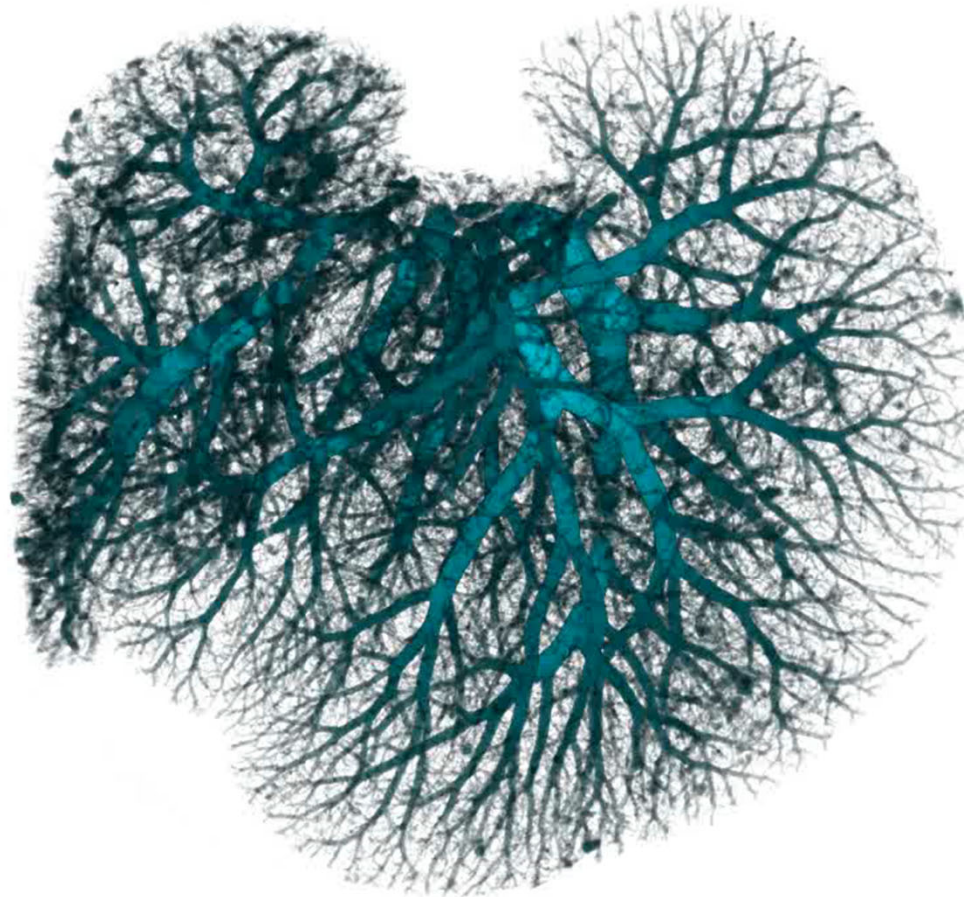


Volume thickness of mouse liver Histogram



MOUSE LIVER

- nano3DX

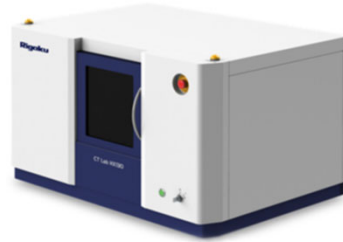


IMAGES WERE COLLECTED ON...

nano3DX



CT Lab HX



CT Lab GX



To learn more ...

A black and white photograph of a person wearing a pinstriped suit jacket over a white collared shirt. They are holding a white rectangular card with both hands. The card has the text 'Rigaku.com → Contact' written on it in a dark blue font. The background is plain white.

