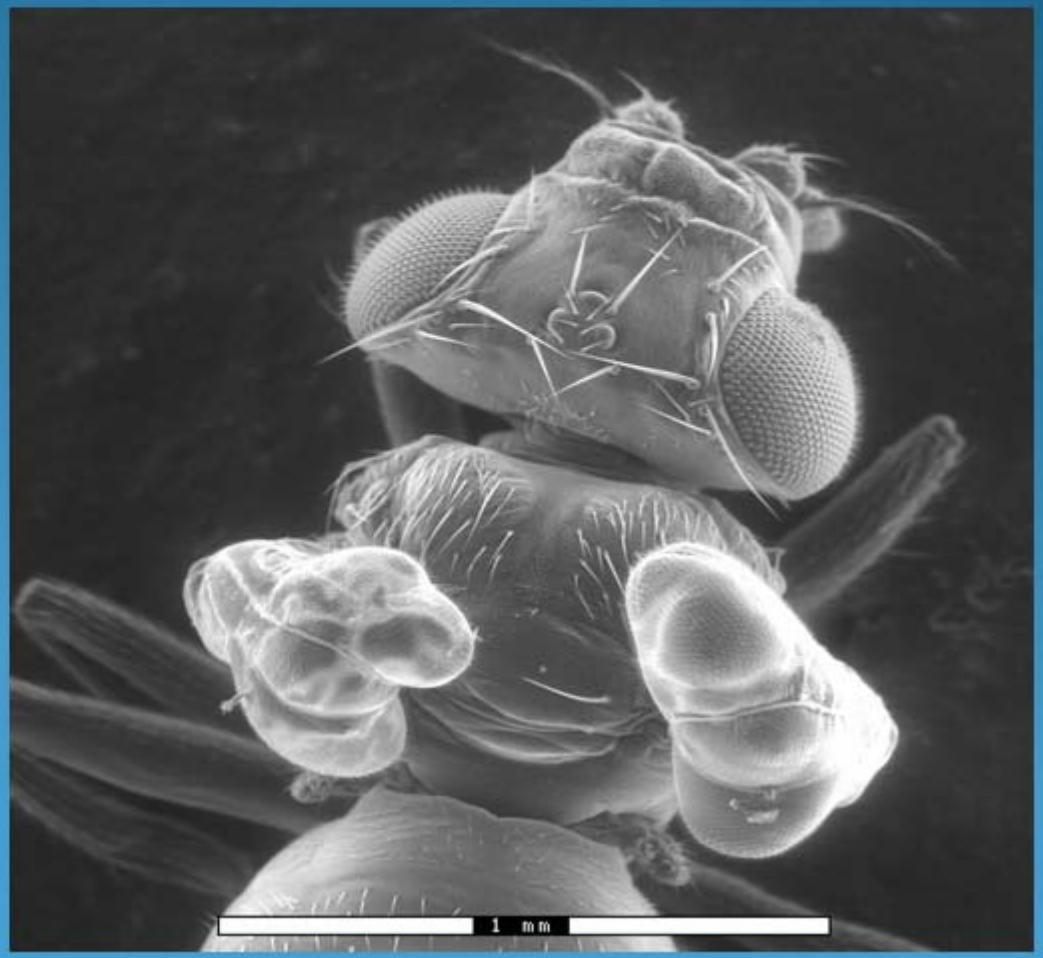
Scanning Electron Microscopy (SEM)



Klaus Schultes
EM Facility

The Scope of this talk is :

1 Why do we use a Scanning Electron Microscope

2 How does a Scanning Electron Microscope work

3 Difference between a conventional SEM and our Environmental SEM or ESEM

Optical vs Scanning Electron Microscopy "Why Bother"

The Human Eye

- The naked human eye has a resolution limit of approximately 0.1 mm and therefore structural details with distances of less than 0.1 mm cannot be resolved by the human eye.

Light Microscope (LM)

- limited in its resolution to about .25 micrometers (if 2 objects are closer than .25 micrometers they blur together and cannot be distinguished as being separate or **resolved**)
- resolution is principally governed by the wavelength of illumination (400 – 750 nanometers for visible light.)
- depth of field (zone of acceptable sharpness) is shallow , about 2 micrometers

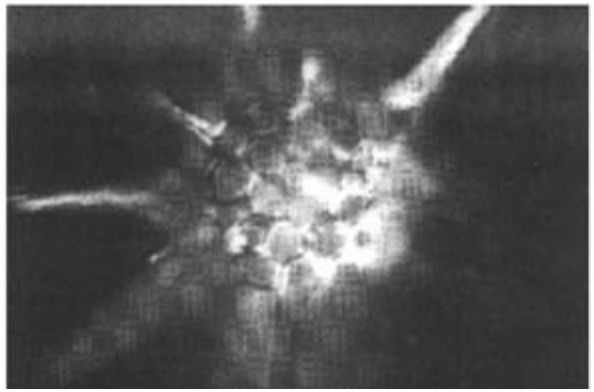
Scanning Electron Microscope (SEM)

• overcomes the resolution limit and achieves resolutions down to 0.2 nanometers with a magnification range of 30x to 100,000x

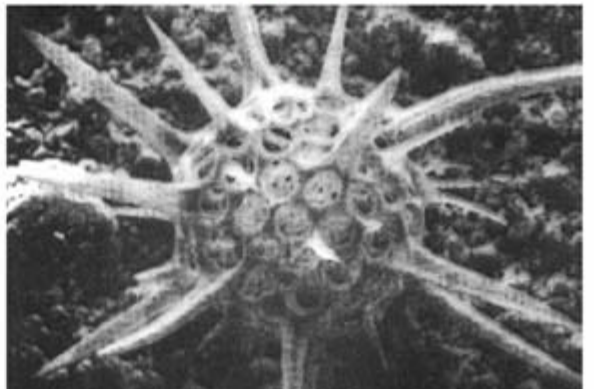
• wavelength of the electron beam is much shorter than light (0.005 nanometers) – ultimately the resolution is determined by the final diameter of the probe which strikes the specimen

•depth of field is about 1000 nanometers (500 times > **LM**)

