HITACHI HIGH TECHNOLOGIES AMERICA, INC. (HTA)

STEM EDUCATIONAL OUTREACH PROGRAM

HTA Learning Lab with Model TM3000 TableTop Scanning Electron Microscope

The HTA STEM Educational Outreach Program offers an opportunity for students to experiment with the world of Nano Science in their classroom.

ANALYZE

Model TM3000 Table Top Scanning Electron Microscope is used for imaging and analysis of materials and biological specimens. HTA will bring the TM3000 to your educational institute (K-post grad) for demonstration or extended use.

PORTABLE

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SUPPORT

HTA-certified and trained personnel assist educators with setup, training, and sample analysis.

SCHEDULE

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RESPONSIBILITY

Educators will be responsible for the instrument while it is located at their facility.

Contact HTA if you wish to request a TM3000 Learning Lab.

Hitachi High Technologies America, Inc. | www.hitachi-hta.com
Contact: Robert J. Gordon | phone 925-218-2817 | email robert.gordon@hitachi-hta.com

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Educational Outreach Programs
&
Change The Equation Participation

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Hitachi & CTEq

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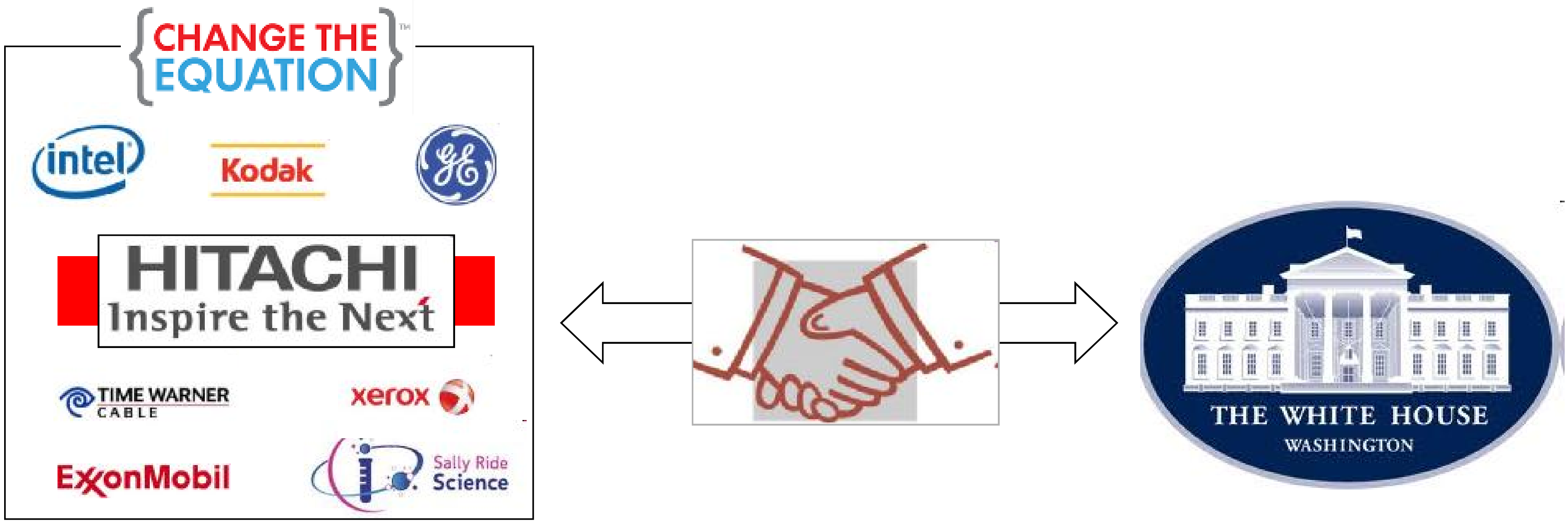

- July 2010 <u>The origin of the relationship between Hitachi and CTEq</u>
  During a meeting between Presidential aide John Holdren and Hitachi Ltd. Chairman Kawamura, STEM education in the U.S. and Japan was discussed, and both acknowledged the importance of STEM education.
- April 2011 Hitachi becomes a member of CTEq
  One of two Japanese companies to become a member (Sony Pictures)

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STEM Outreach Activities

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Hitachi is prominent in STEM Education Outreach Programs through out the U.S. Market.
Teacher and educator sharing of learning modules and teaching tools now exist across North and South America.

