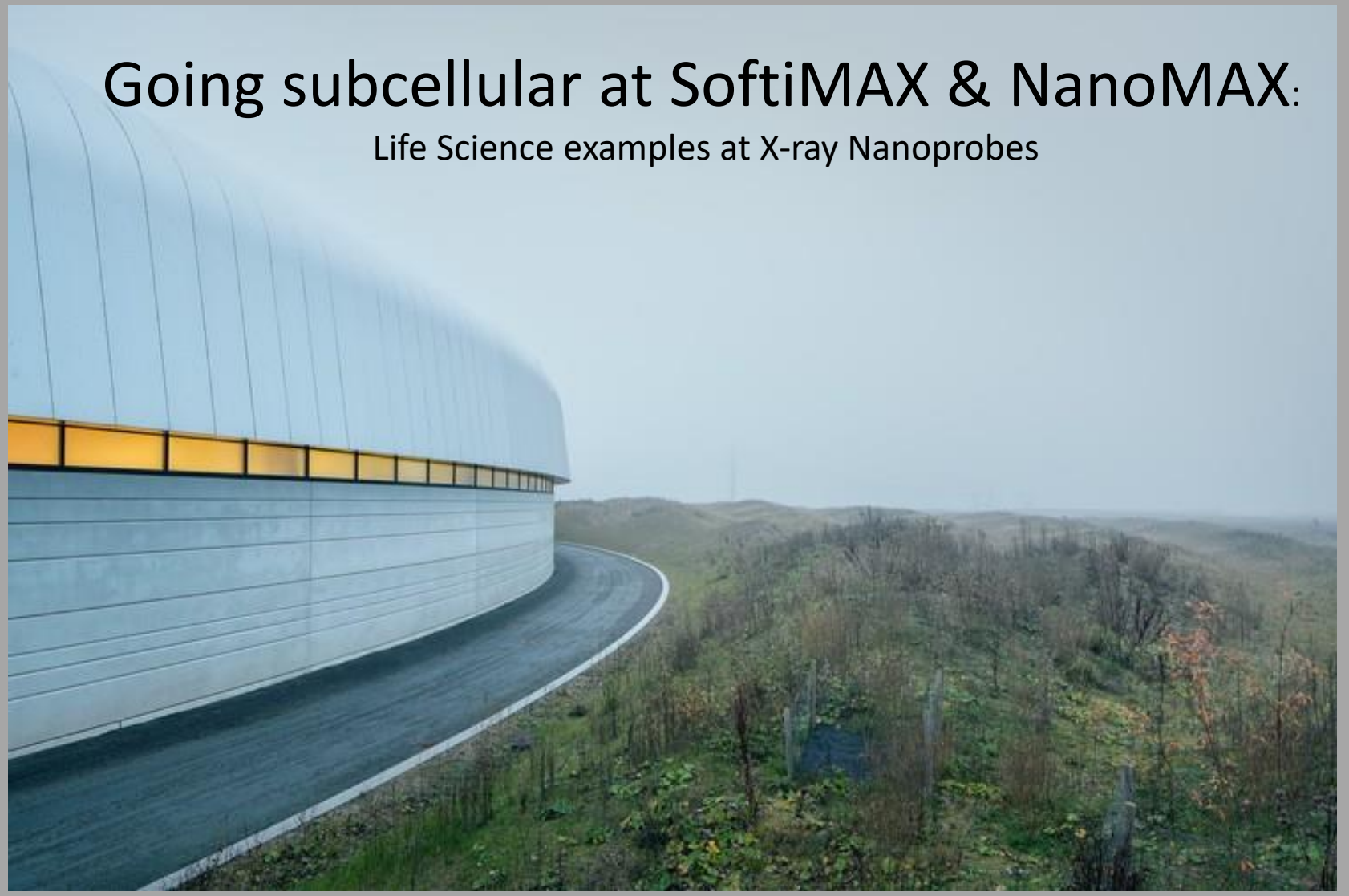
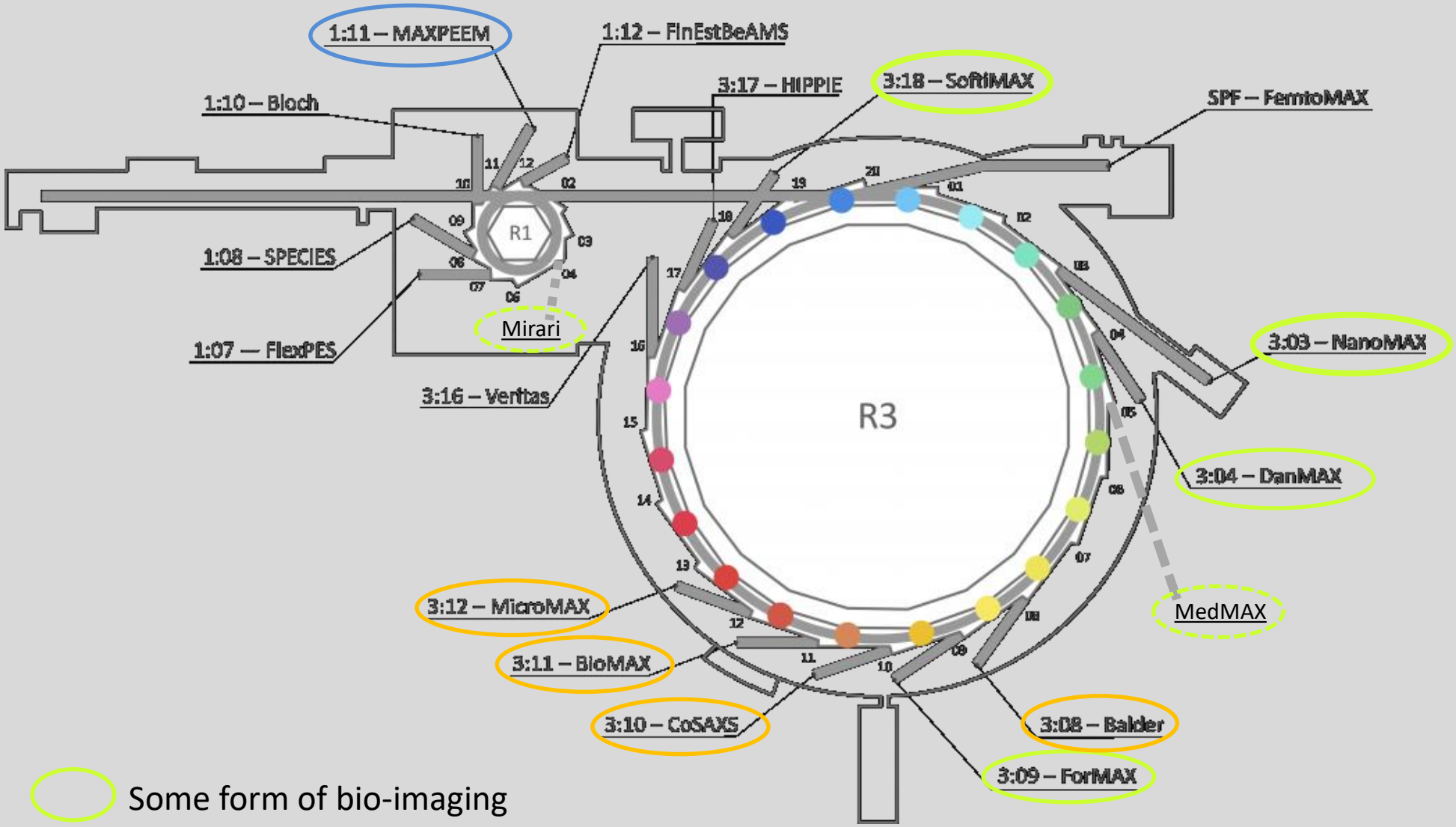
Going subcellular at SoftiMAX & NanoMAX:

Life Science examples at X-ray Nanoprobes



Karina Thånell

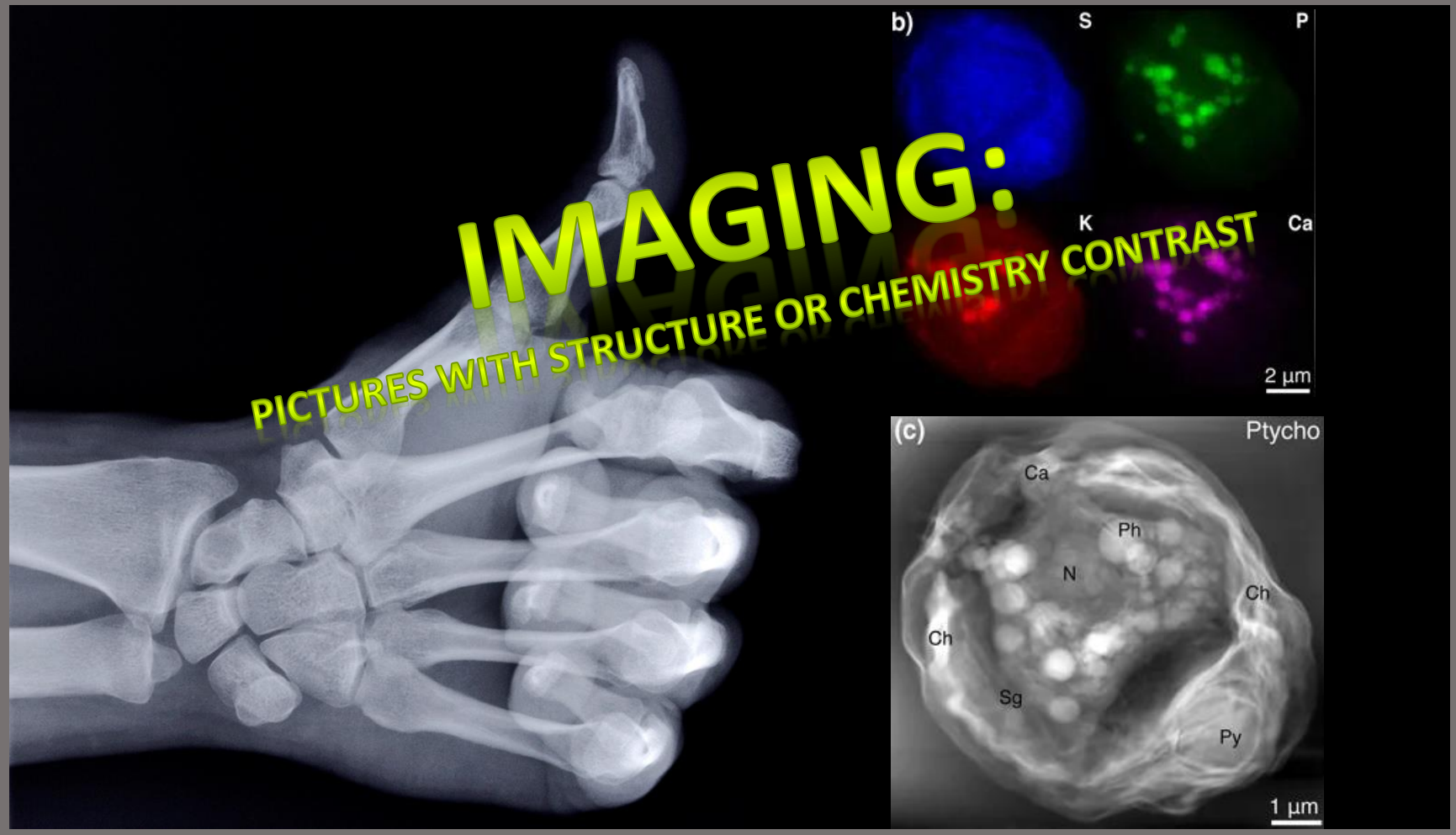
Which beamlines?



Some form of bio-imaging

Also *bio*, but not imaging

Also *imaging*, but no bio



IMAGING:

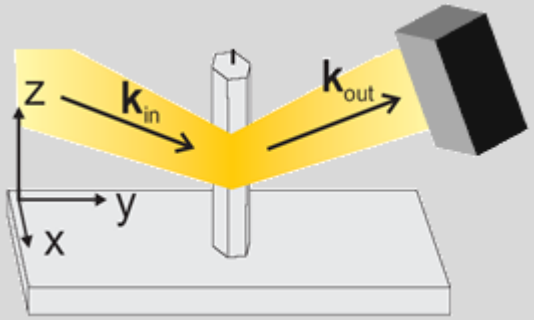
PICTURES WITH STRUCTURE OR CHEMISTRY CONTRAST

Flavours of imaging at MAX IV

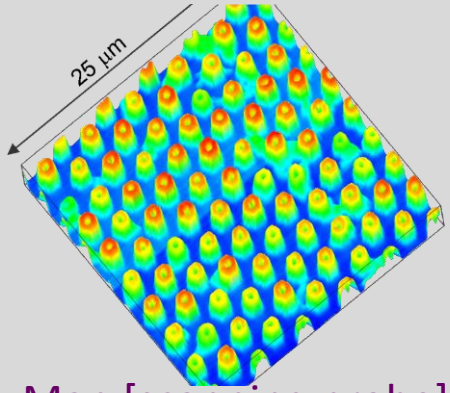
Direct imaging: spatial resolution is determined by the x-ray probe size:
- Nano-diffraction mapping
- X-ray Fluorescence mapping → NanoMAX
- Scanning Transmission X-ray Microscopy → SoftiMAX
- IR spectromicroscopy

Indirect imaging: scattering or diffraction-based contrast is used, and 'translated' into a real space image (usually more about structure):
- Phase contrast imaging/tomography
- SAXS tensor tomography
- Ptychography (Bragg & Forward) & CDI

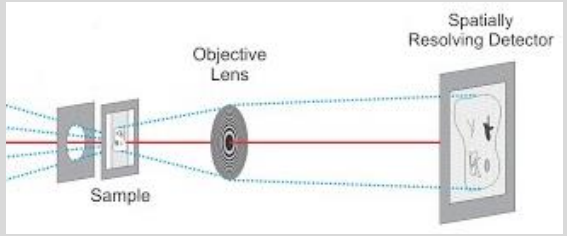
Other: - AFM-IR imaging, STM, SEM (+EDX), SPELEEM techniques