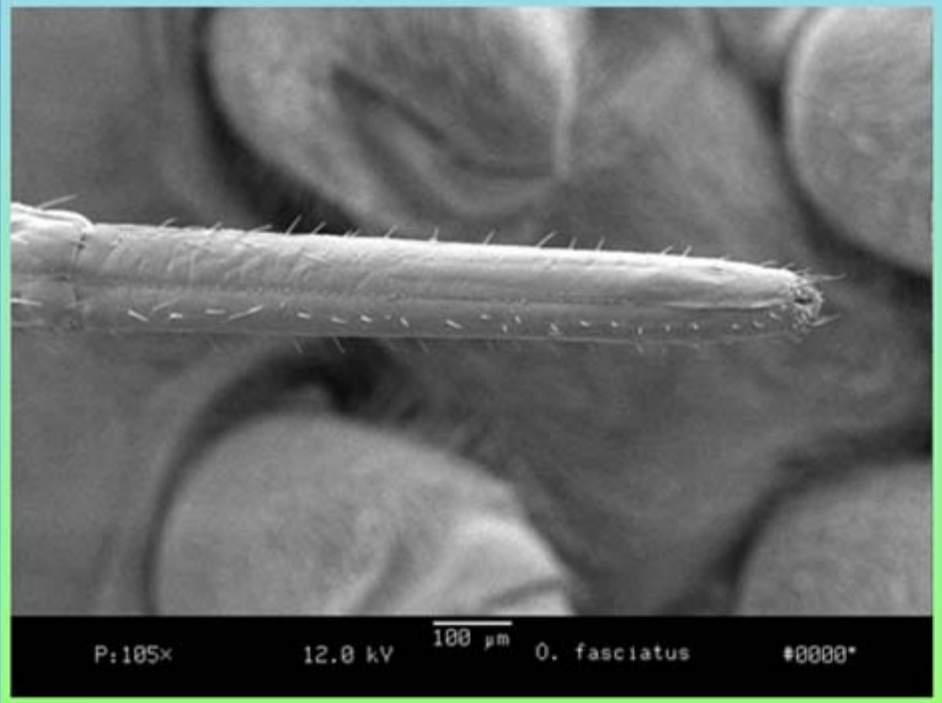
- **Light Microscope**

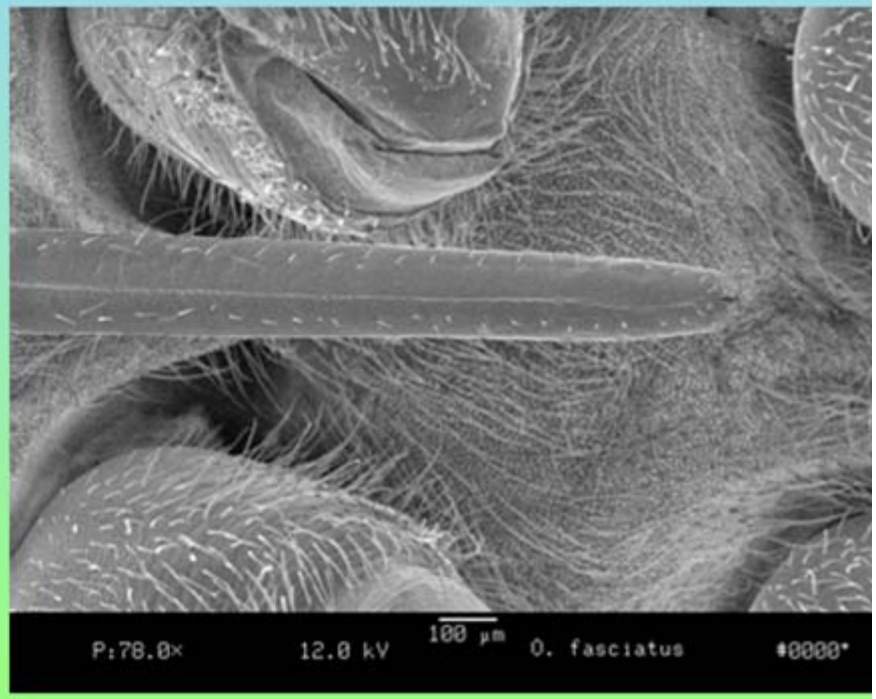


- **Scanning Electron Microscope**

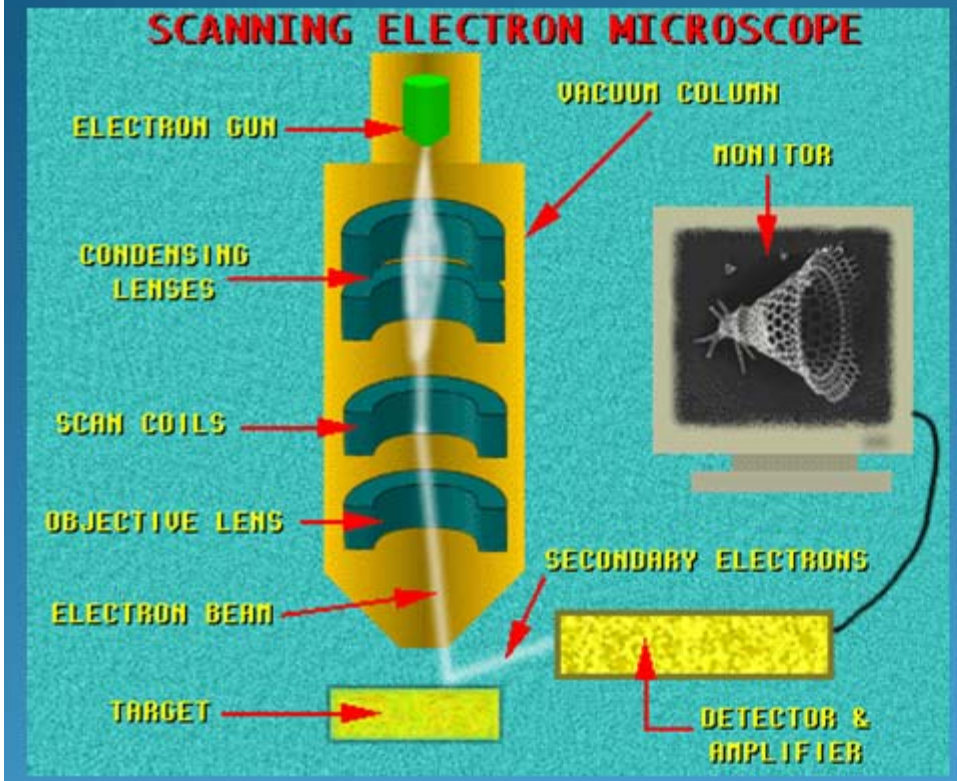


This increased depth of field can also be varied in the SEM





Scanning Electron Microscope
Basic Components



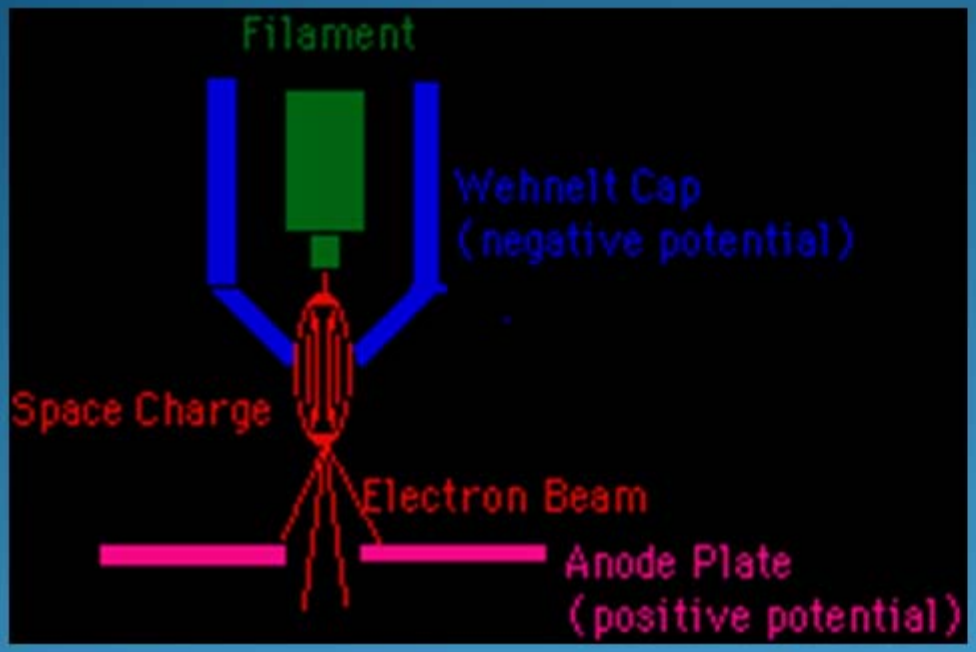
An electron gun (at the top) emits a bea of high energy electrons(in a vacuum). T beam travels downward through a serie magnetic lenses designed to focus the electrons to a very fine spot

A set of scanning coils moves the focuse beam back and forth across the specime row by row

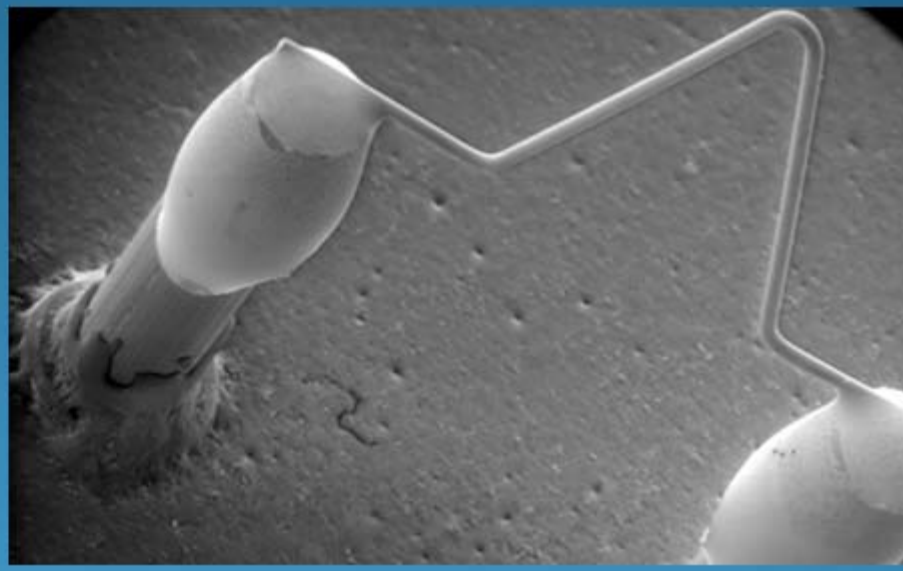
As the electron beam hits each spot on t sample , secondary electrons are knocke loose from its surface. A detector counts these electrons, which are amplified to f a final image on a display monitor

