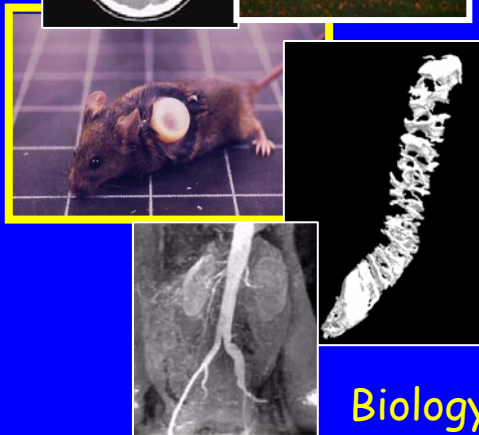
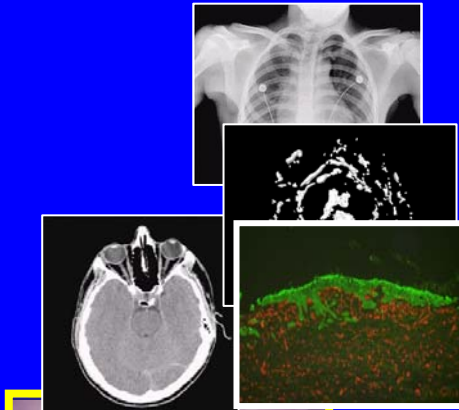


Image processing and measurements in material science and biology



Astronomy

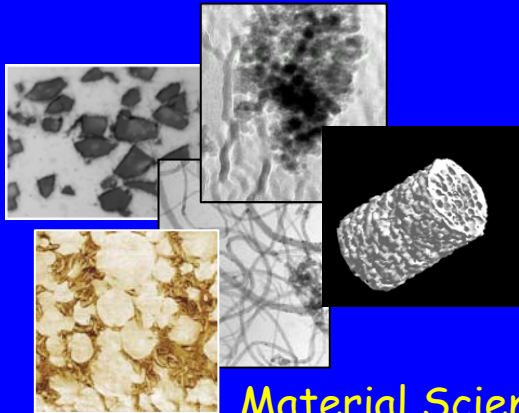
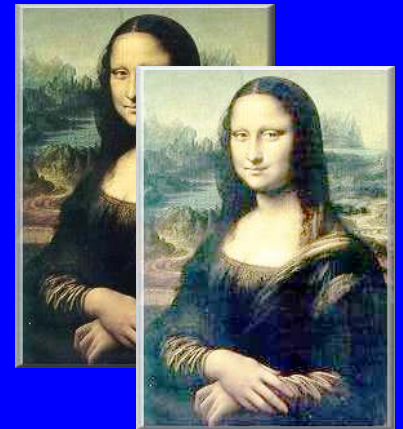


Biology-Medicine



Foods

DaVinci co.. lons



Material Science

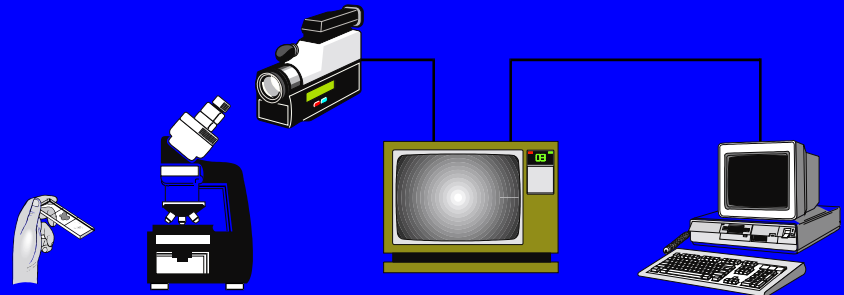
Image analysis

Quantitative image analysis:

- Morphological analysis of structures and its quantitative characterization by parameters.
- Set up of relations between morphological parameters and other properties (physics, biologics, chemists,).

It requires:

- Input/output images system: acquisition & visualization.
- Image processing software :filtering, segmentation, measurements



Development of algorithms for image analysis requires:

- **Filtering:** Application of an operator to modify the grey-levels of an image: noise, inhomogeneous illumination, contrast, etc

a) *Filters derived from classical signal processing techniques:*

Two kinds of filters : convolutions with a kernel, FFT,

b) *Morphological filters:* uses tools of mathematical morphology, non-linear operators :erosion, dilation..

On each group:*Low-pass* : remove high frequencies, smooth.....loss of contrast

High-pass : remove low frequencies. increases the contrast,...increases noise too

- **Segmentation (optional):** transformation of the grey-level into a binary image in which pixel of the objects are white (1) and the background is black (0).

- **Measurements:** Quantitative description of morphologies by parameters or functions.

Global measurements: porosity, density,

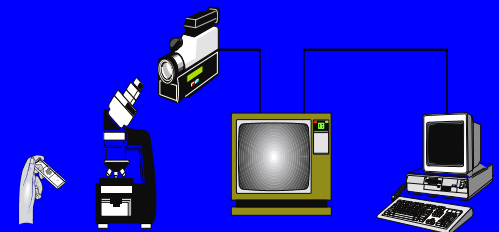
Sizes: Perimeters, Surfaces, Volumes , diameters, lengths....

Shapes: elongation, circularity....

Dispersion: correlation functions, covariace, Voronoi....

Granulometry: in number, in sizes...

Fractal analysis....



Back to basics: What is a digitized image?

Is a table of numbers (matrix) defined by:

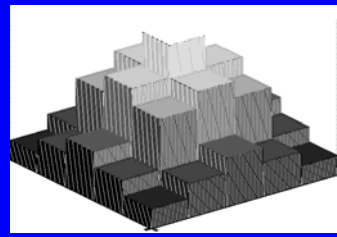
- a) Its number of elements ($M*N*Z$)
- b) The number of values that each element can take

-For 2D images, the elementary unit is the pixel

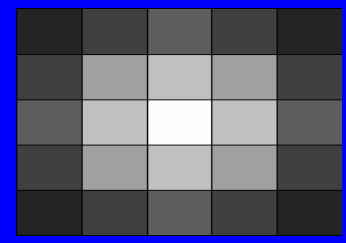


35	73	94	73	35
73	155	199	155	73
94	199	255	199	94
73	155	199	155	73
35	73	94	73	35

=



=



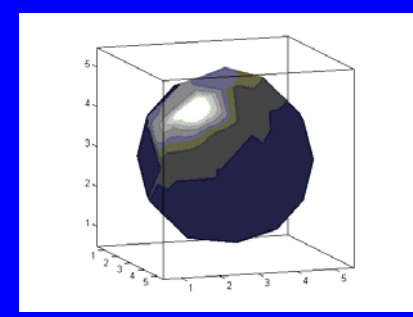
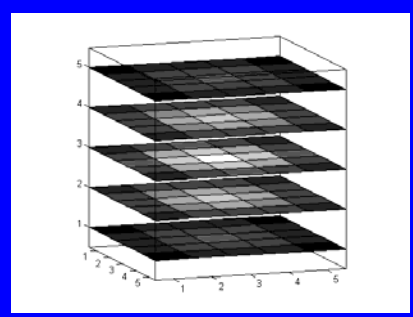
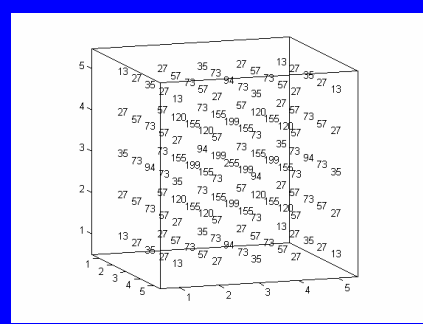
$M \times N$ matrix

3D graph

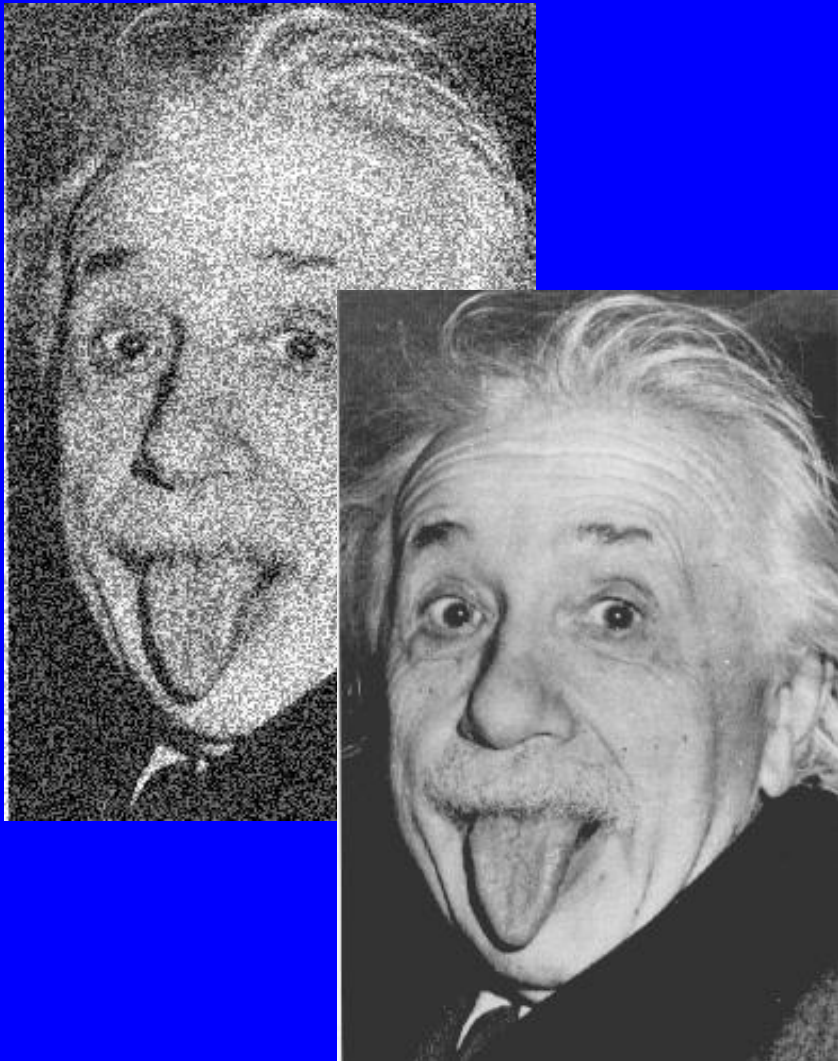
Grey-level Image

-For 3D images the elementary unit is the voxel :