Single object [local probe]

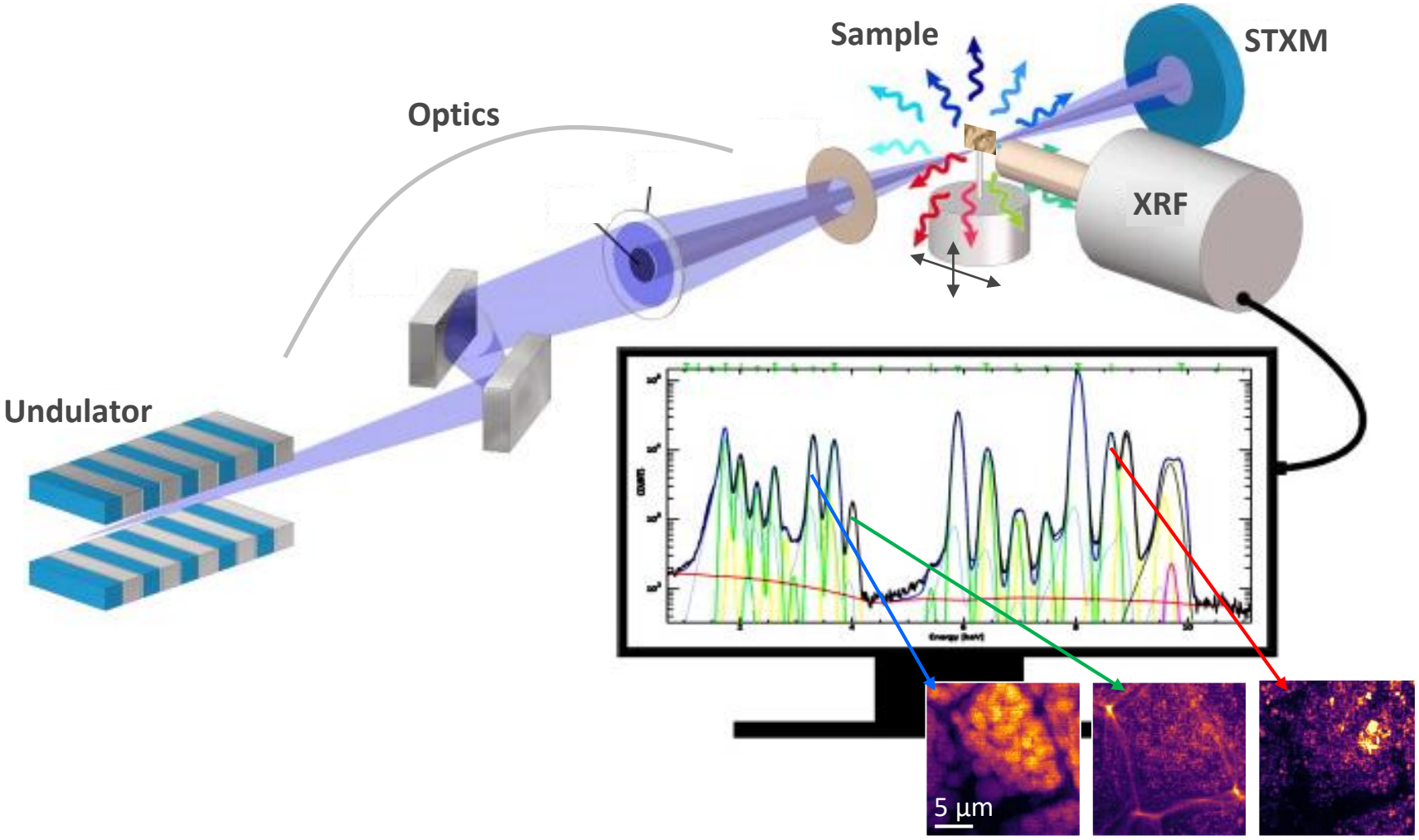


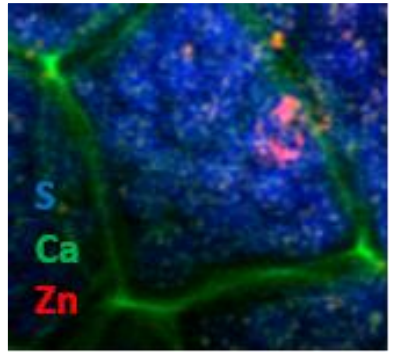
Map [scanning probe]



Full-field [resolving detector]