Some key components of the SEM

Electron gun configuration

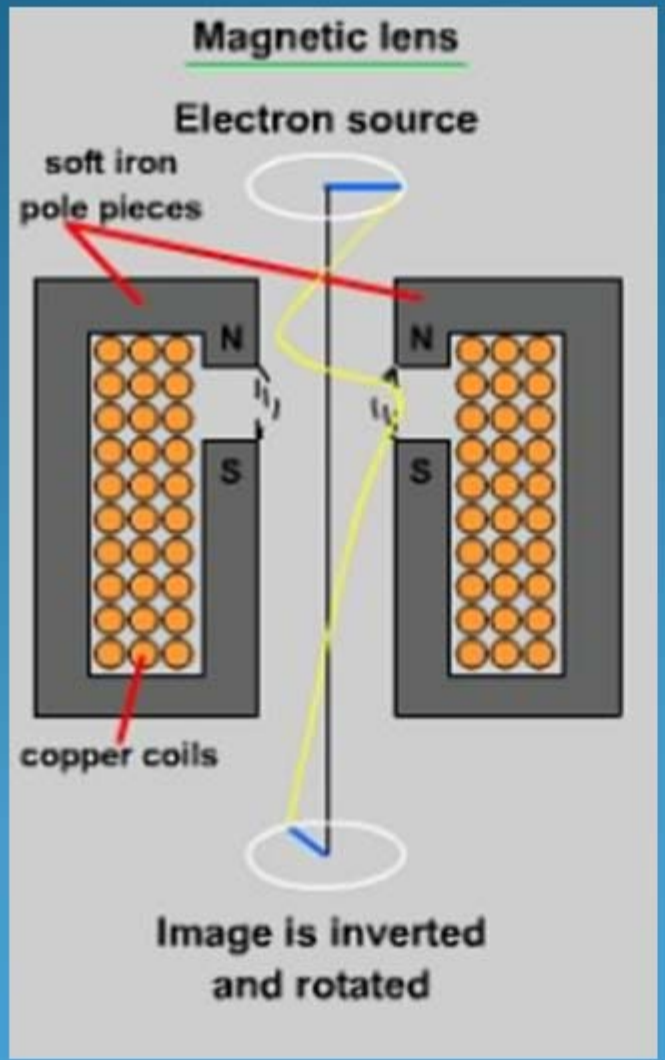


Typical tungsten hairpin filament



This filament is a loop of tungsten which functions as the cathode. A voltage is applied causing the loop to heat up. The anode which is highly positive with respe to the filament forms powerful attractive forces for the electrons. This causes the electrons to accelerate toward the anode. Some accelerate right by the anode an down the column to the sample.

Electromagnetic Condenser Lens

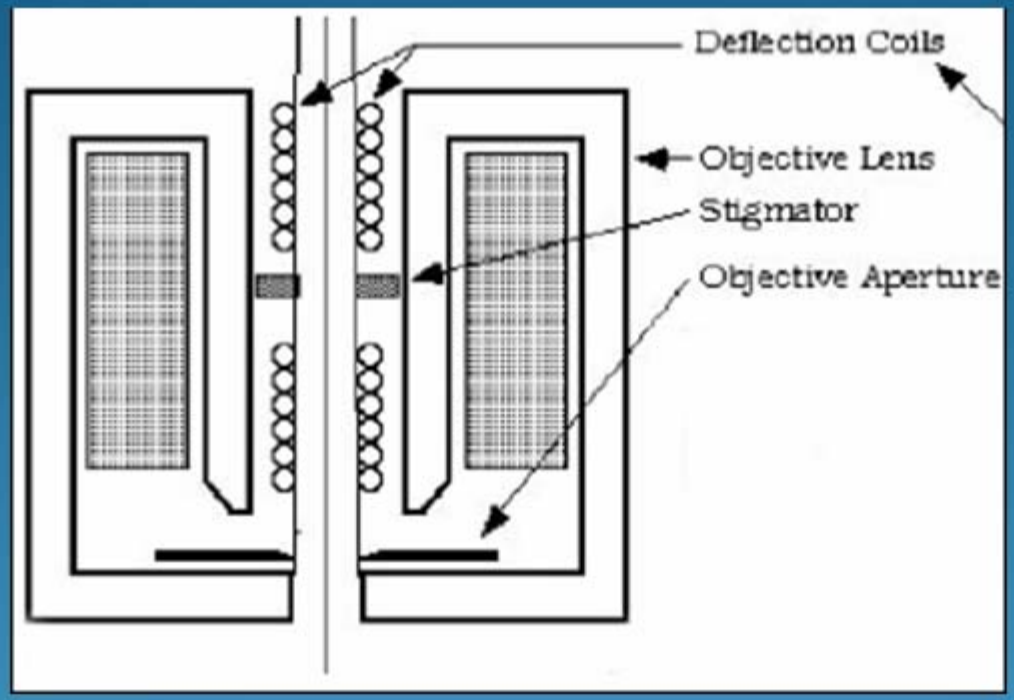


When an electrical current is sent thro
the copper coils an electromagnetic fiel
created between the pole pieces which f
a gap in the magnetic circuit

By varying the current through the coils
the magnification of the lens can be vari

The condenser lens function to demagn
the electron beam to a smaller probe
diameter

The final objective lens

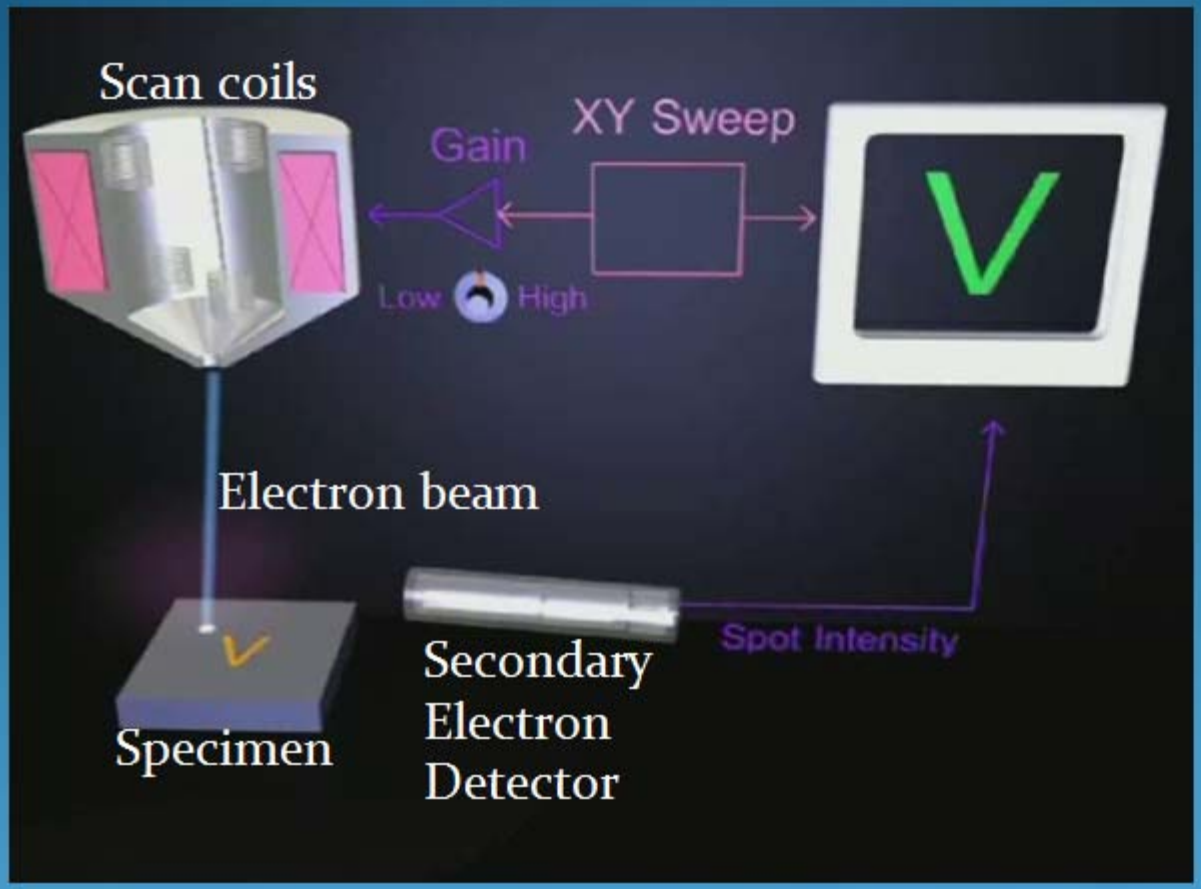


The final lens in the system is a highly modified condenser lens called the objective. The onjective is the workhouse and functions to focus the beam of electrons towards the sample.