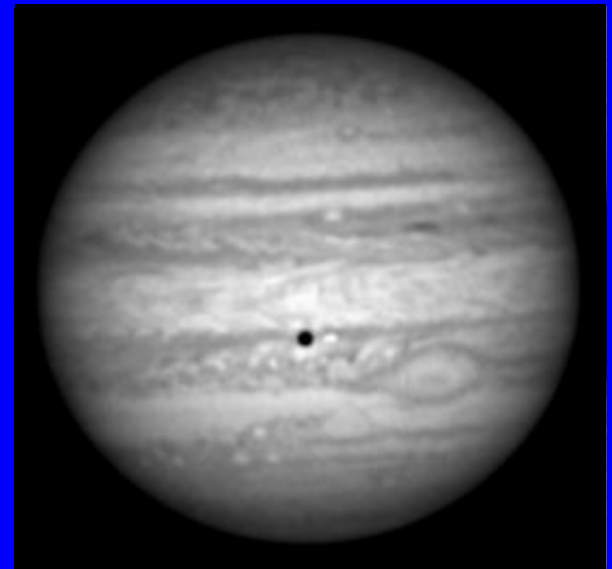
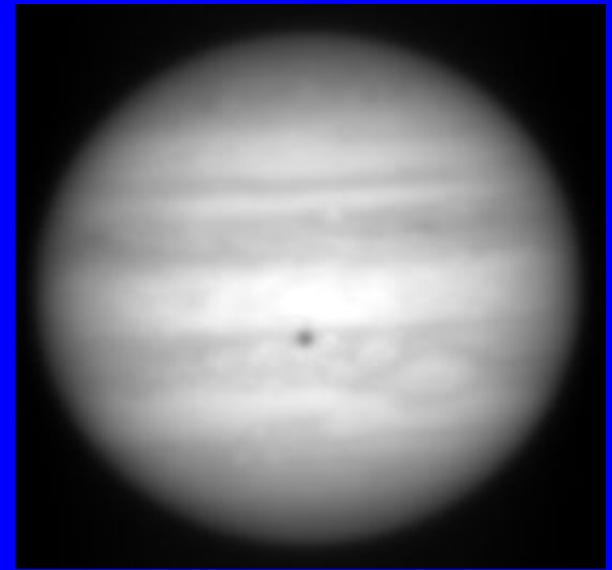
Confocal microscopy, Microtomography, Electrontomography...



« Salt & pepper » noise

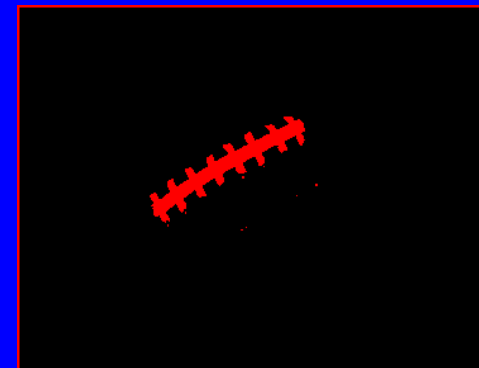
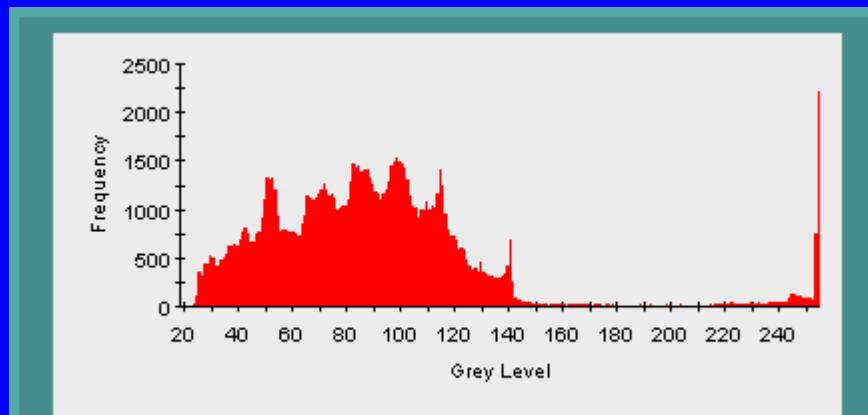
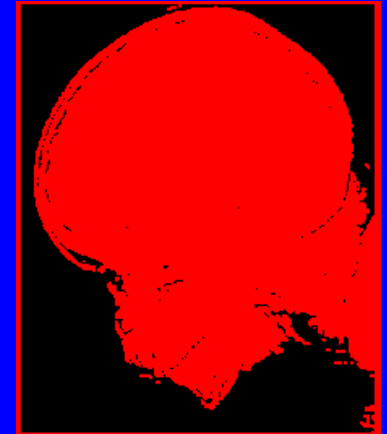
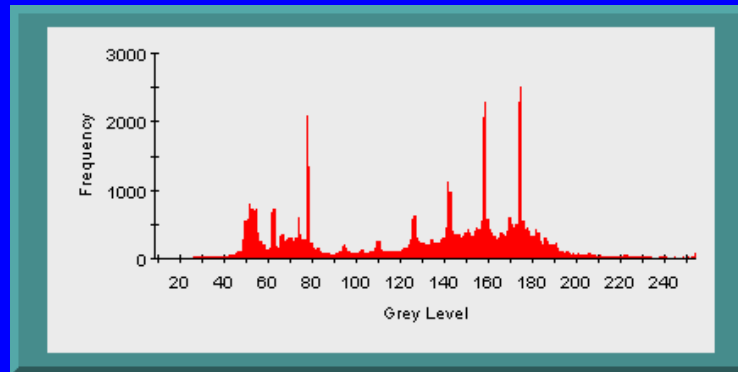
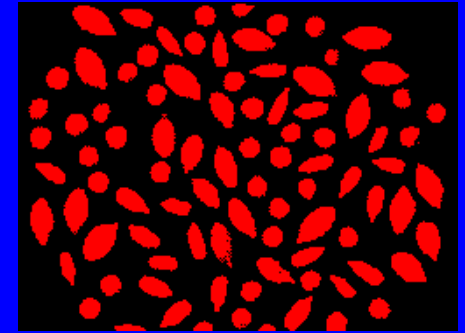
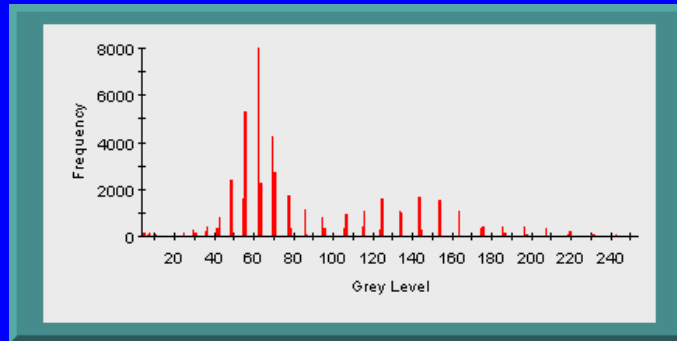
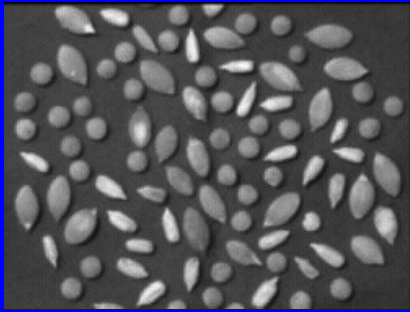


Jupiter rings



Histogram of grey-level intensities

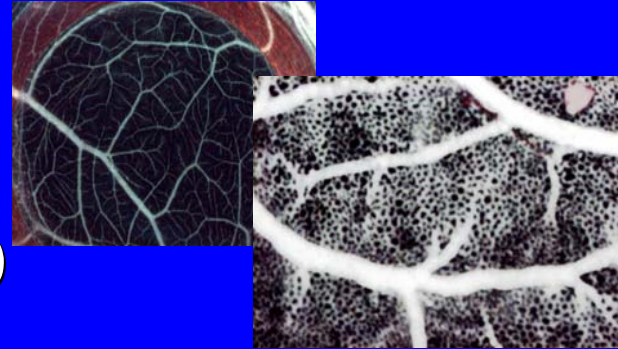
It is a graph showing the number of pixels at each gray-level of an image.



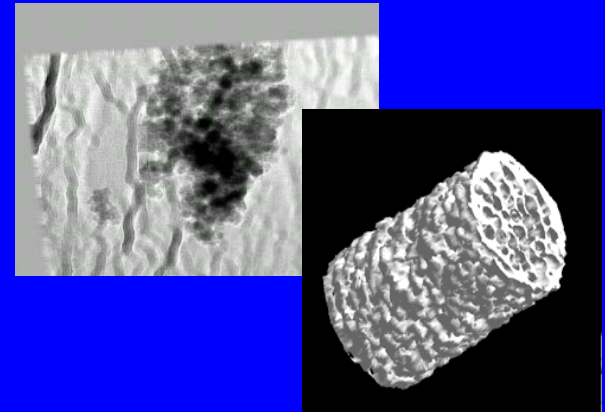
How to combine the tools of signal processing and of mathematical morphology to solve practical problems?