Scanning X-ray nanoprobe principle





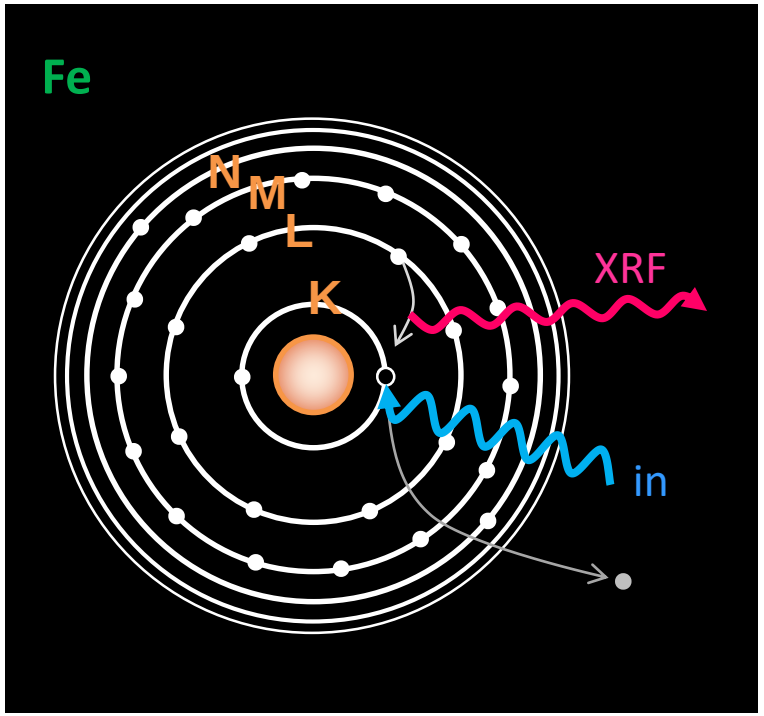
X-ray Flu·o·res·cence

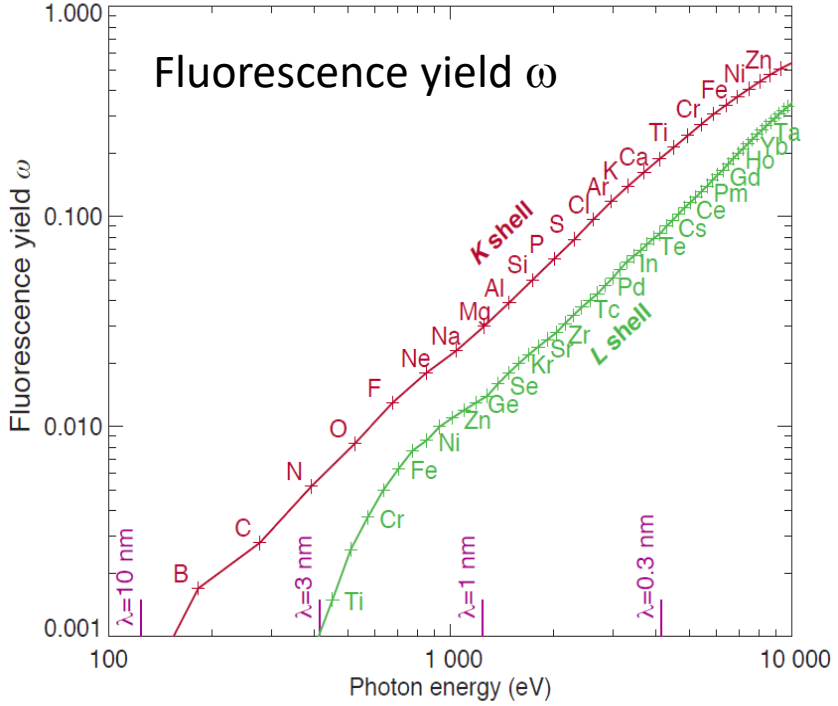
/eks-rey flʊəˈrɛs(ə)ns,flɔːˈrɛs(ə)ns/

X-ray Fluorescence is the emission of **characteristic**, secondary X-rays by a material that has absorbed (more energetic) X-rays, or other electromagnetic radiation. The emitted light corresponds to an energy difference between two atomic levels and its wavelength is unique for each element.

XRF

- Hard X-rays = better
- No need for labelling: it's element specific!
- Forget about the low Z elements...
- XRF sensitivity: down to ≈1-100 µg/kg





NanoMAX

- Photon Energy 5-28 keV
- Spotsize 30-200 nm
- Sample thickness <10 µm

- Samples in air/He/vacuum
- Cooling? Next year...

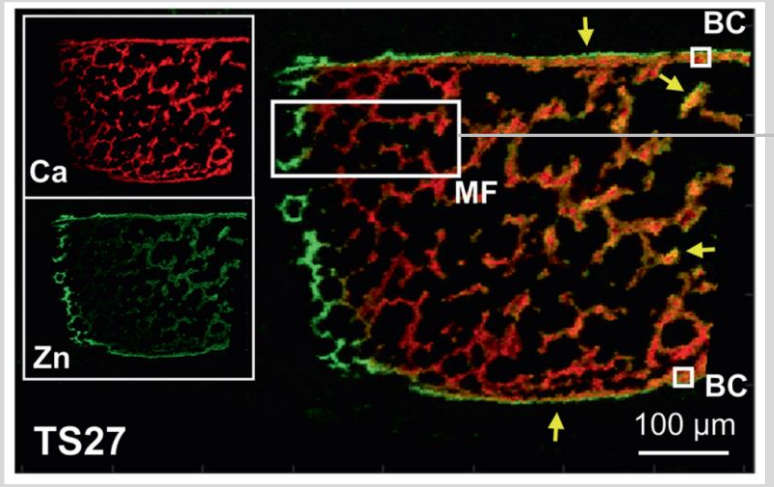
Embryonic bone mineralization

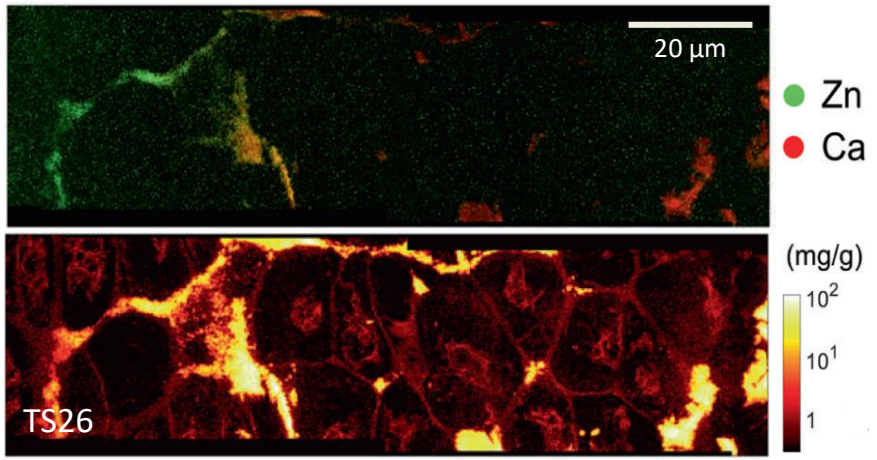
I. Silva Barreto, D. B. Raina, H. Dejea I Velardo, H. Isaksson - LU

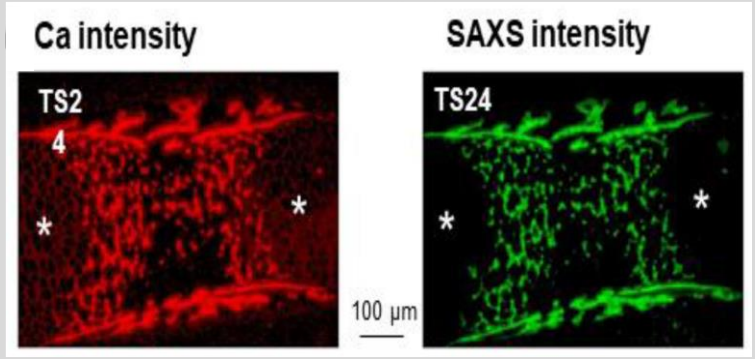
- Zn @ leading edge of Mineralization Front, Ca follows

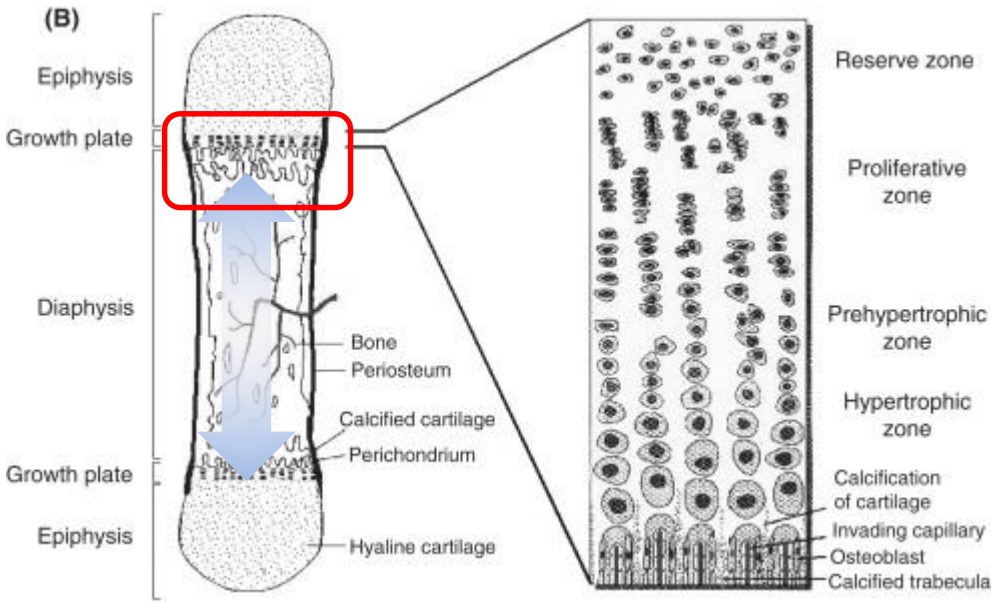
- Ca concentration in bone center increases during bone maturization