It houses Scan generator

Stigmator coils and a Limiting aperture

Scanning and image forming components

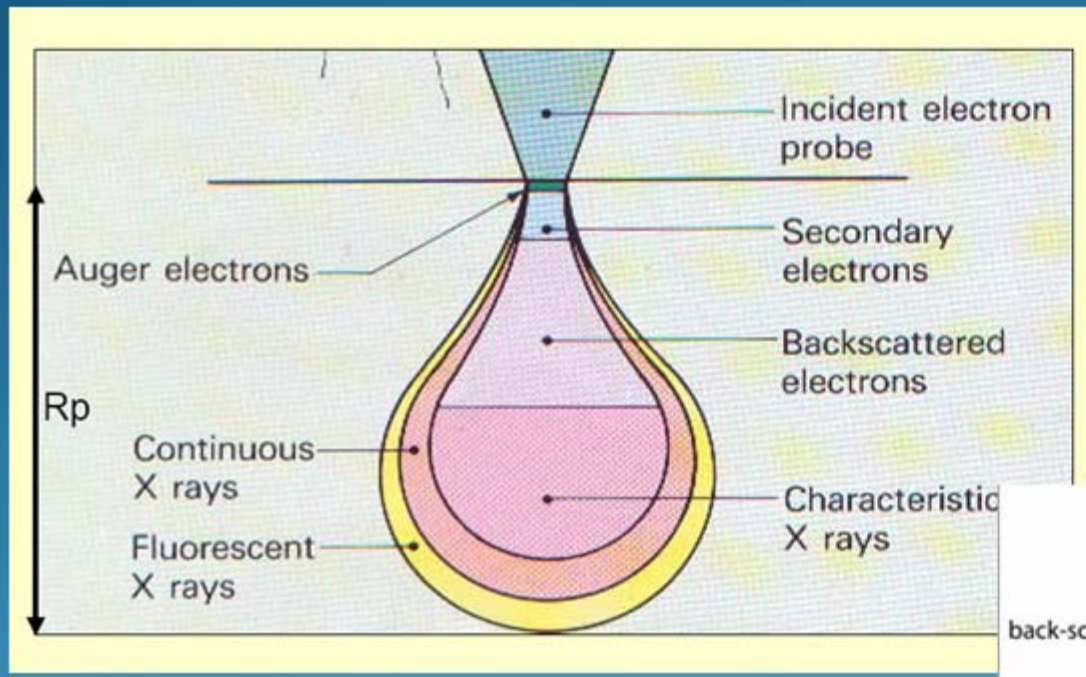


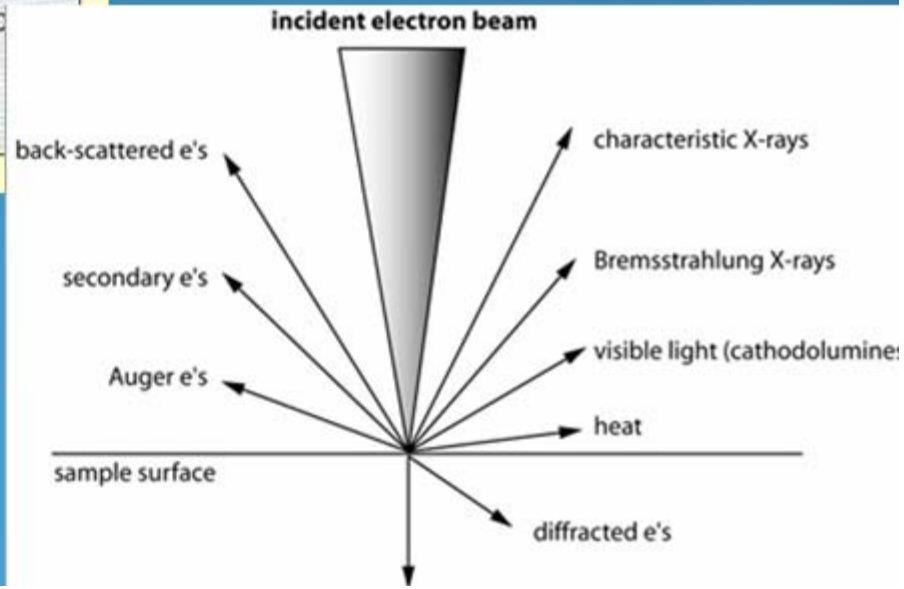
The specimen surface is scan
by the focused electron beam
sweeping it across a rectangu
shaped area called a raster.

The probe moves across the
sample left to right point by p
to complete one line then bac
again to the next line thereby
building up an image.

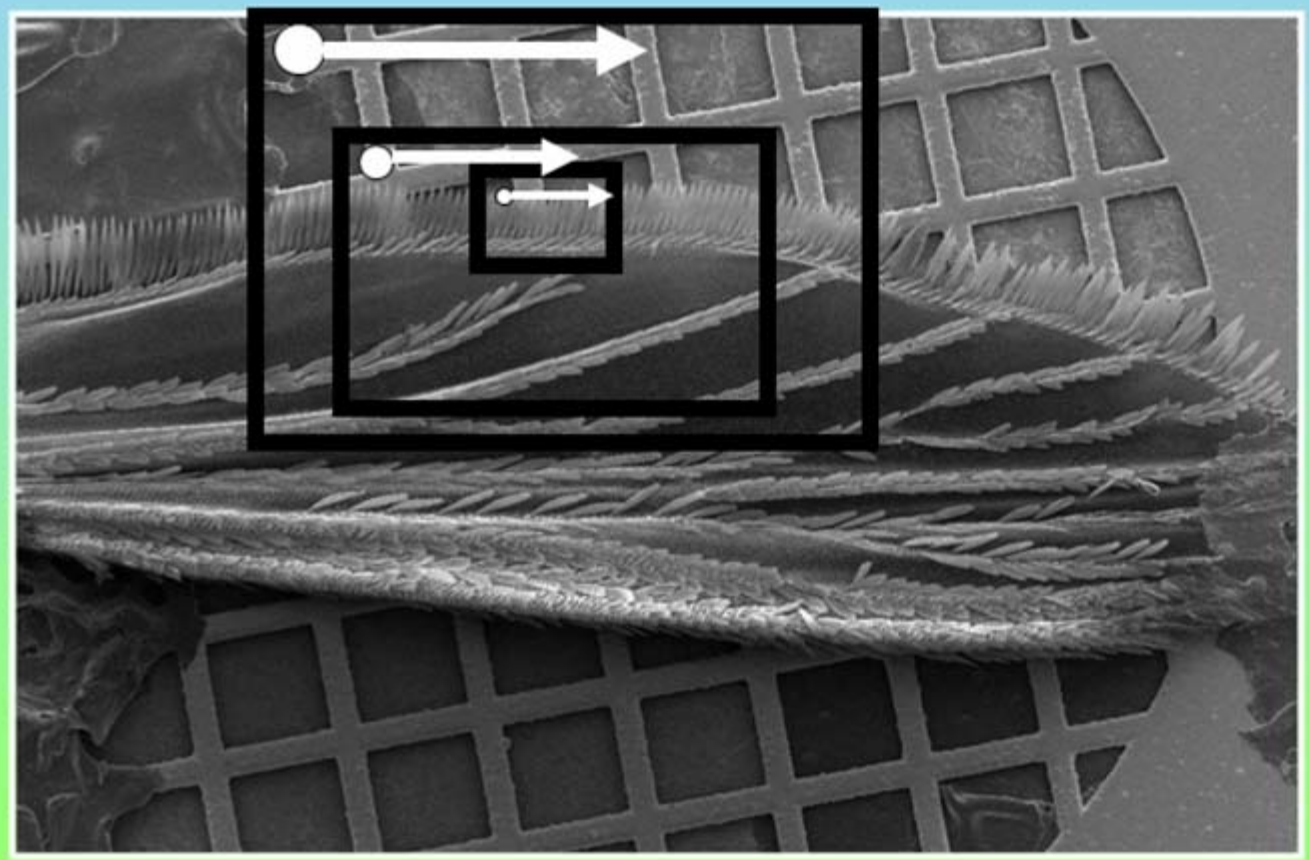
It is important that the scann
probe is synchronized with th
display monitor to yield poin
to point translation

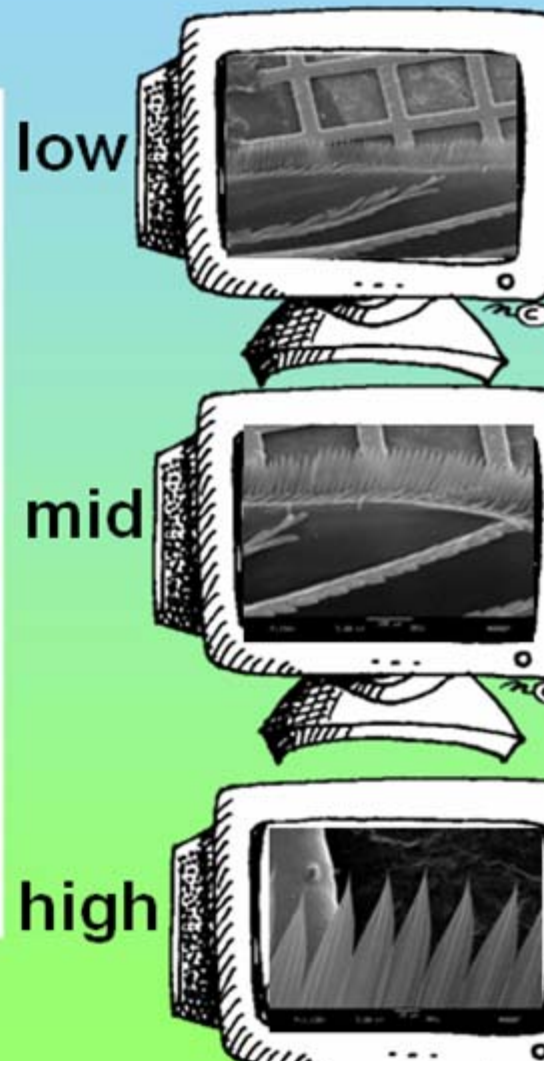
What happens when the primary beam strikes the sample surface