Three applications:

- Characterisation of angiogenesis on the Chorioallantoic membrane of the chick embryo (CAM) model (Optical microscopy)



- 3D image analysis characterisation of metallic xerogel catalysts supported on alumina foams (Electron and X-ray μ -CT)

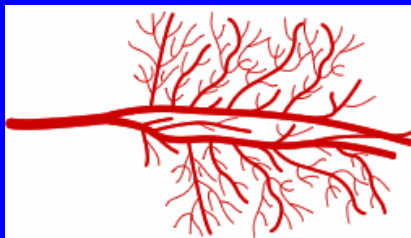


- Characterization of dried banana chips quality (X-ray μ -CT)

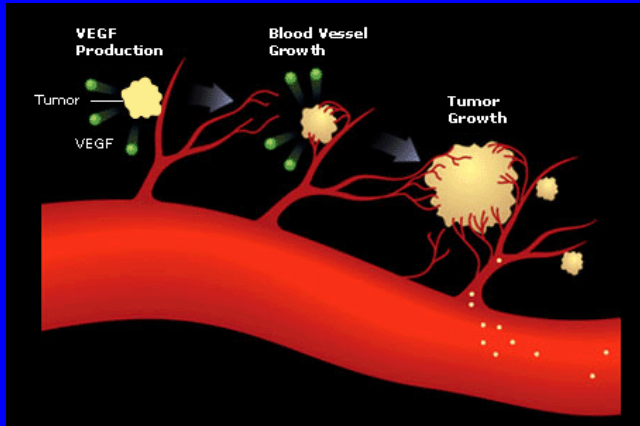


Angiogenesis

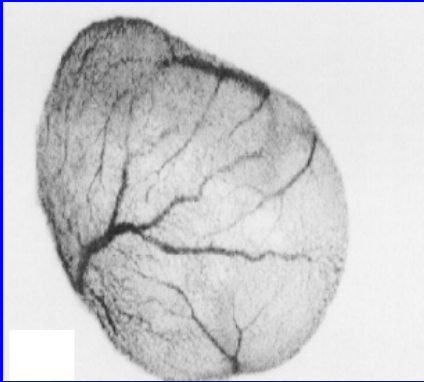
1. ANGIOGENESIS: New endothelial cells are generated by sprouting of pre-existing vessels



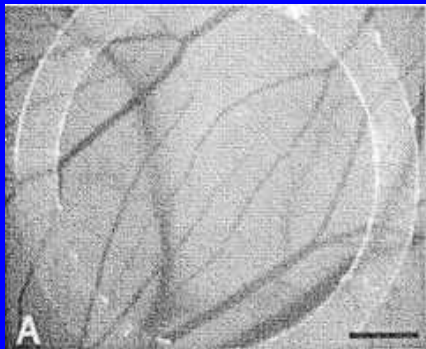
Angiogenesis, is essential for tumor growth, progression and metastasis



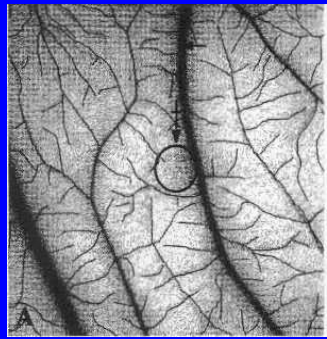
The chorioallantoic membrane of the chick embryo (CAM) assay is a widely used model to examine angiogenesis and anti-angiogenic agents.



CAM model

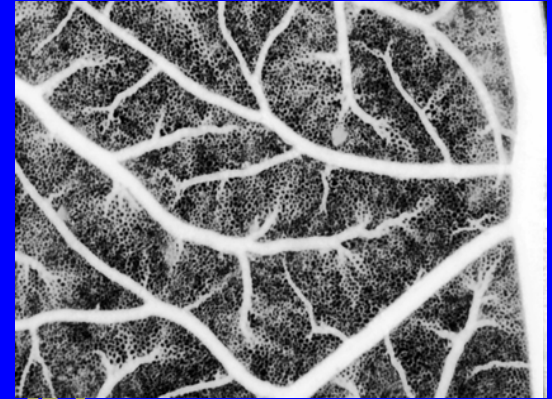
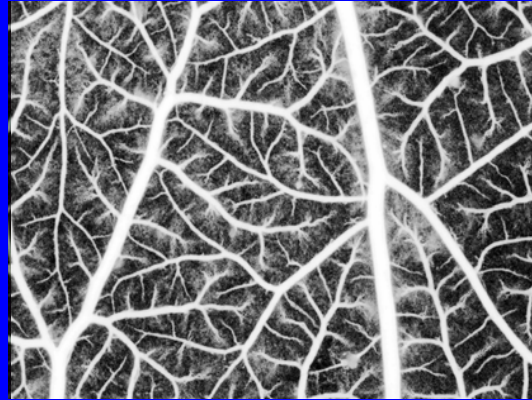
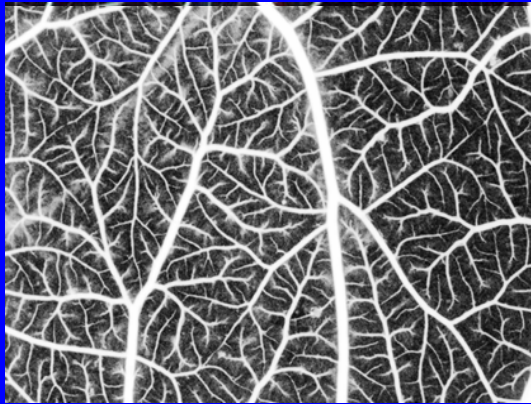


A silicone ring (10mm) is laid randomly on the CAM and testing solutions are deposited.

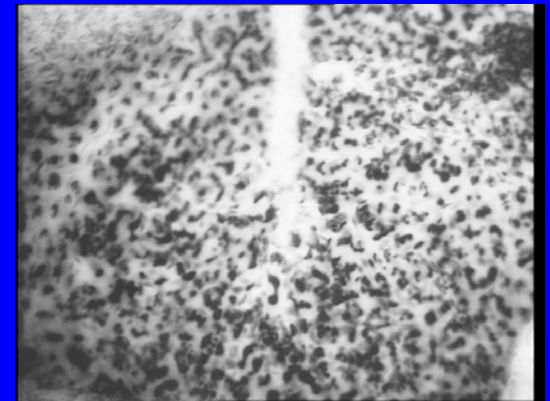
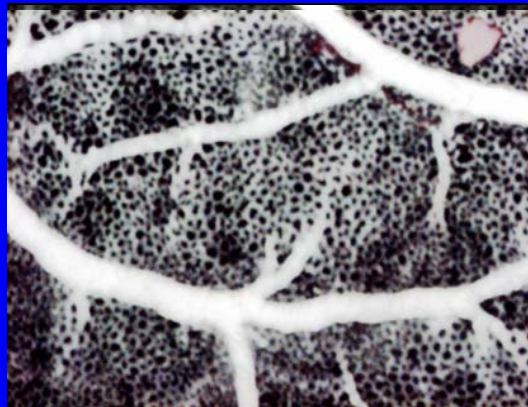
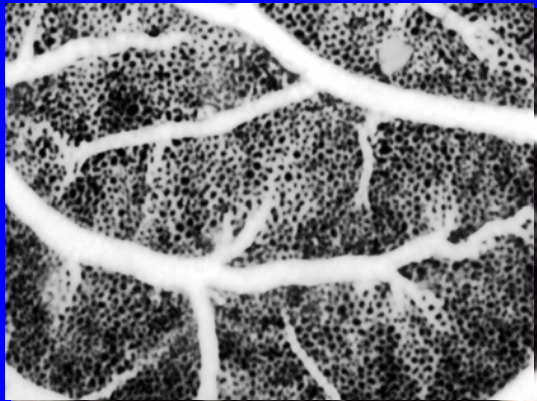