- Non-ordered Ca deposits: not hydroxyapatite before bone formation







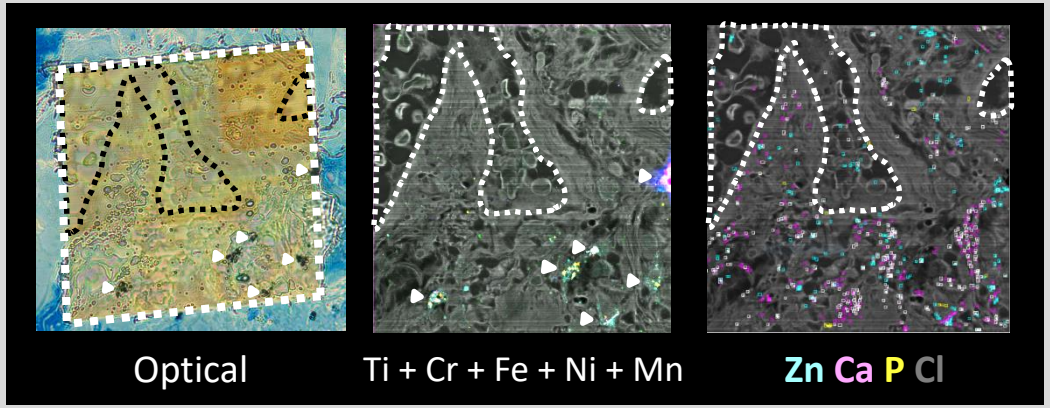


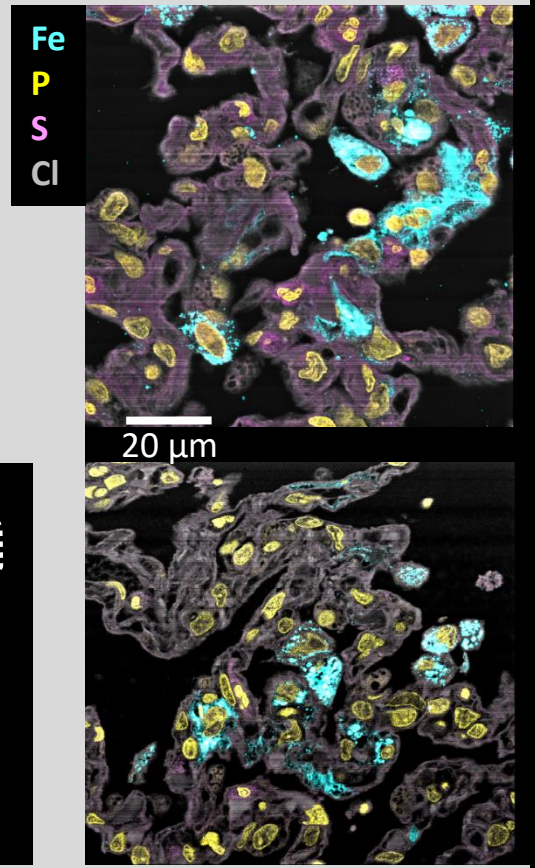
Isabella Silva Barreto *et al.*, Adv. Sci. **2020,** 2002524

Idiopathic pulmonary fibrosis (IPF)

Bryan Falcones Olarte, M. Kahnt, L. Elowsson, K. Thånell, G. Westergren-Thorsson

IPF: a fatal chronic lung disease accompanied by impaired breathing and fatigue. Some studies have found that elements such as Calcium (Ca), Zinc (Zn) and/or Iron (Fe) are important during the development and pathophysiology of IPF, and display a dysregulated metabolism.