How Magnification works





Constraints on the use of Electrons

- high energy electrons (beam electrons) have a path length of a few mm in air, also air in the presence of a hot filament would cause it to burn out

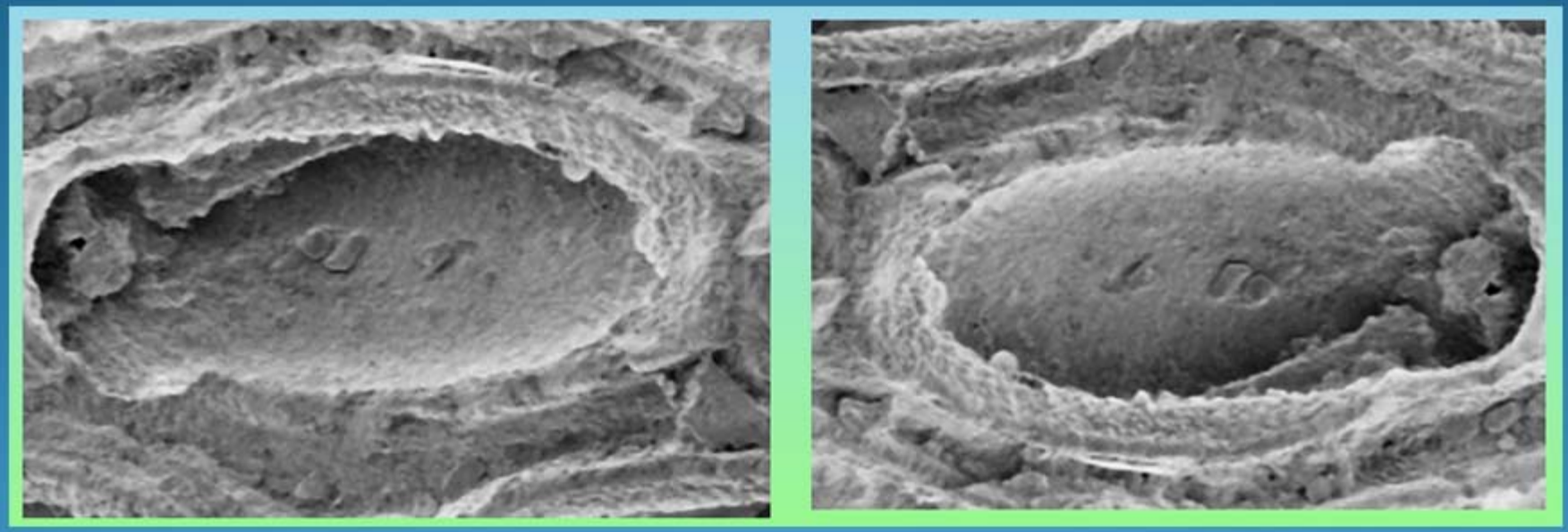
- the electron optical column is about .5 meters in length so you need a vacuum to get the beam to the sample

- need to maintain a vacuum creates a problem for the specimen. Wet samples must be stabilized and dried before placing in the chamber.

- electrons have a charge which if allowed to accumulate in a specimen will also give it a charge. This charge buildup will repel the primary beam therefore it it must be conducted away. Insulating samples must be coated with a thin conducting material (gold, carbon)

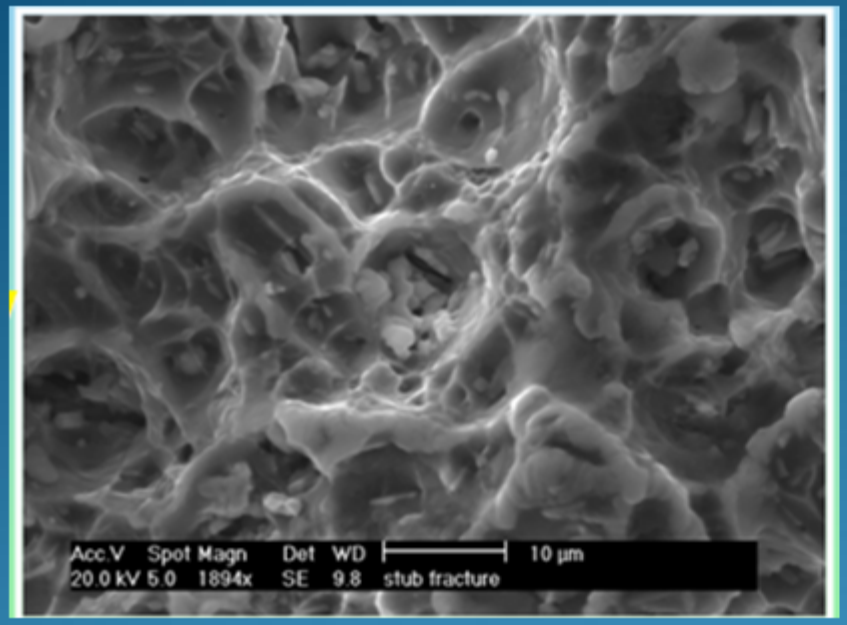
- beam electrons have considerable kinetic energy, if transferred to the specimen
  instability and damage will occur. You can literally "cook" or burn a hole in your
  specimen