Blood vessels are manually counted in a randomly selected treated zone

Scaling characterization of the CAM



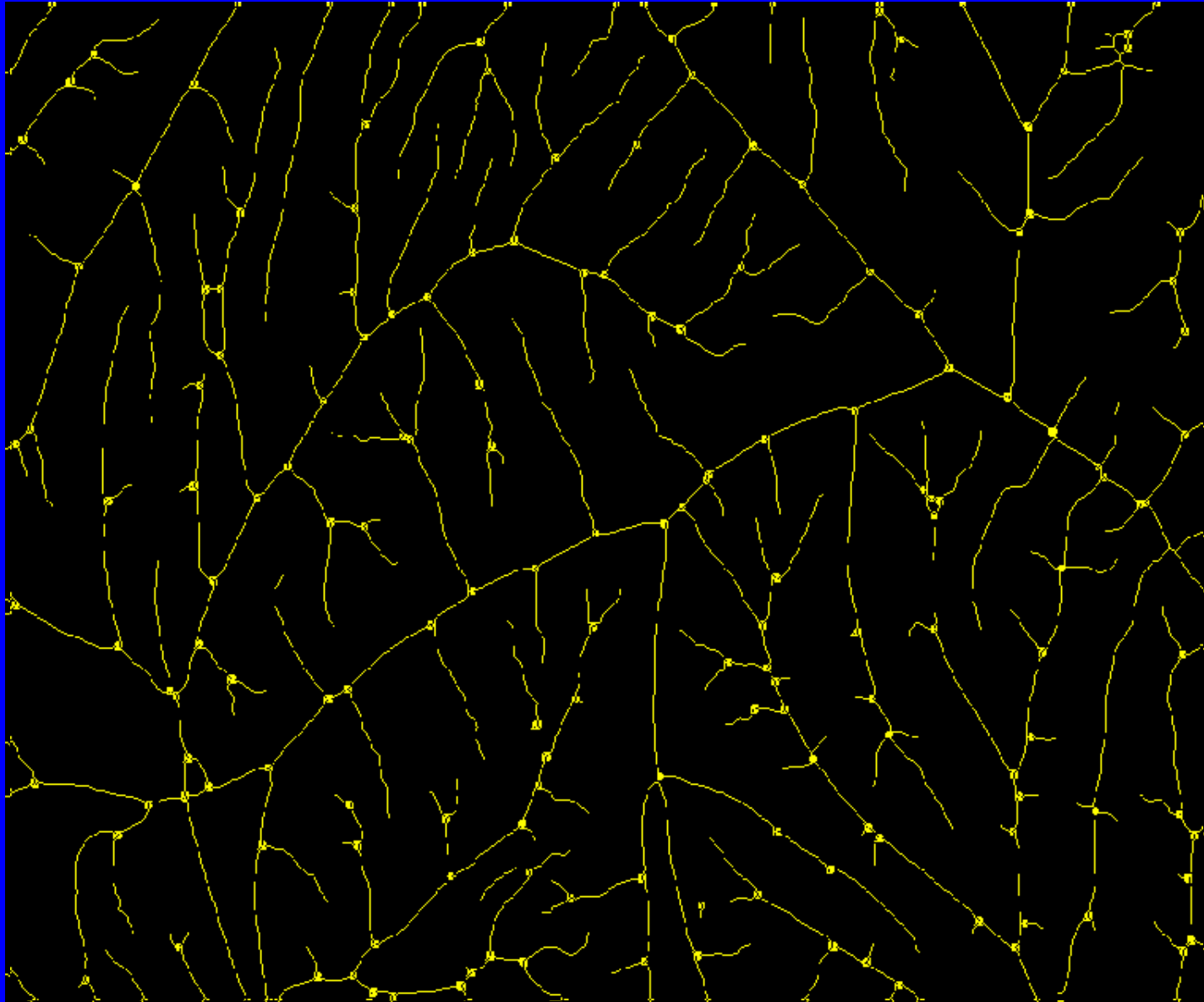
Histogram equalization



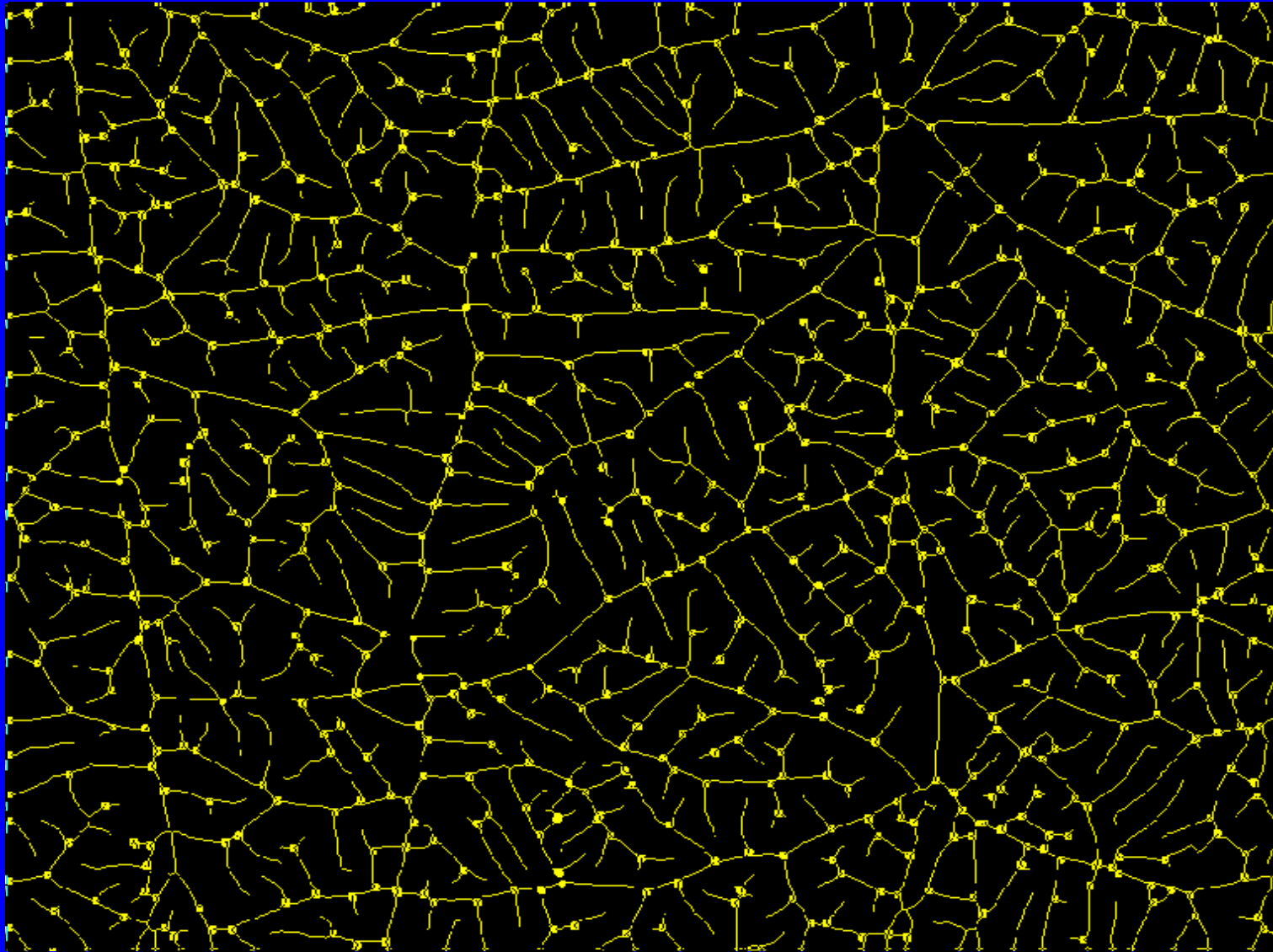
Low magnification : New vessels? More branching?

High magnification : Pillars size distribution changes?

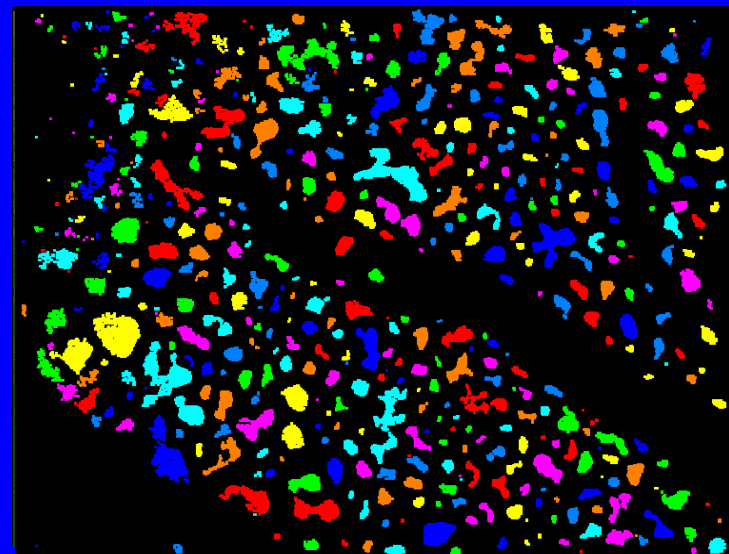
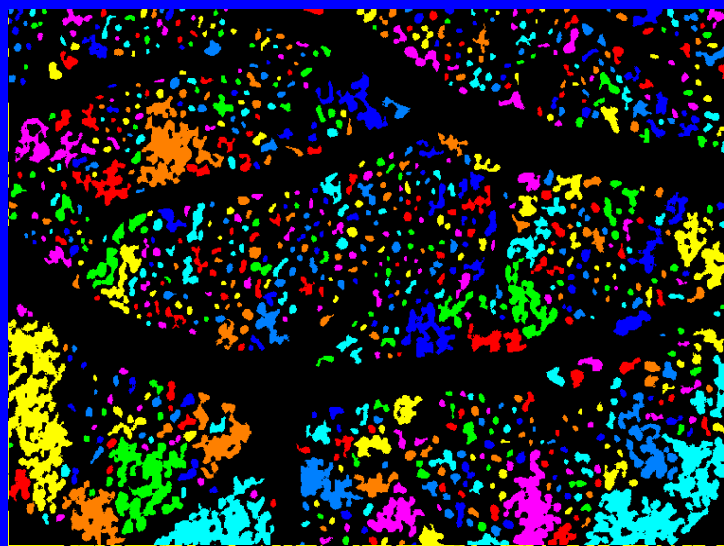
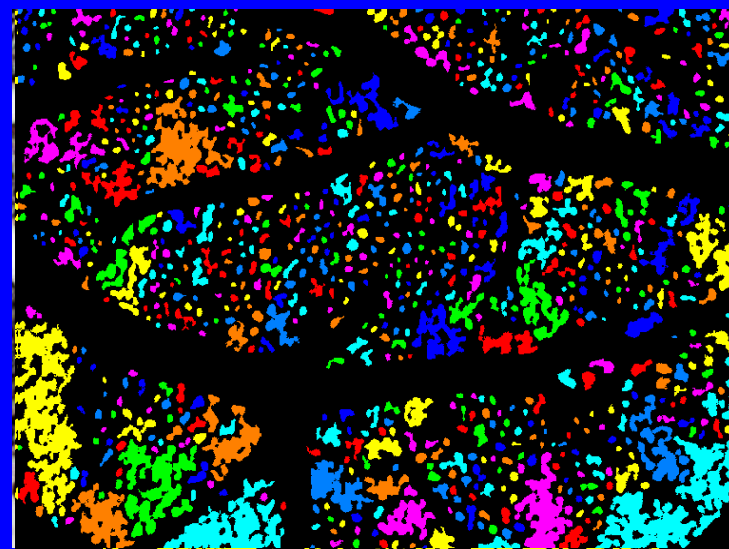
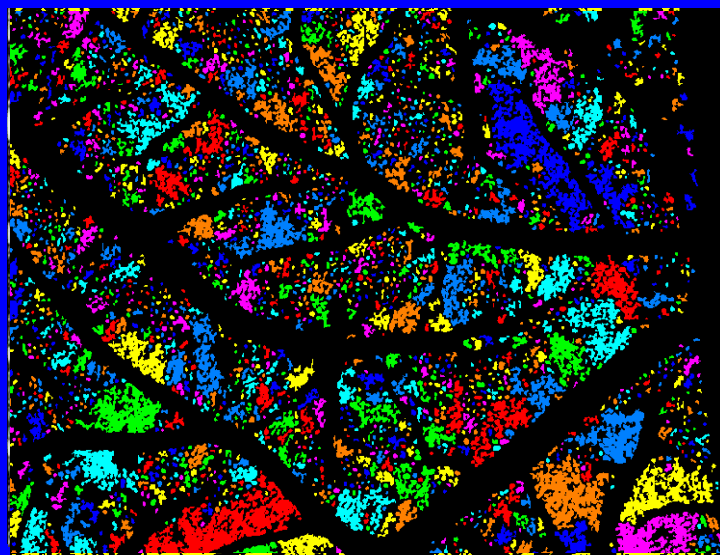
DAY 7