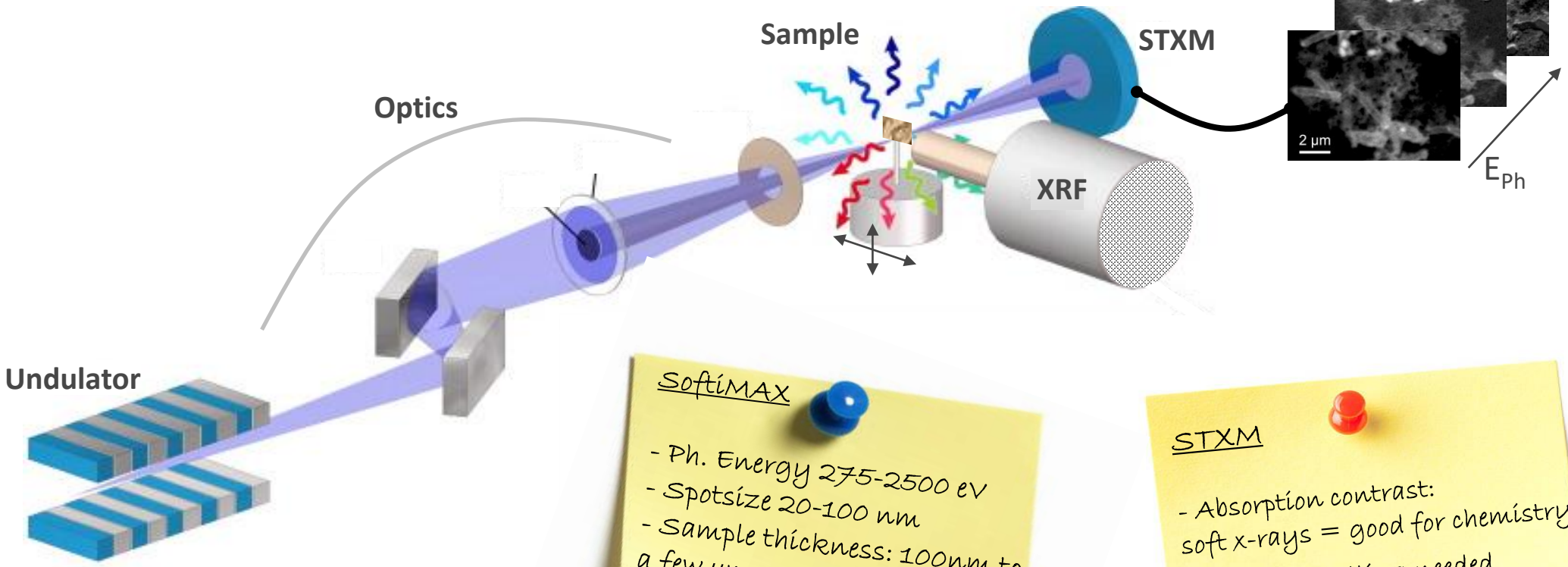


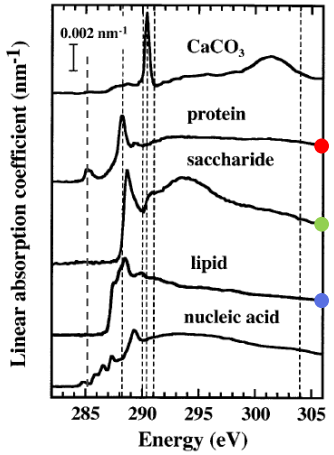


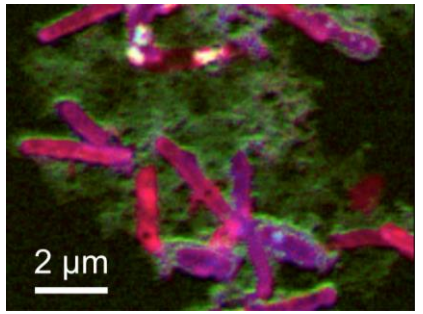
Healthy

Unpublished!

Scanning X-ray nanoprobe principle







SoftiMAX

- Ph. Energy 275-2500 eV
- Spotsize 20-100 nm
- Sample thickness: 100nm to a few µm.

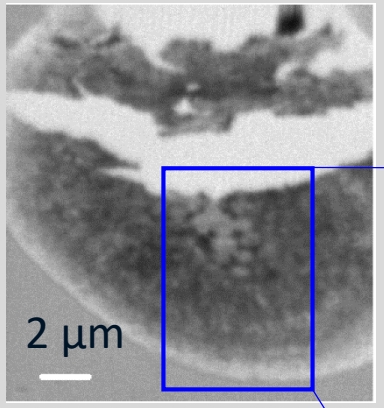
- Samples in vacuum/He/cell
- Cooling? Next year...

STXM

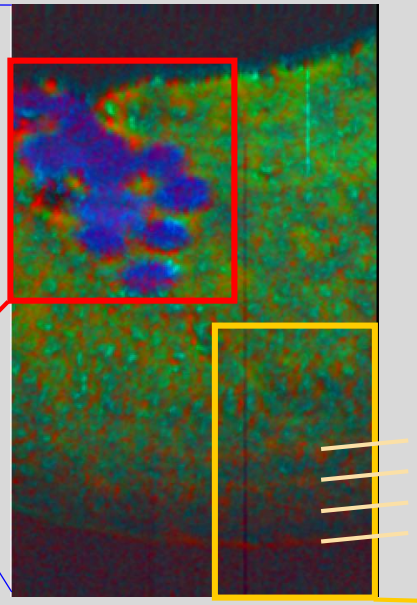
- Absorption contrast: soft x-rays = good for chemistry
- Still no labelling needed
- Yes! Low Z elements too!
- Sensitivity limit: 0.1-1%
- Quantifiable (Beer's law)

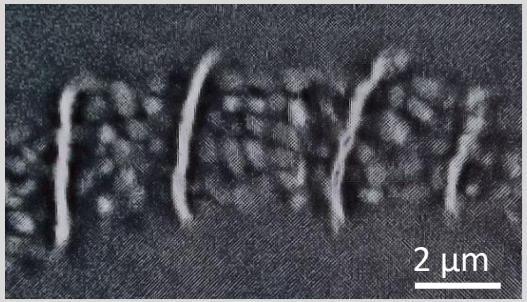
Otolith ($CaCO_3$ fish ear bone) in 6d old cod larva

Yvette Heimbrand, K. Limburg (SLU); B. Falcones Olarte, K. Thånell (LU), AP Hitchcock