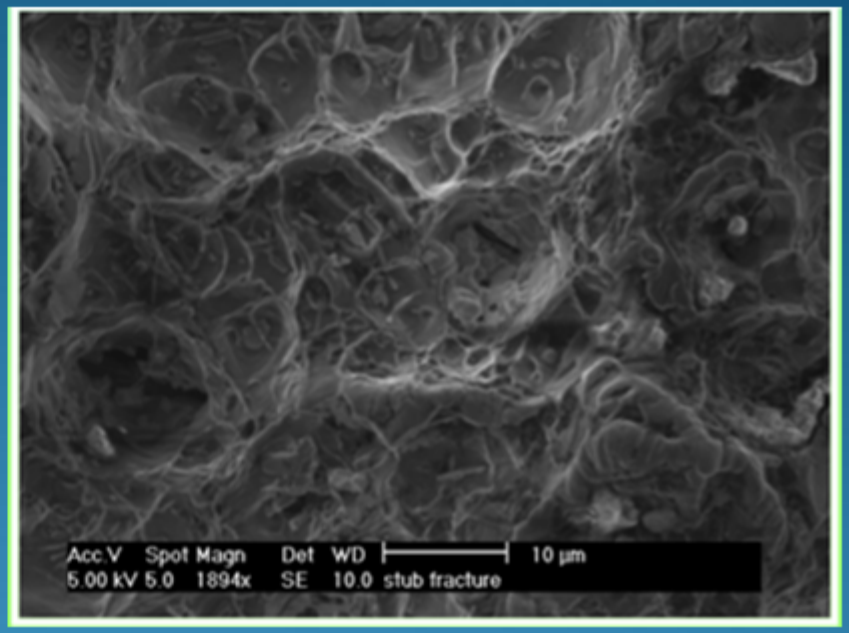
What is Reality

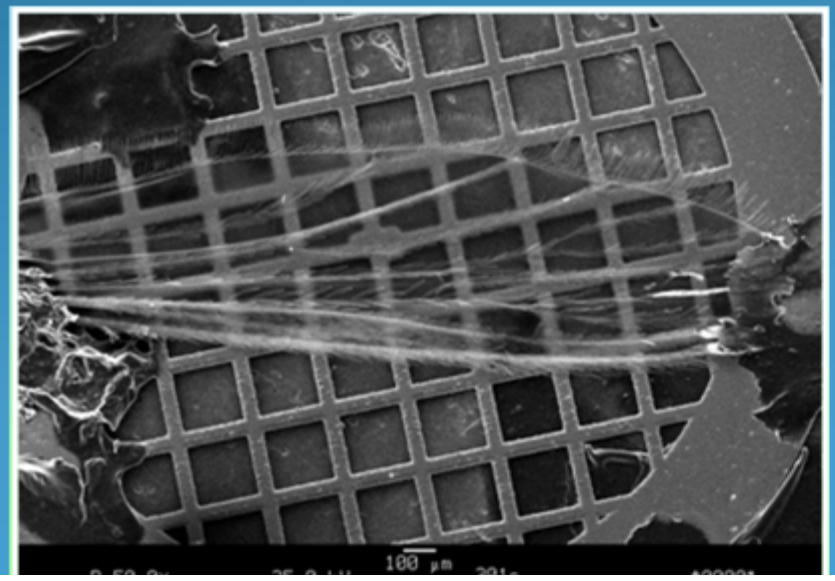


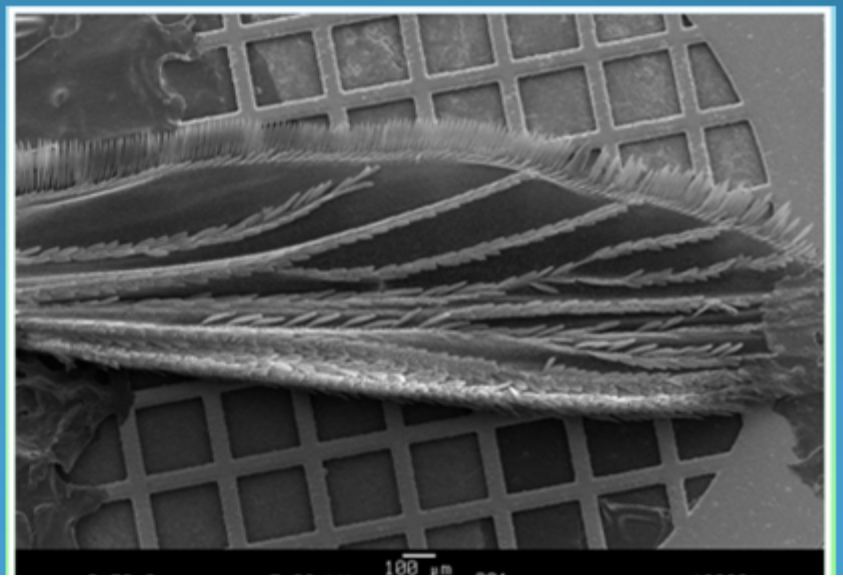
Preparation and subsequent gold coating of biological samples can introduce its own set of artefacts.