DAY 13



Pillars, meshes, and large non-vascular regions.....

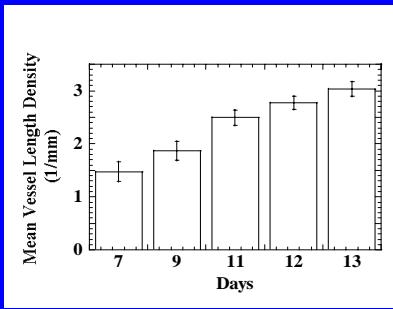


Histogram Equalization →

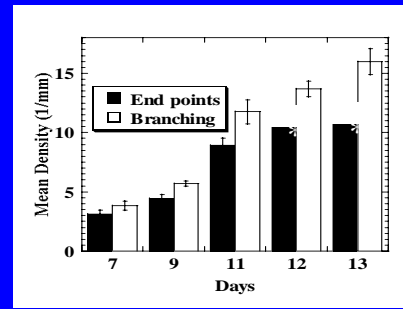
Binarization →

Labelization

-Evaluation of vascular parameters during normal growth of the CAM from Day 7 to Day 13

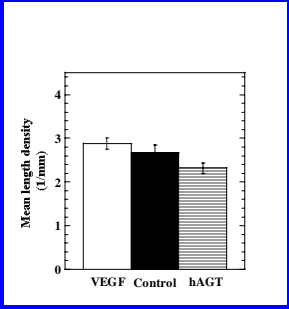
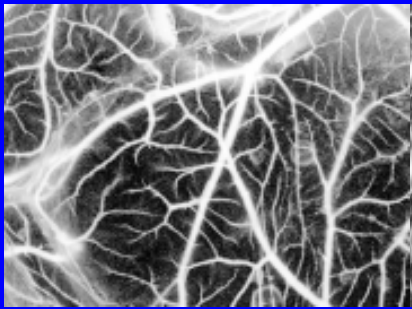


Length density

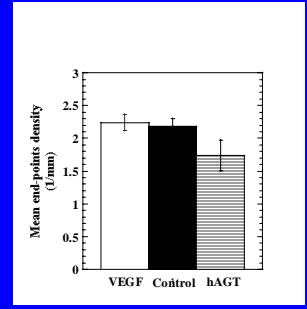


End-points and branching densities

-Evaluation of vascular changes after modulation at day 7 with an anti-angiogenic agent (AGT, inhibitor)

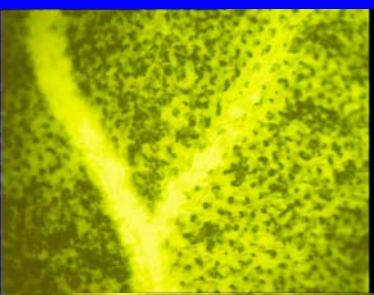


Length density

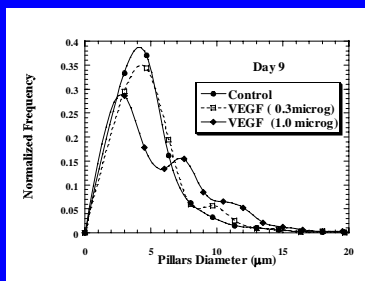


End-points density

-Modulation of pillars with VEGF at various doses (Day 9)



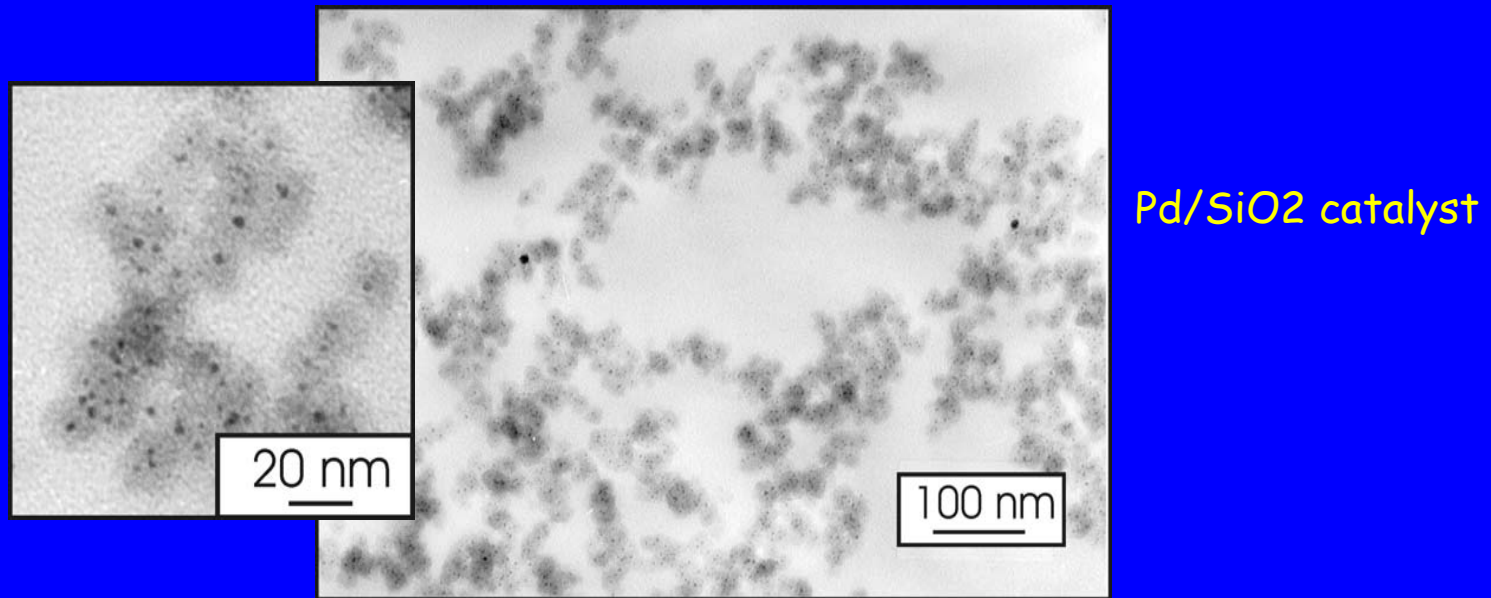
Control
 VEGF (0.3 μg)
 VEGF (1 μg)



Pillar size distributions

Catalysts supported on alumina foams

2. Metallic xerogel catalysts supported on alumina foams

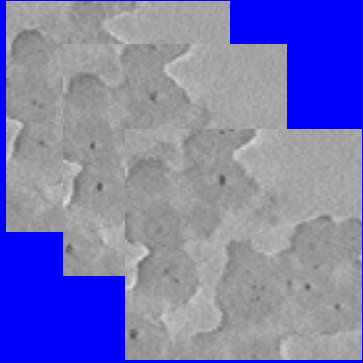


Metal/Alloy particles (~3 nm) finely dispersed in a highly porous support.

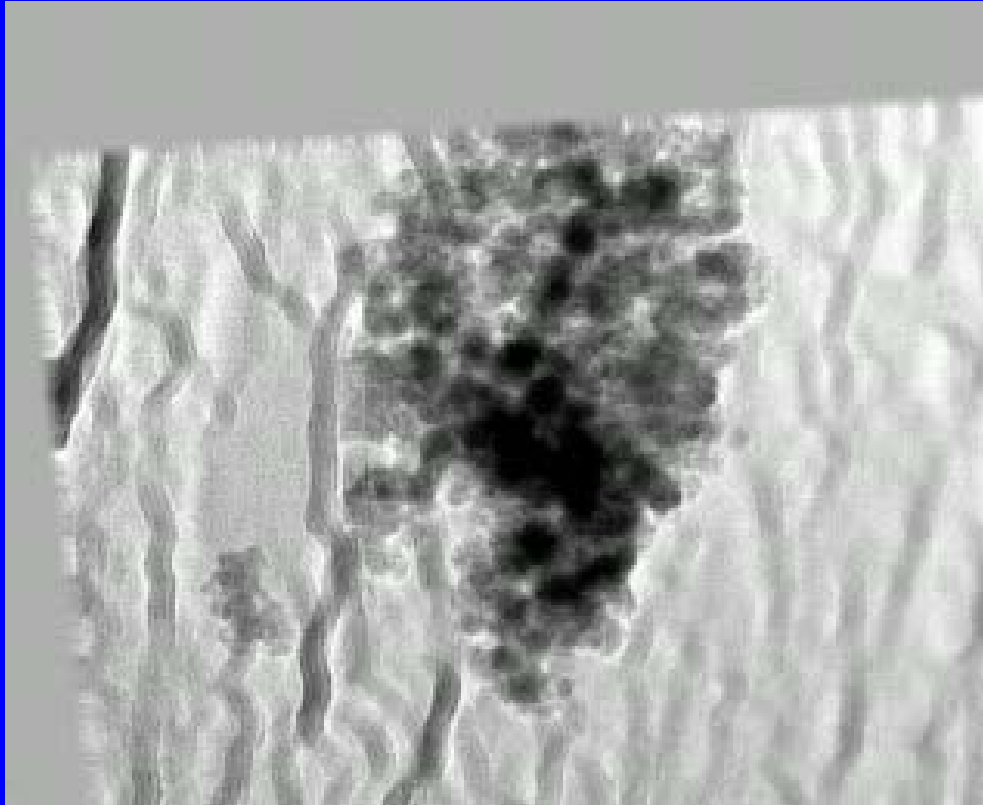
Highly active for hydrogenation and oxydation reactions.