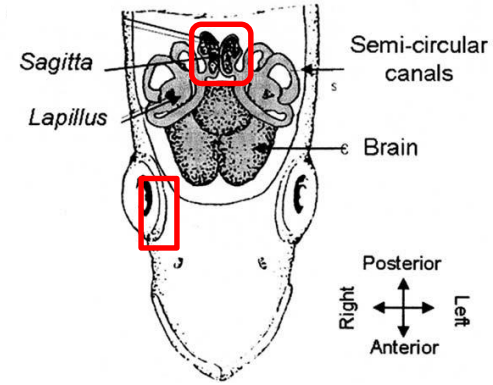


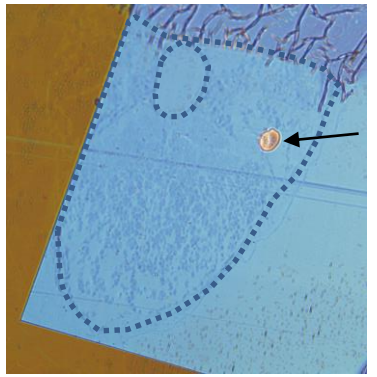
amorph calcite residu



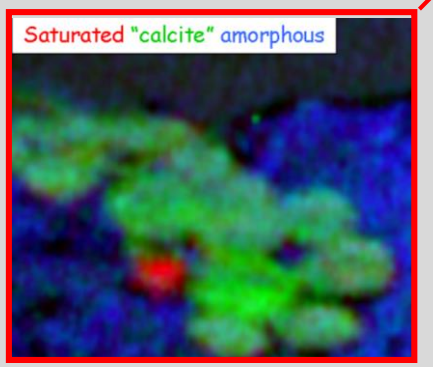


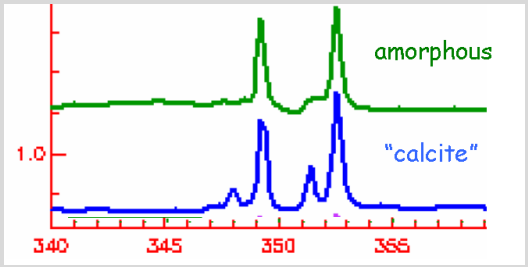
Bonus: edge of the eye

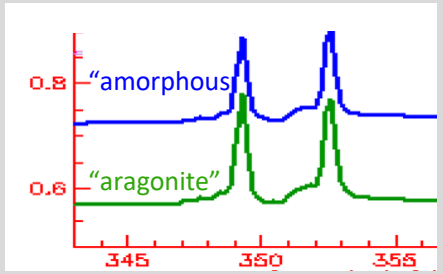




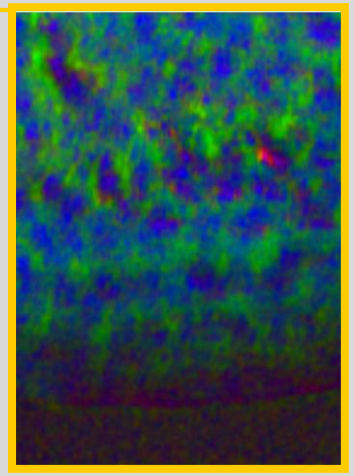
CORE

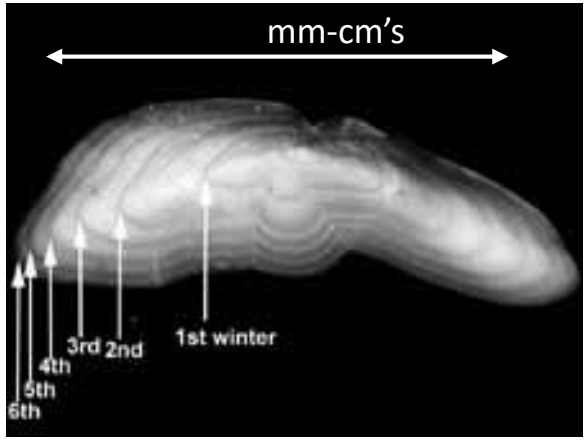






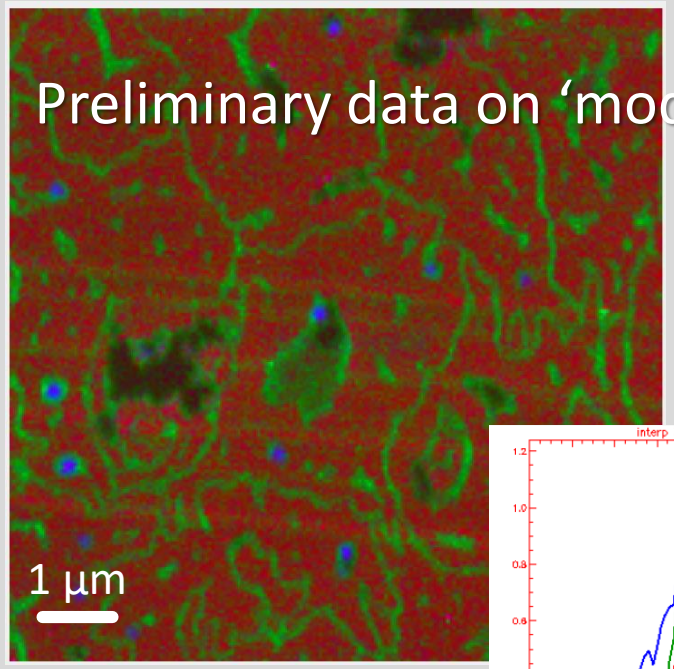
GROWTH EDGE

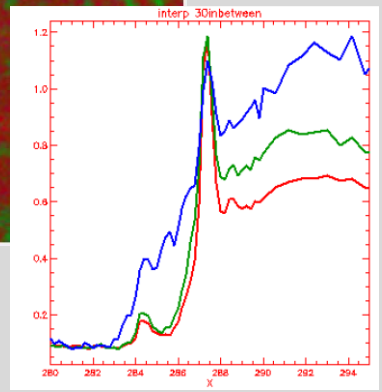


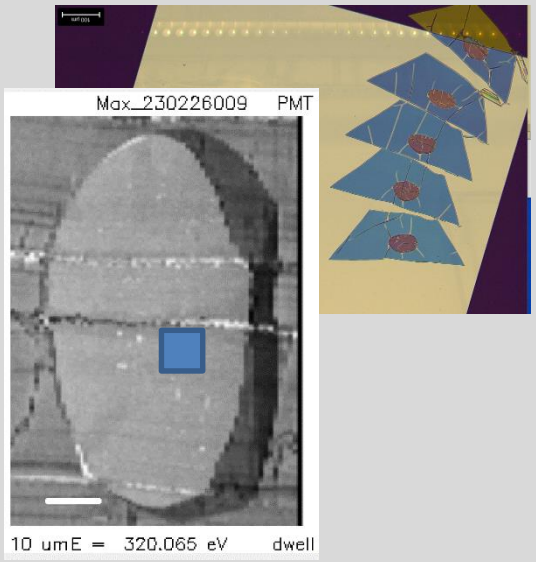


Splitting hairs

Karina Thånell, B. Falcones Olarte (LU), H. Druid , B. Uusma (KI)



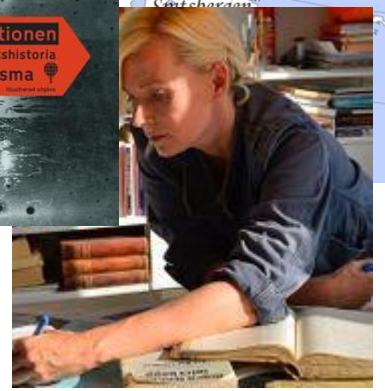




What can be found in the hair?
Chemical compounds (drugs)? ≈
Elemental: Hg, Pb -> NanoMAX, Balder

— Melanin; melanosome (indole derivatives)
— Cell membrane complex: lipid bilayers
— Cortex: keratin & other polypeptides

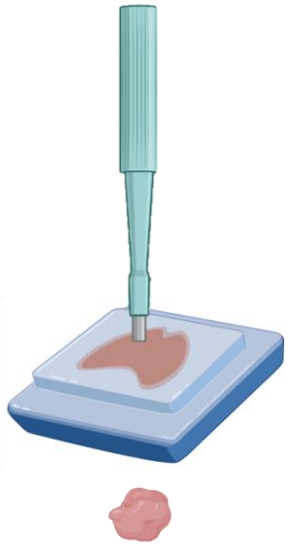
Andrée Polar expedition 1897



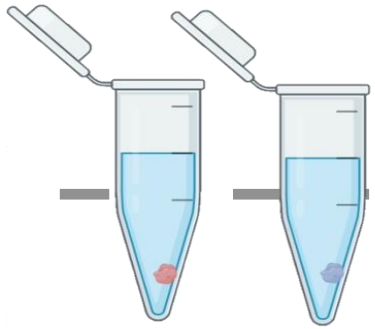
Bea’s quest:
what killed Andree?