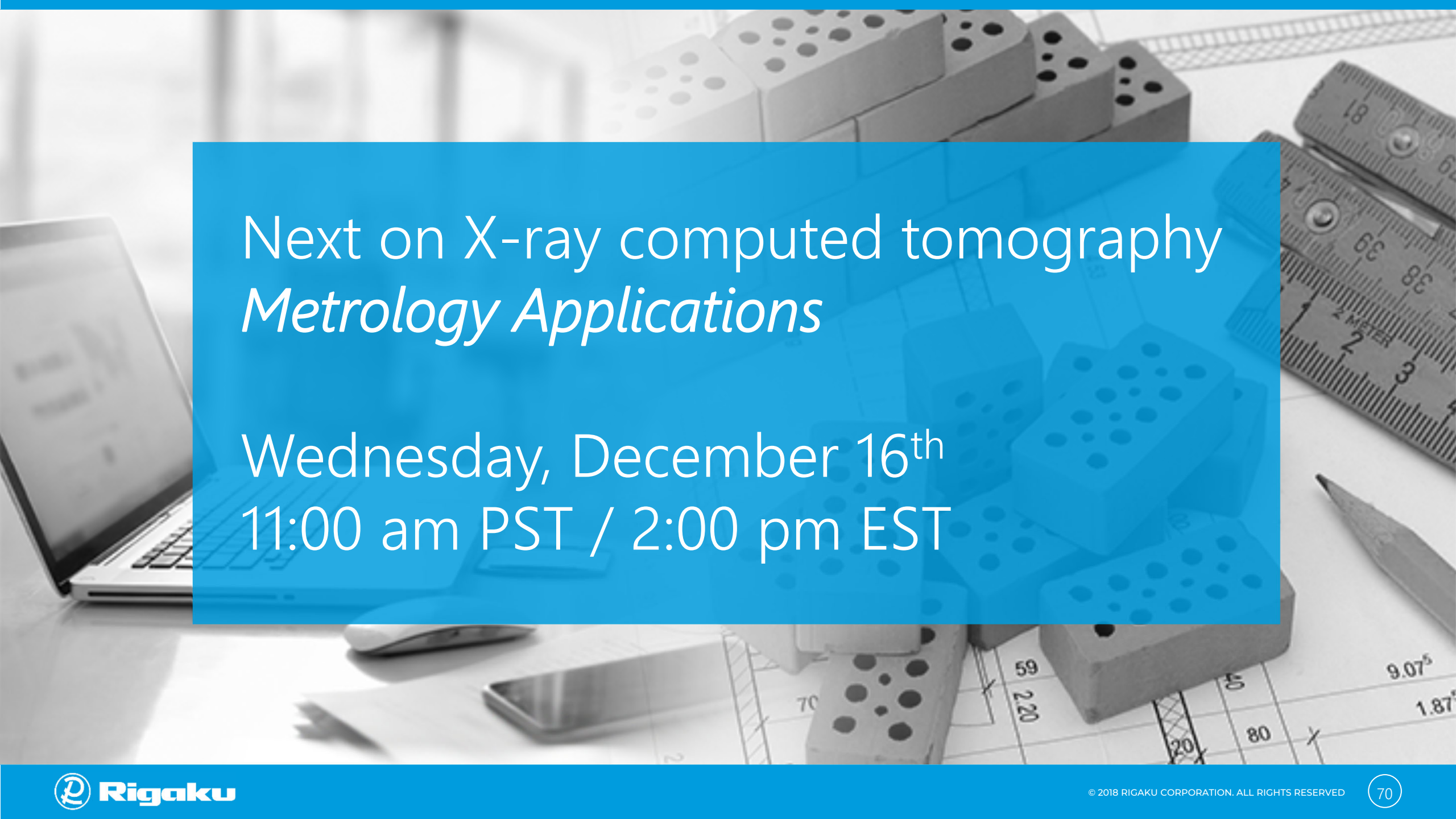
Rigaku.com → Contact

PREVIOUS WEBINARS

[www.rigaku.com/webinars/
x-ray_ct_introduction](http://www.rigaku.com/webinars/x-ray_ct_introduction)

Rigaku webinar





Next on X-ray computed tomography *Metrology Applications*

Wednesday, December 16th
11:00 am PST / 2:00 pm EST

Q & A SESSION



Angela Criswell



Tom Concolino





We'll follow up with
your questions.



Recording will be
available tomorrow.



Register for
the 8th webinar.



THANK YOU FOR JOINING US
SEE YOU NEXT TIME!