Where exactly are the Pd particles located ?
On the surface, or buried in the silica?

Electron tomography* (3D TEM)



Five hundred 2D images!!!
Thousands of Pd particles!!!!
A very complex structure!!!!

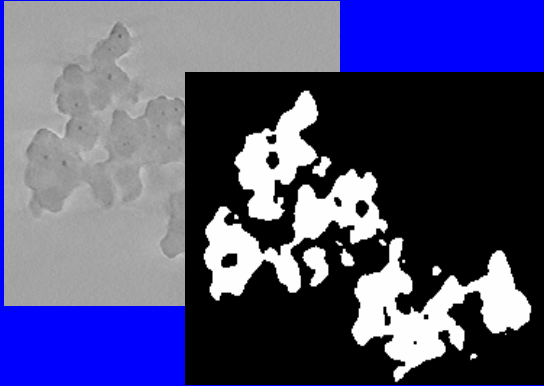


—
~ 100 nm

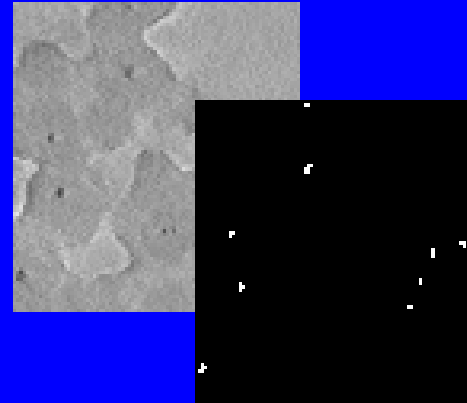
*In collaboration with the Department of Inorganic Chemistry
and Catalysis (Utrecht University)

Two steps processing

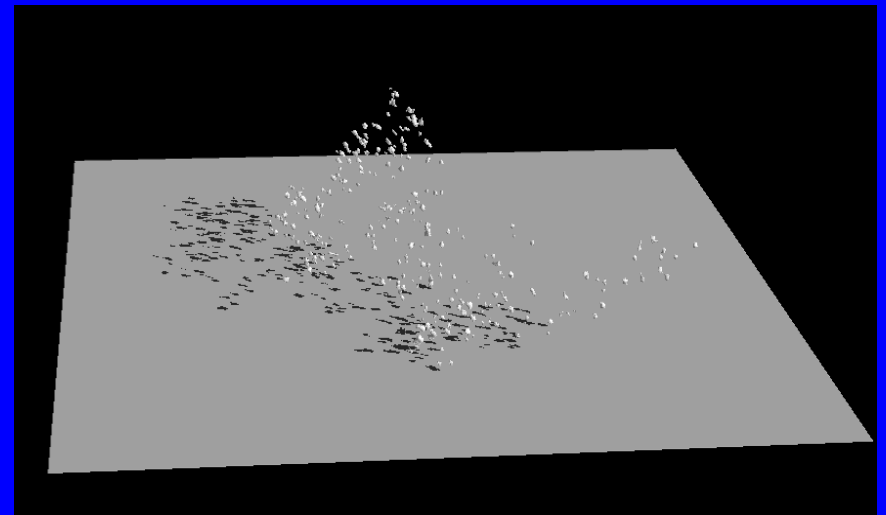
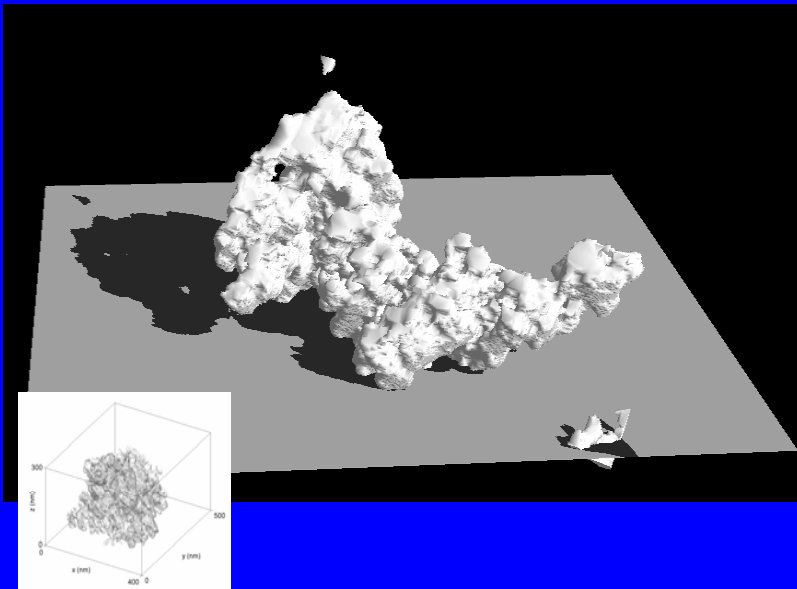
Segmentation of silica skeleton



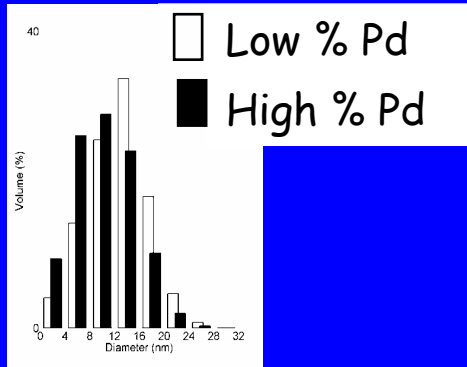
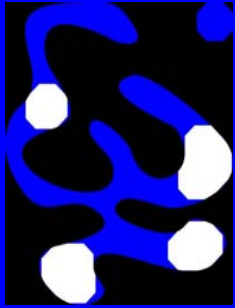
Segmentation of the Pd particles



Segmented tomograms



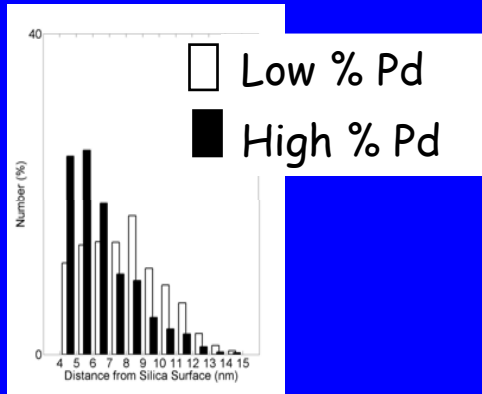
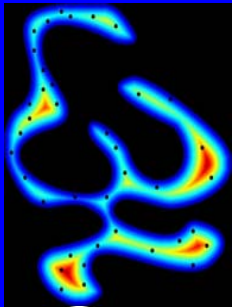
1. Size distributions of the silica skeleton: Opening granulometry



The size distribution of the silica skeleton is almost the same for both samples

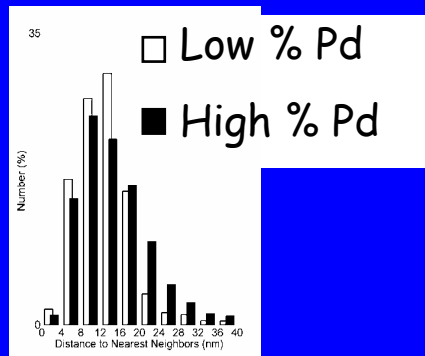
For low % Pd diameter 12.5 ± 4.8 nm
For high % Pd diameter 10.3 ± 4.8 nm

2. Statistical distributions the metallic particles: Distance function



-For low %Pd, distribution has a maximum at a finite distance from the surface,
- For high % Pd, the maximum is nearer to the silica surface.