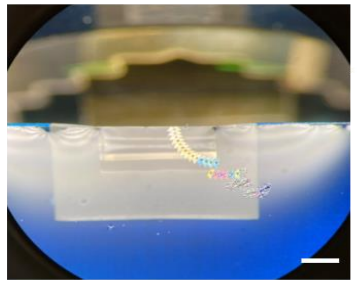
Sample preparation

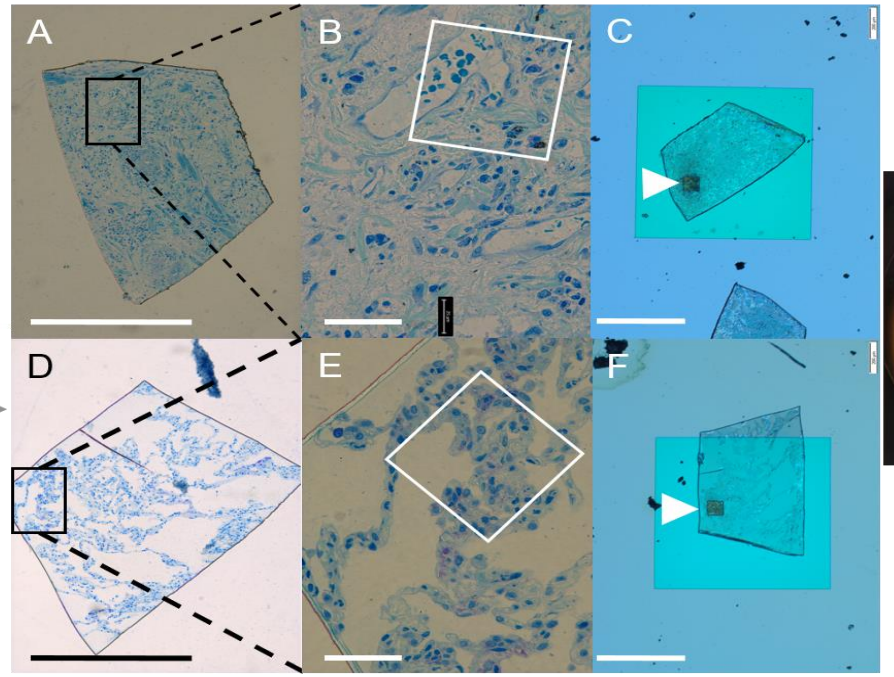
Punch & Fixate

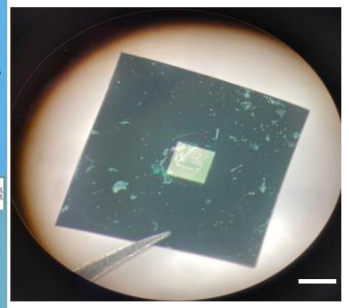


(Re}embedding and sectioning

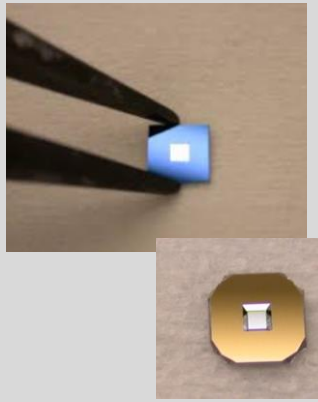


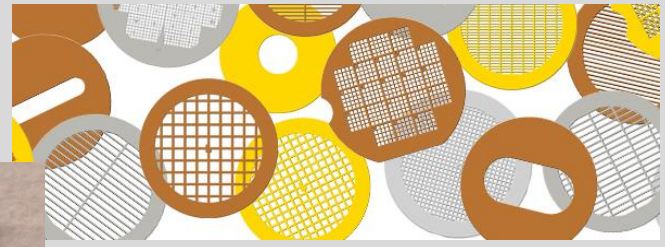






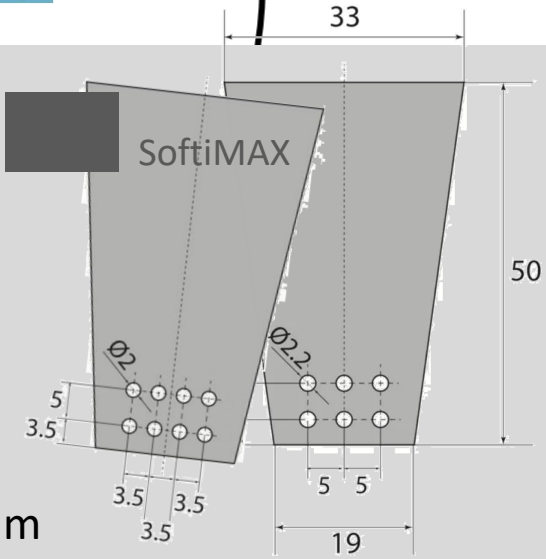
NanoMAX





Si_3N_4: 0.2-1 µm

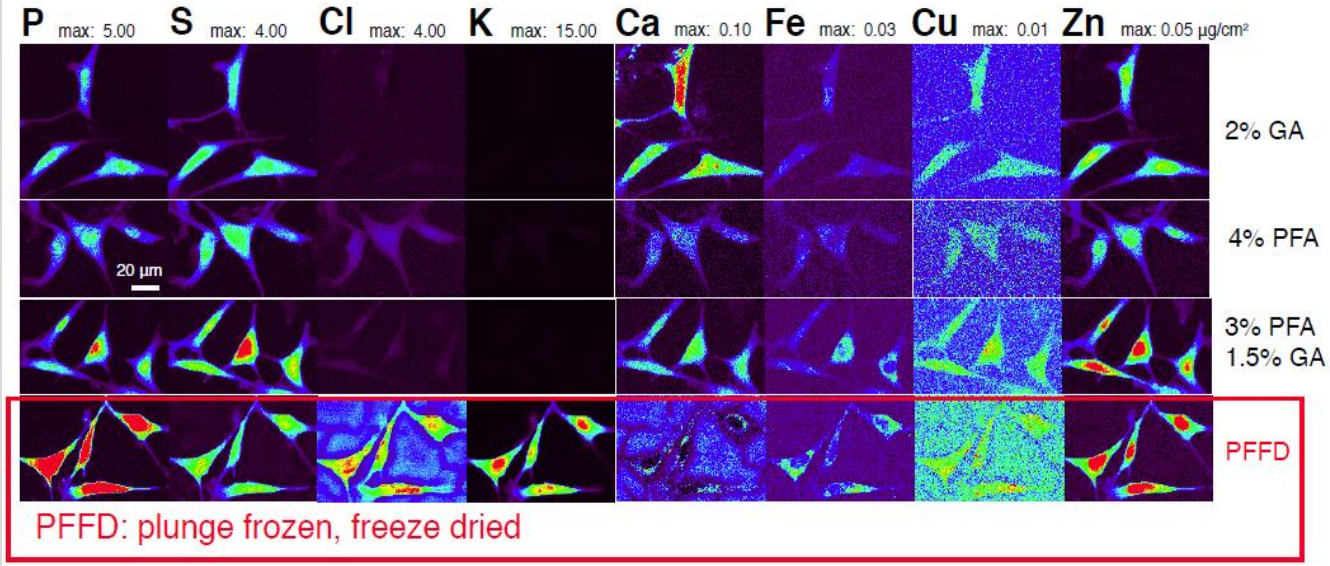
SoftiMAX



Si_3N_4: 50-100 nm

…and finally

Cryo preservation keeps chemistry intact



- Jin, Paunesku, Lai, Gleber, Chen, Finney, Vine, Vogt, Woloschak, and Jacobsen, *J. Microscopy* **265**, 81 (2017).
- See also Perrin, Carmona, Roudeau, and Ortega, *J. Analyt. Atom. Spectr.* **30**, 2525 (2015).

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SoftiMAX: karina.thanell@maxiv.lu.se
jorg.schwenke@maxiv.lu.se

Data analysis software:
XRF: PyMCA
STXM: Axis2000, Mantis, (Quasar)
Jupyter Notebooks

MAX IV:
- Twice/year call for proposals
  - Feb & Aug, apply per BL
  - max. 3 pg. for 2-6 day beam
  - judged on scientific merit
- Free of charge = publish
- Also: "Fast Access", 1 day max.
  ↘ apply throughout the season

Before an experiment, think about:

1) Resolution needed
2) Information needed: contrast
3) Beam damage & radiation dose
4) Sample preparation!!!
5) Combine techniques?
6) Contact us!