Different Realities

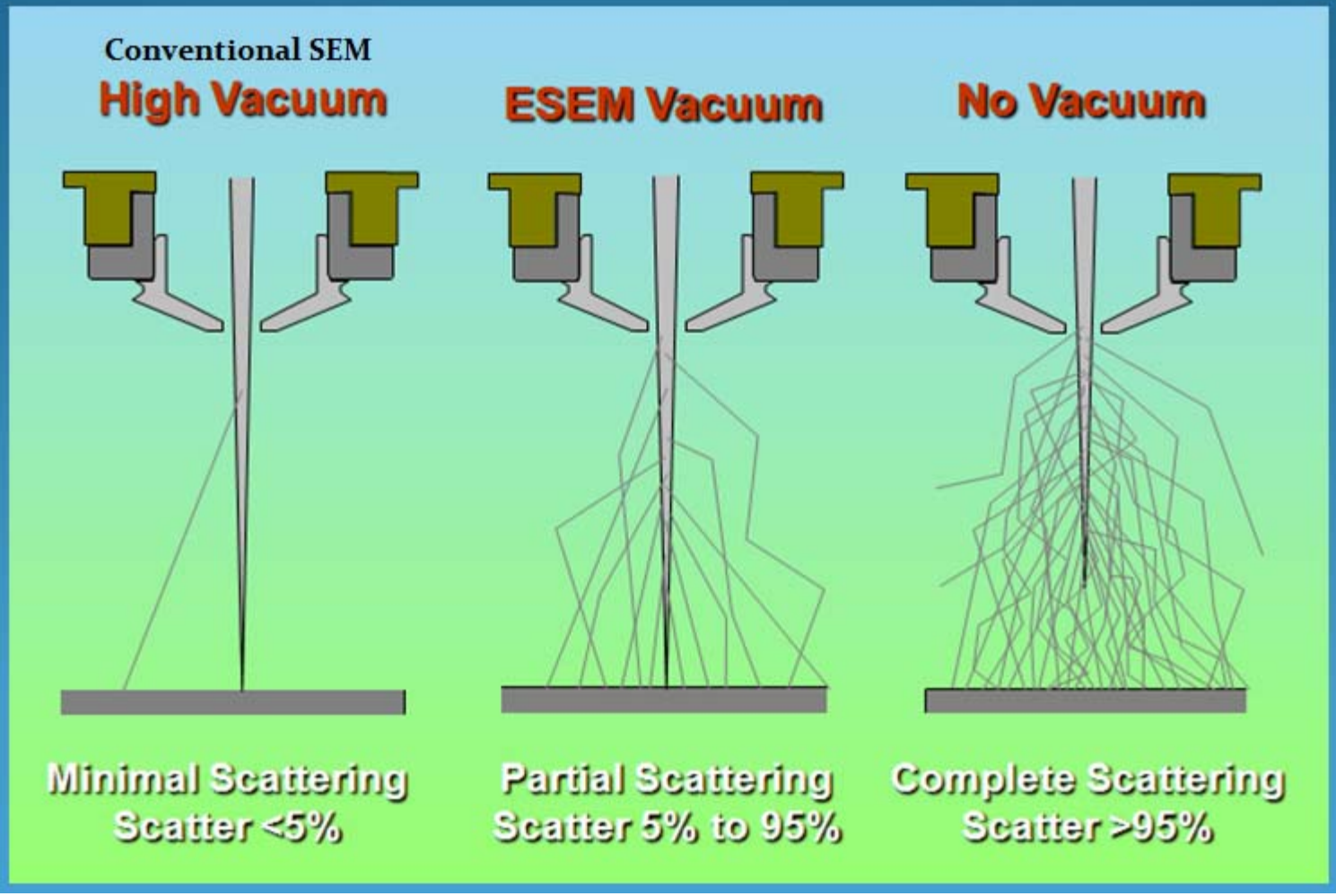




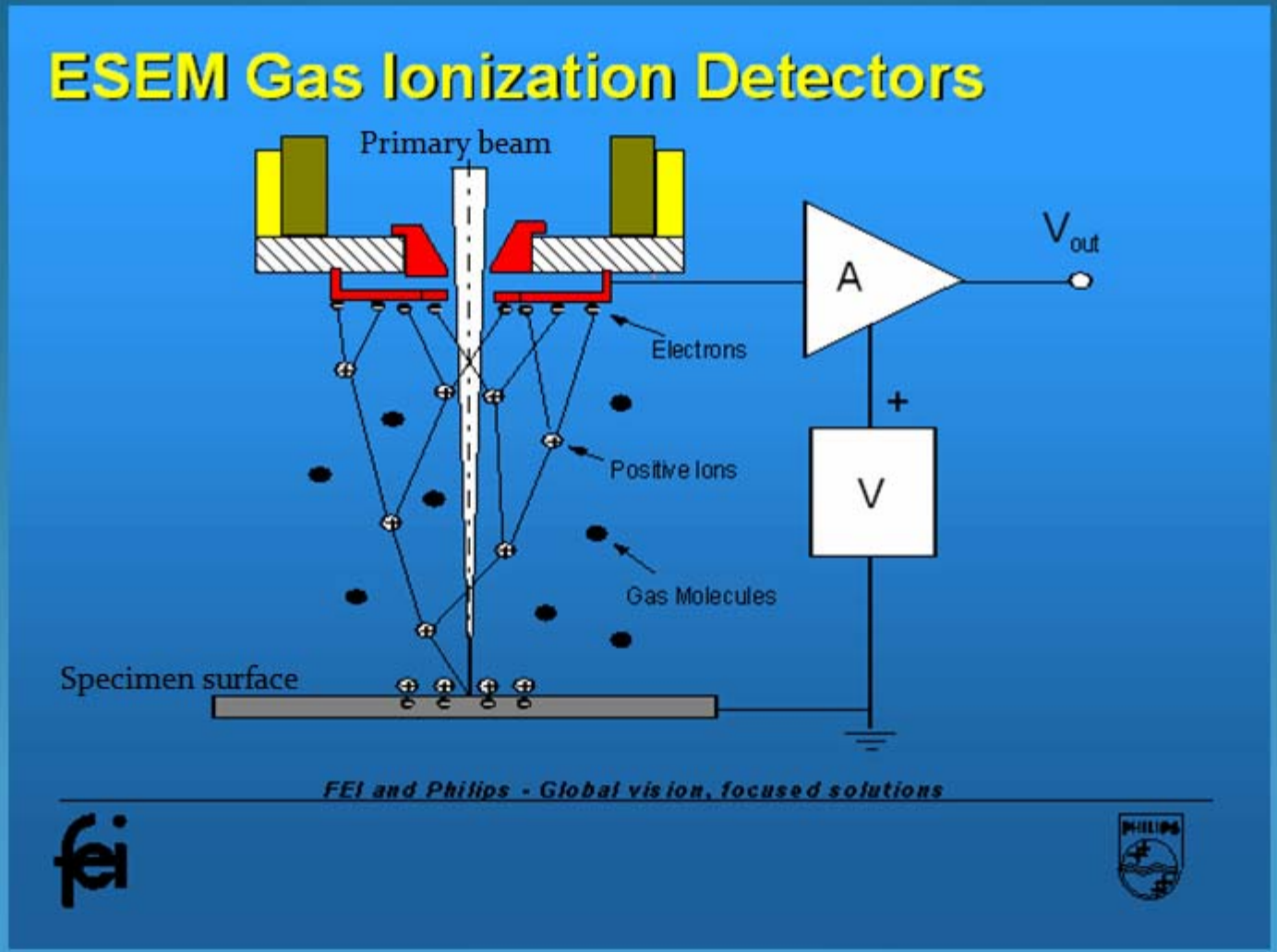




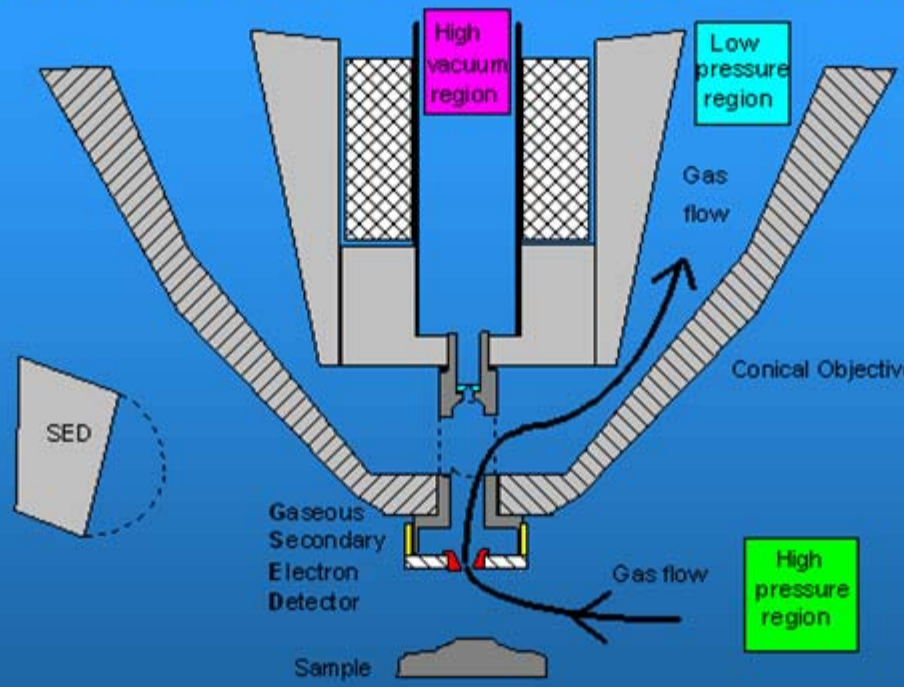
The Environmental SEM (ESEM)



How an ESEM works



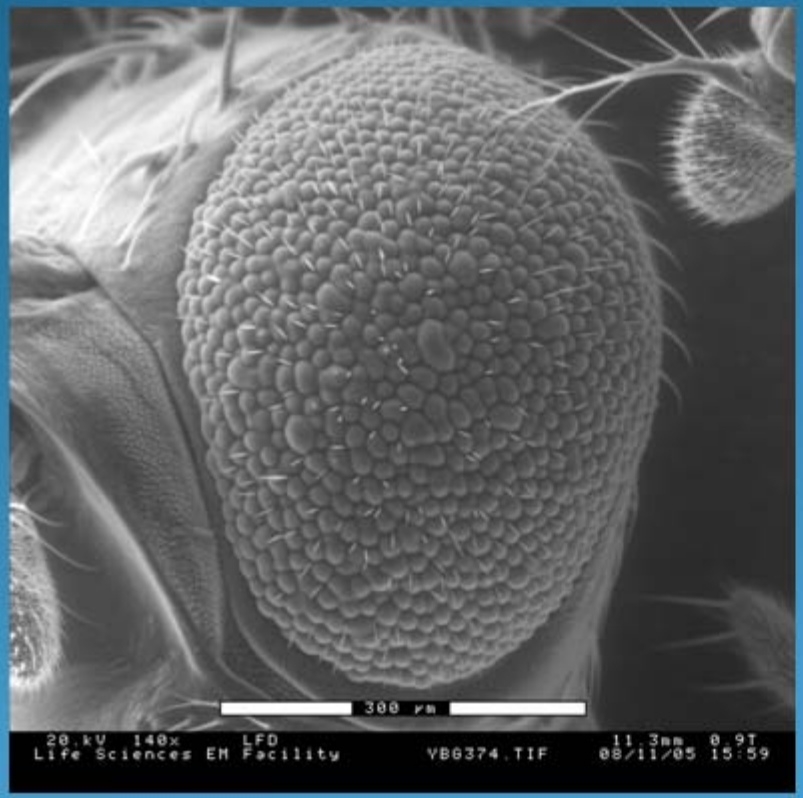
ESEM Dual PLA Pumping System

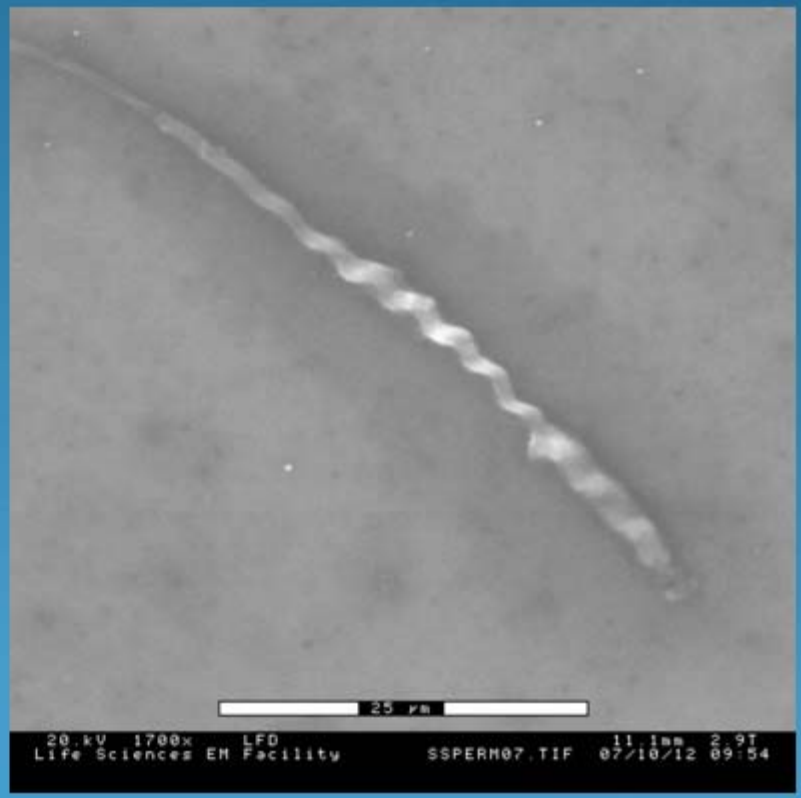


FEI and Philips - Global vision, focused solutions

ESEM Applications

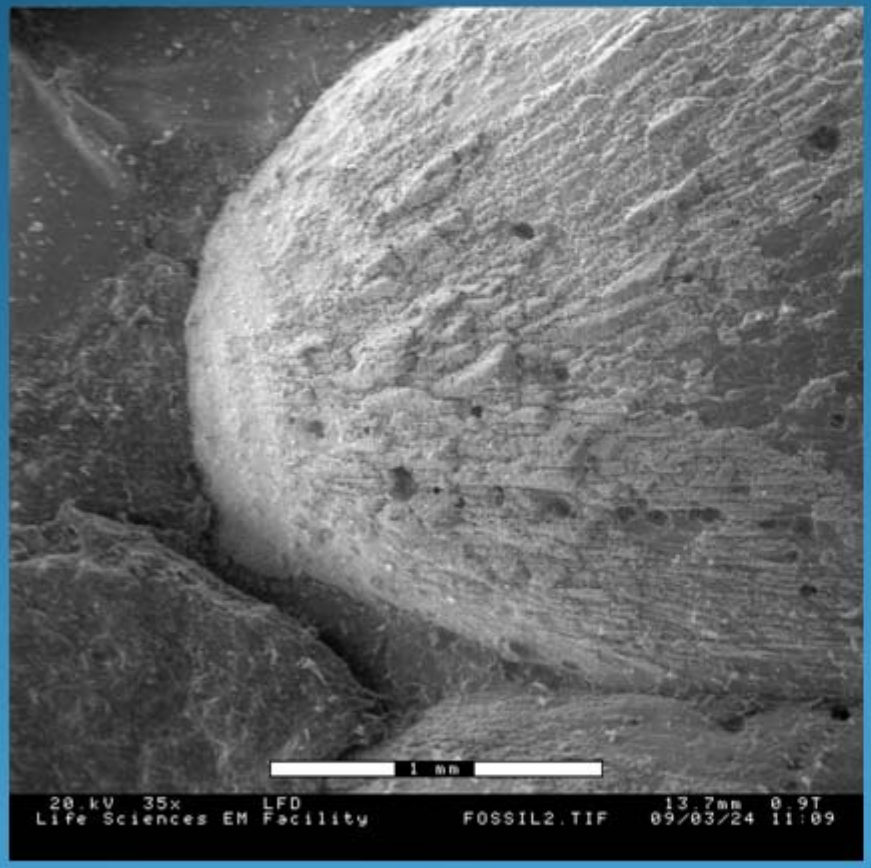
Uncoated and "unprepared samples"