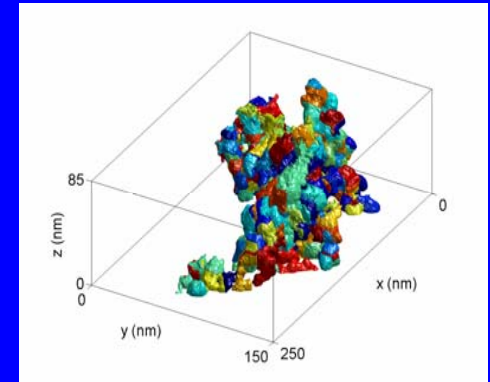
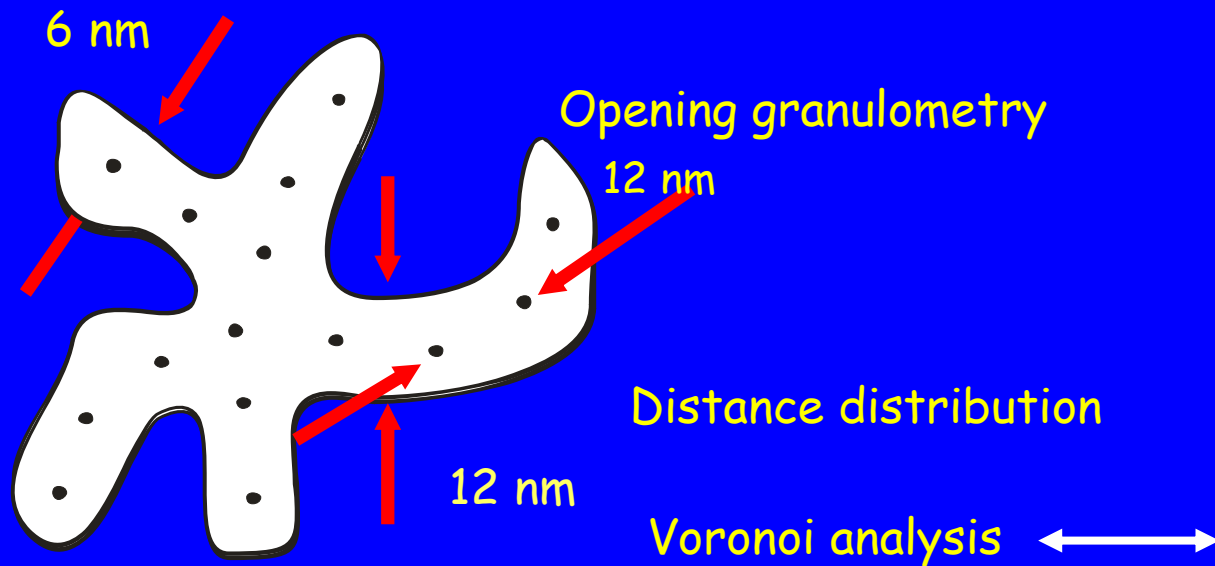
3. Are Pd particles clustered or uniformly distributed inside the silica?



Mean distance to neighboring Voronoi cells

For low %Pd 12.8 ± 5.6 nm

For high %Pd 14.6 ± 7.0 nm

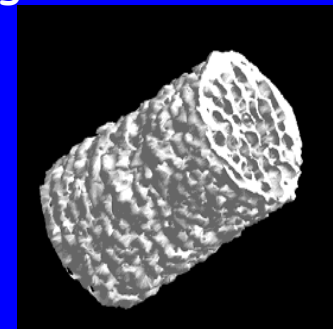


The palladium is almost regularly dispersed in the middle of the struts of the silica skeleton!

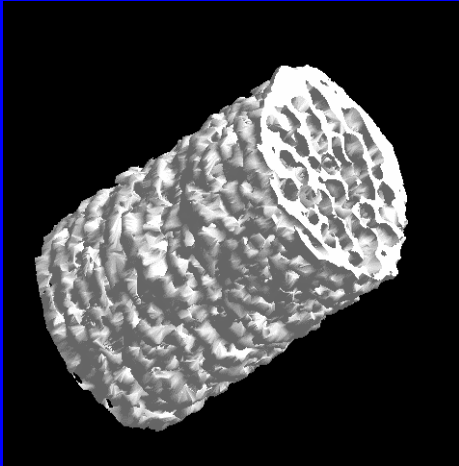
Pre-shape of the catalyst for its extrapolation to the industrial scale:

The catalyst xerogels were synthesized in the interior of alumina foams of large porosity (pore sizes ~ 0.5 mm) and high strength

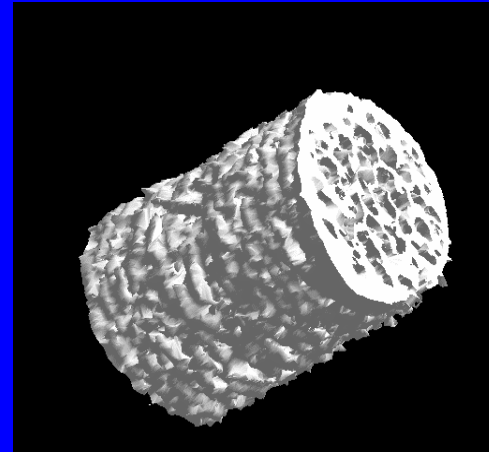
What is the extent of impregnation? Are the xerogel catalyst uniformly distributed on the alumina foam?



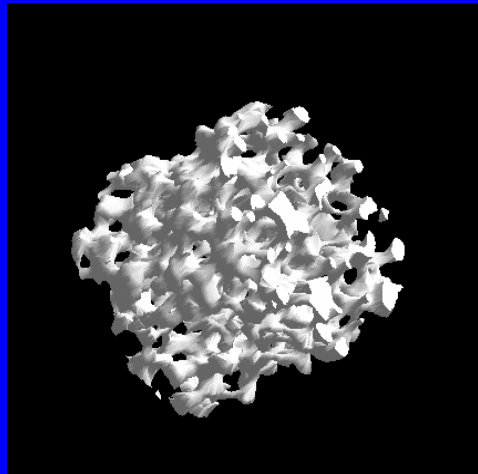
Support AL1



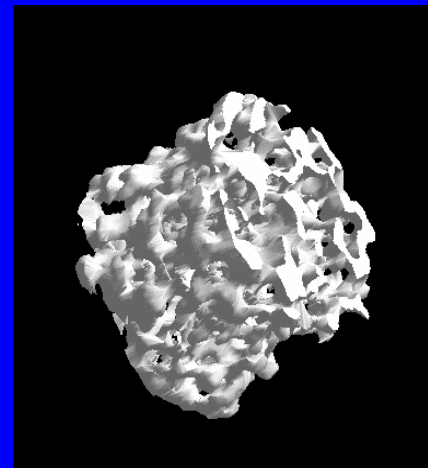
Support AL1 impregnate with a Pd/SiO₂ gel



Support AL3



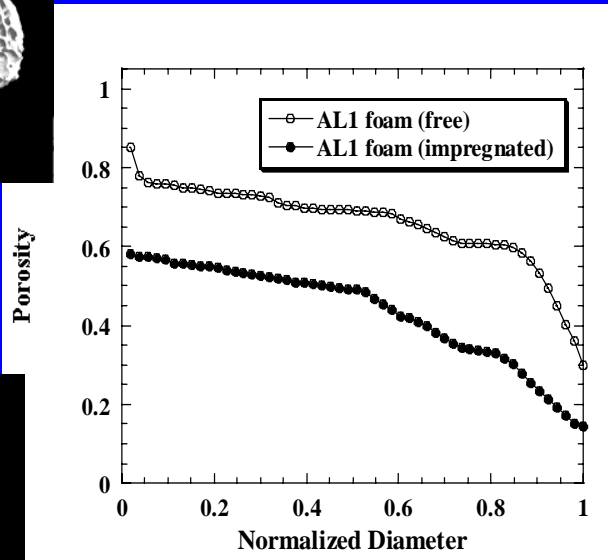
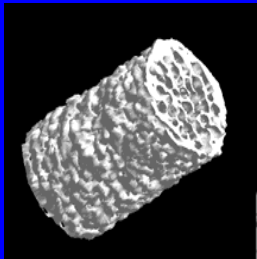
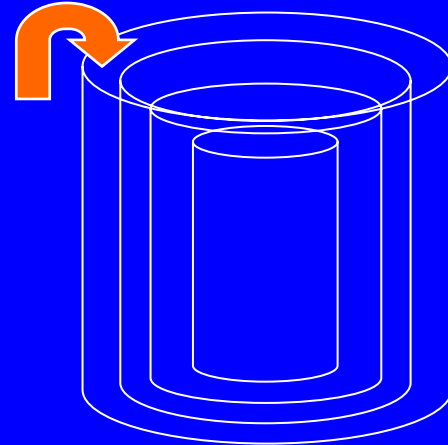
Support AL3 impregnate with a Pd/SiO₂ gel



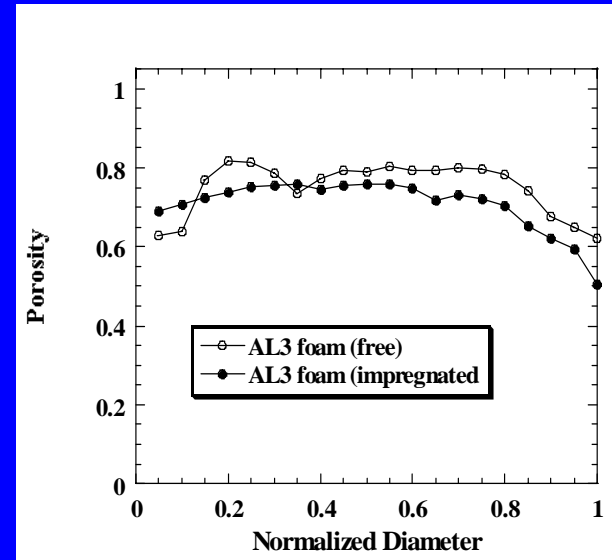
•Determination of the local porosity variations of alumina foams before and after the impregnation process*.