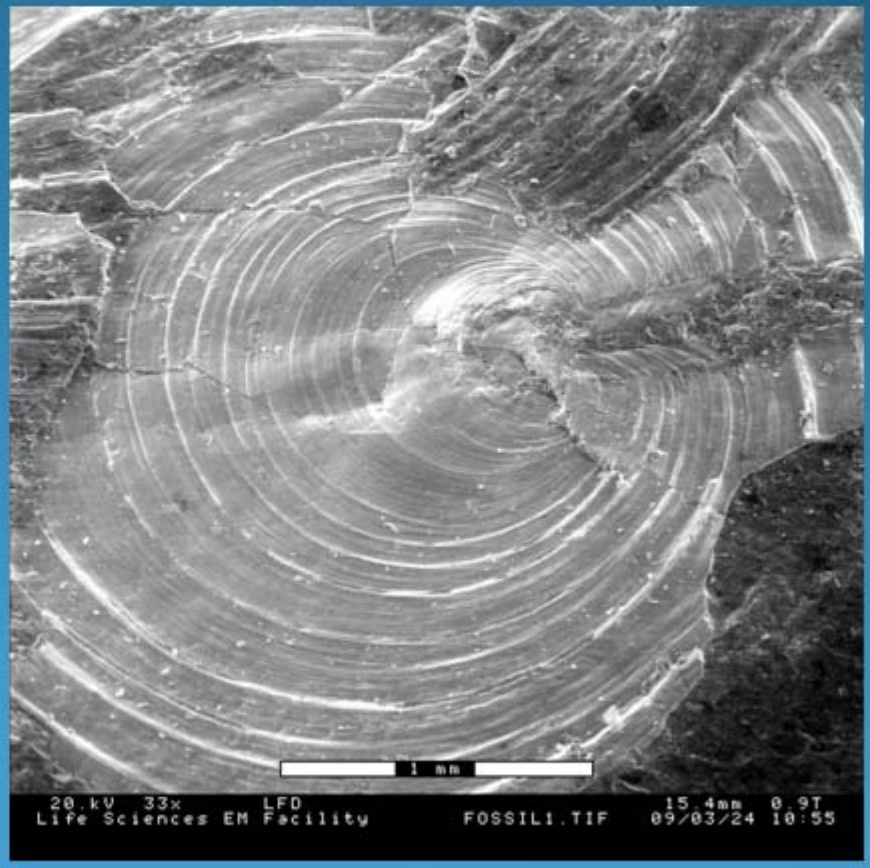




ESEM Applications

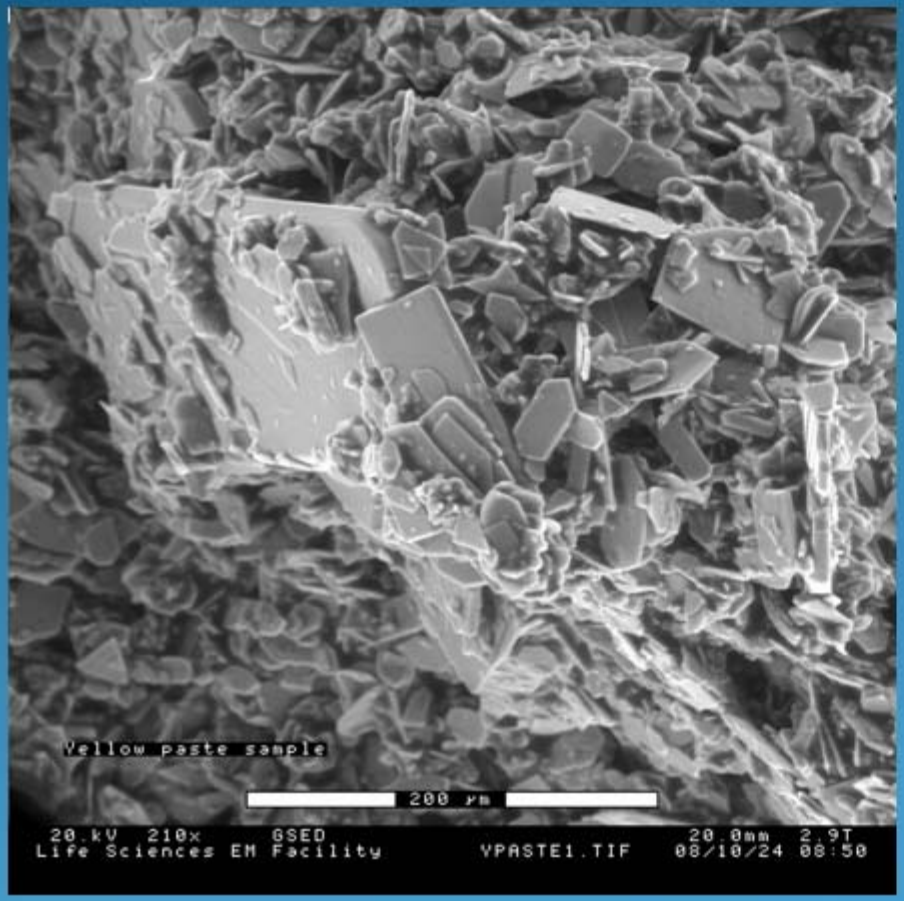
Delicate and sensitive samples

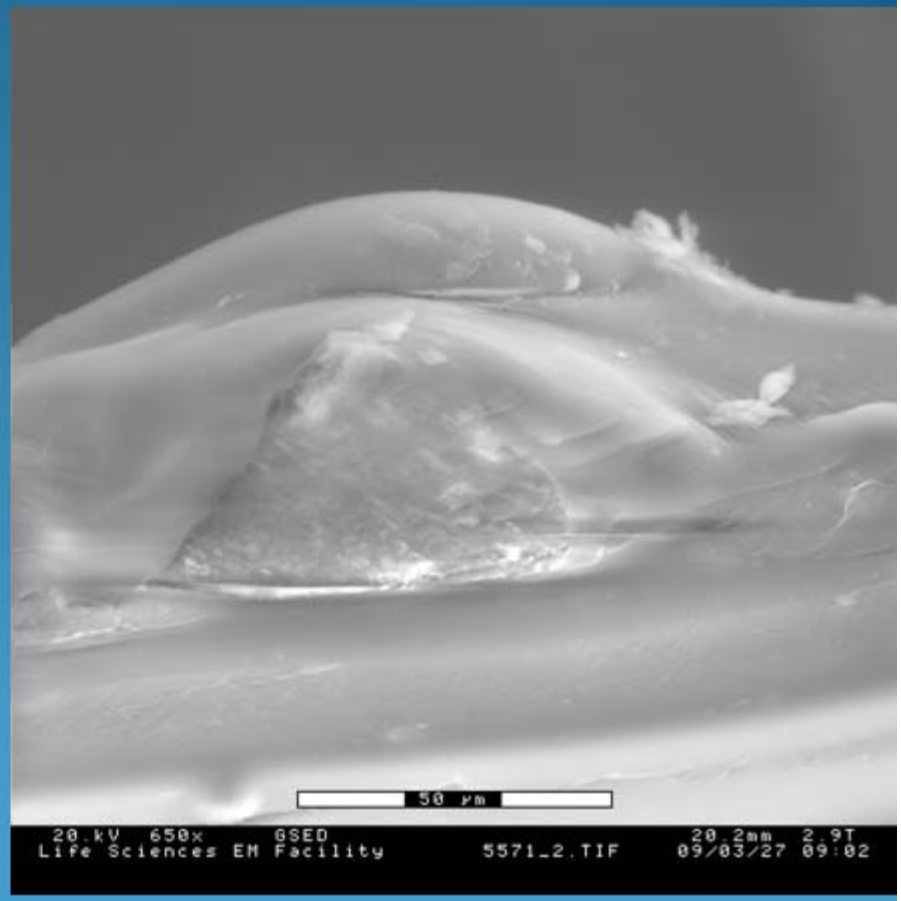




ESEM Applications

Difficult and sensitive samples





ESEM Applications

Dynamic experiments