Porosity distribution in function to the distance to the external edge

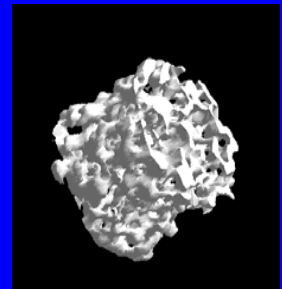
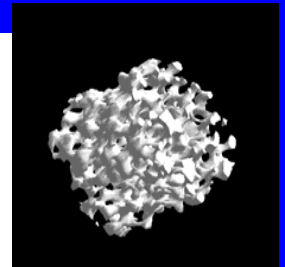
Local porosity is measured in concentric cylinders defined by the boundaries of the minimal cylinder containing the sample, eroded $n=1, 2, 3..$ times



Support AL1

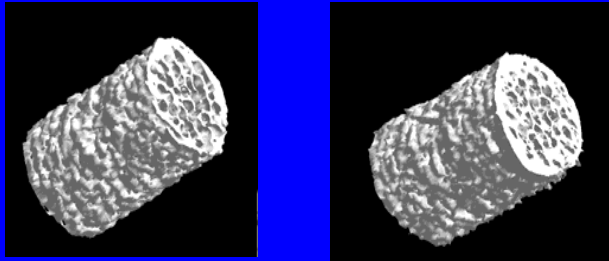


Support AL3

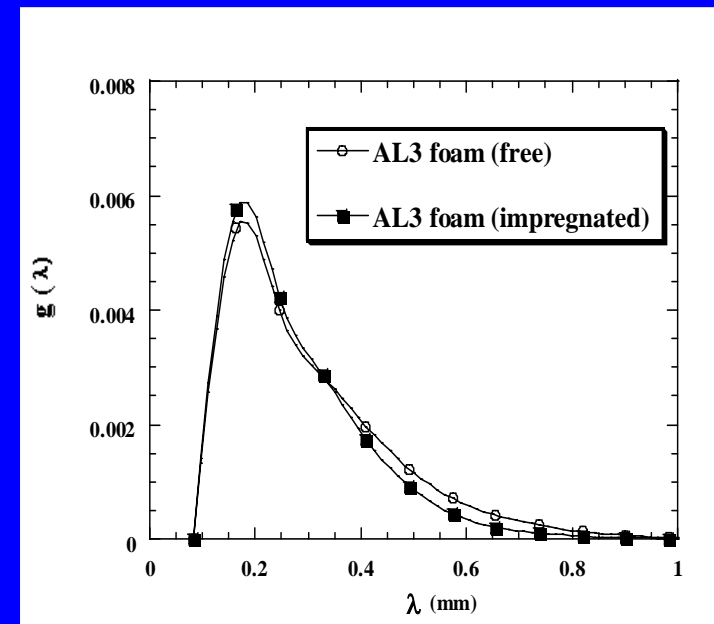
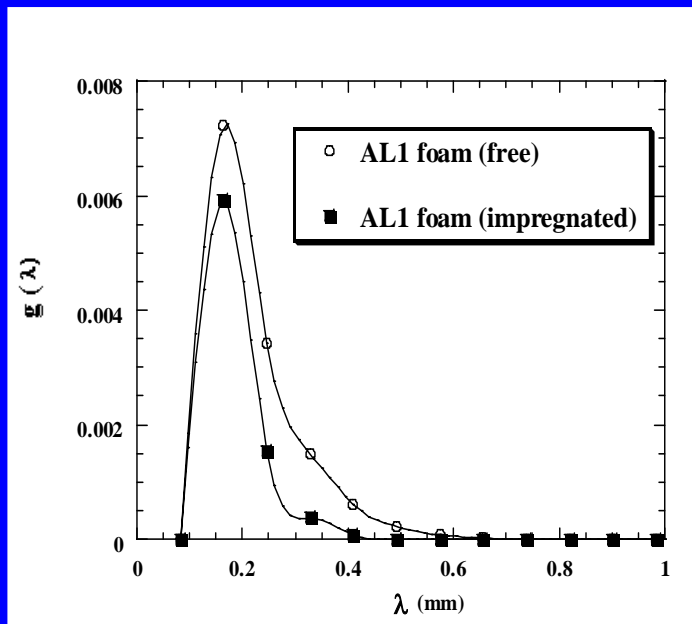
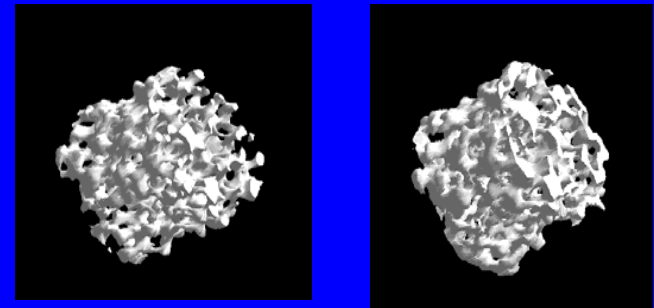


Pore size distribution: open granulometry

Support AL1



Support AL3



Dried banana chips

3.Characterization of dried banana chips quality by X-ray μ -CT

-Drying: way to preserve food.

-Final quality depends of the drying technology: color, rehydration properties, strength, crispiness, etc

-Relation between quality and microstructure: crispiness is mainly related to porosity

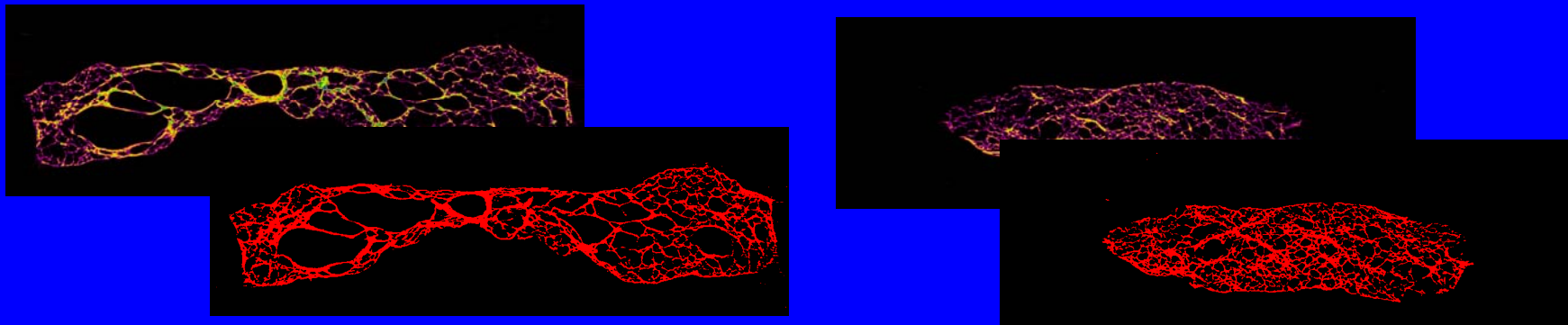
-Samples : Gros Michel Bananas (*Musa Sapientum* L.), local thai market
Slicing: 3 mm thickness and 30 mm diameter

Comparison of different drying techniques

- Low pressure superheated steam drying (LPSSD)
- Vacuum drying (VAC)
- Each previous technique assisted by infrared radiations (FIR- LPSSD and FIR-VAC)
- Medium temperature : 90°C - Pressure : 7 kPa

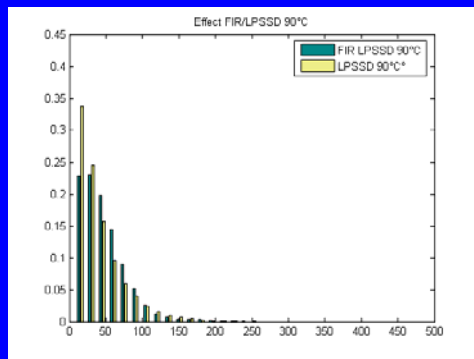


Microstructure of 3D images obtained by X-ray μ -CT

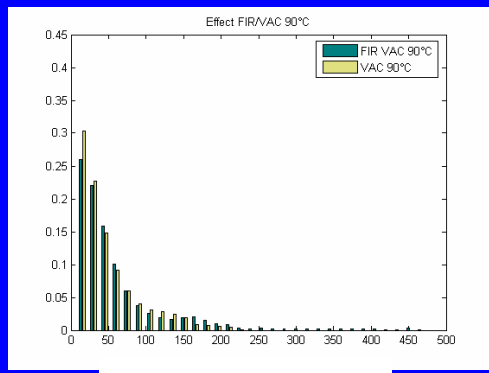


Measurements: -Total porosity
 -Pore size distribution: opening size granulometry

Drying method	Porosity
LPSSD	0.53
LPSSD-FIR	0.70
VACUUM	0.46
VACUUM-FIR	0.63



Pore diameter (μm)



Pore diameter (μm)

-Porosity increases with IR radiation
 -In relation with augmentation of crispiness and better rehydration

-Pore distributions shift towards larger pore size when IR are used
 - More important effect for vacuum drying

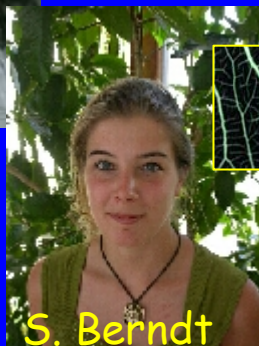
Conclusions

- Image analysis enables to describe in a quantitative way the content of images obtained by any imaging technique in order to relate its morphology with physico-chemical properties
- This technique is quite universal and can be applied on a large spectra of materials.
- In most cases a multiscale analysis is essential to obtain accurate quantitative results : at each scale, information concerning a particular mechanism is depicted.
- Electron tomography and X-ray micro-tomography are powerful complementary non-destructive techniques which allows to visualize 3D structures from the nanometer to micrometer scales.
- 3D visualization coupled with image analysis represent a large improvement in relation to 2D measurements, as morphological parameters can be directly determined without any assumption (homogeneity, isotropy, etc).

Acknowledgements



Pr. A. Noel

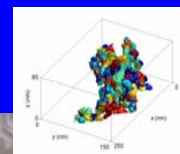


S. Berndt



Laboratory of Tumor and
Developmental Biology, ULG

Image analysis was performed
with Matlab 7.0 and Aphelion (Adcis)



C. Gommès

Laboratory of Chemical
Engineering, ULG



A. Léonard



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S. Devahastin
Dept. food engineering Bangkok,
Thailand