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Duke University Educational Outreach

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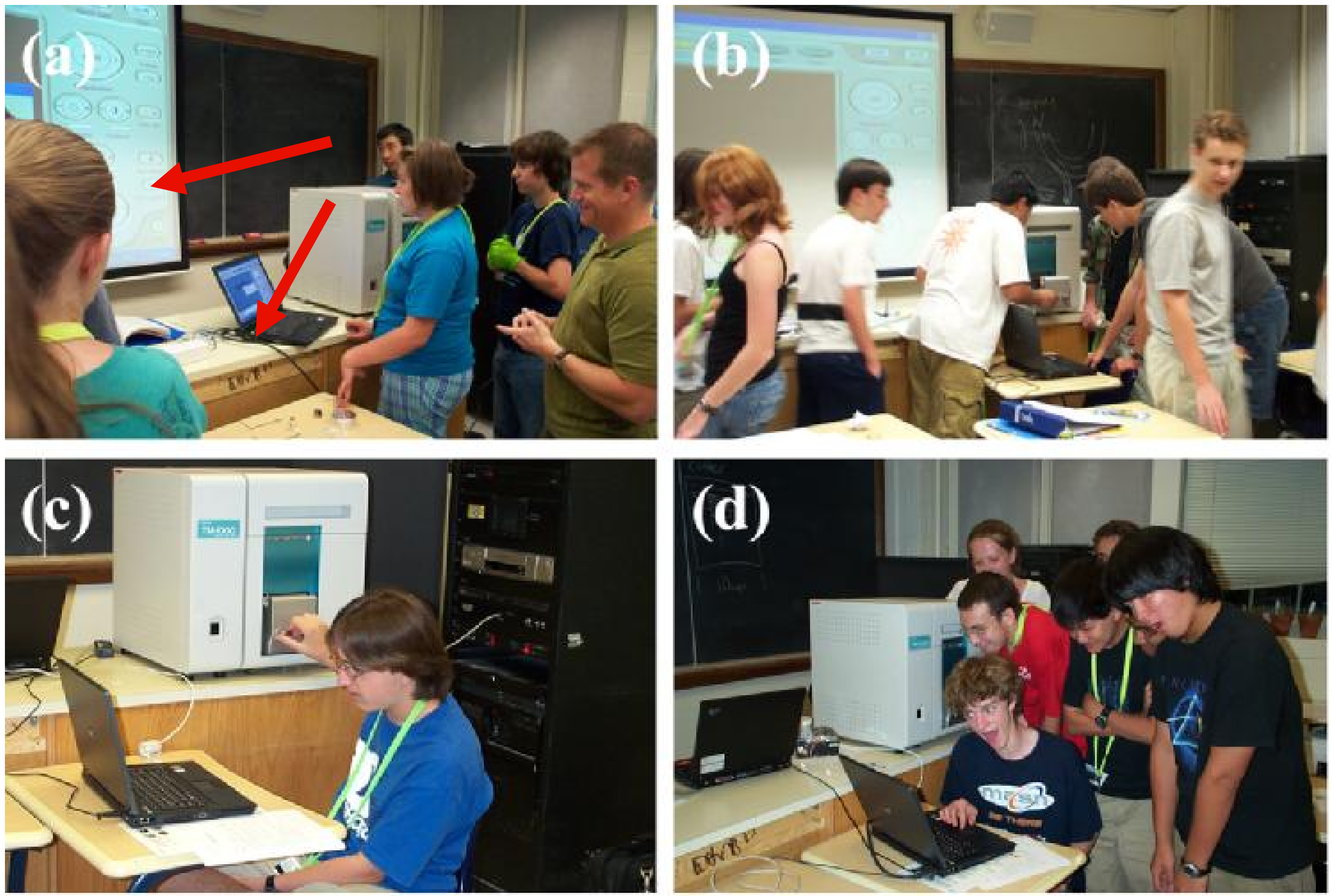
- LCD projector used to train entire class
- All students signed up for two 1/2hr SEM sessions
- Acquired 50x, 500x and 5000x of samples they chose



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National Nanotechnology Infrastructure Network (NNIN)

- Integrated partnership of 14 universities
- Serve the resource needs of Nanoscale Science and Engineering (NSE) researchers – state-of-the-art facilities
- Integrated education and outreach program (k-gray)

NNIN Education and Outreach

Funded by NSF Award ECS 0335765

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National Science Teachers Association – Indianapolis

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Materials Camp - University of Tennessee Knoxville

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Why Nano Education?

- The NSF estimates that by the year 2015 there will be a need for 2 million workers worldwide in the fields of nanoscience and nanotechnology.
  - An additional 5 million workers will be needed in support areas for these fields
    - 0.8-0.9 million – US
    - 0.5-0.6 million – Japan
    - 0.3-0.4 million - EU
- By 2015, nanotechnology is expected to be a $2.0 trillion "industry"

NNIN
Nanoscale Science, Engineering & Technology

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What is Nanoscale Science?

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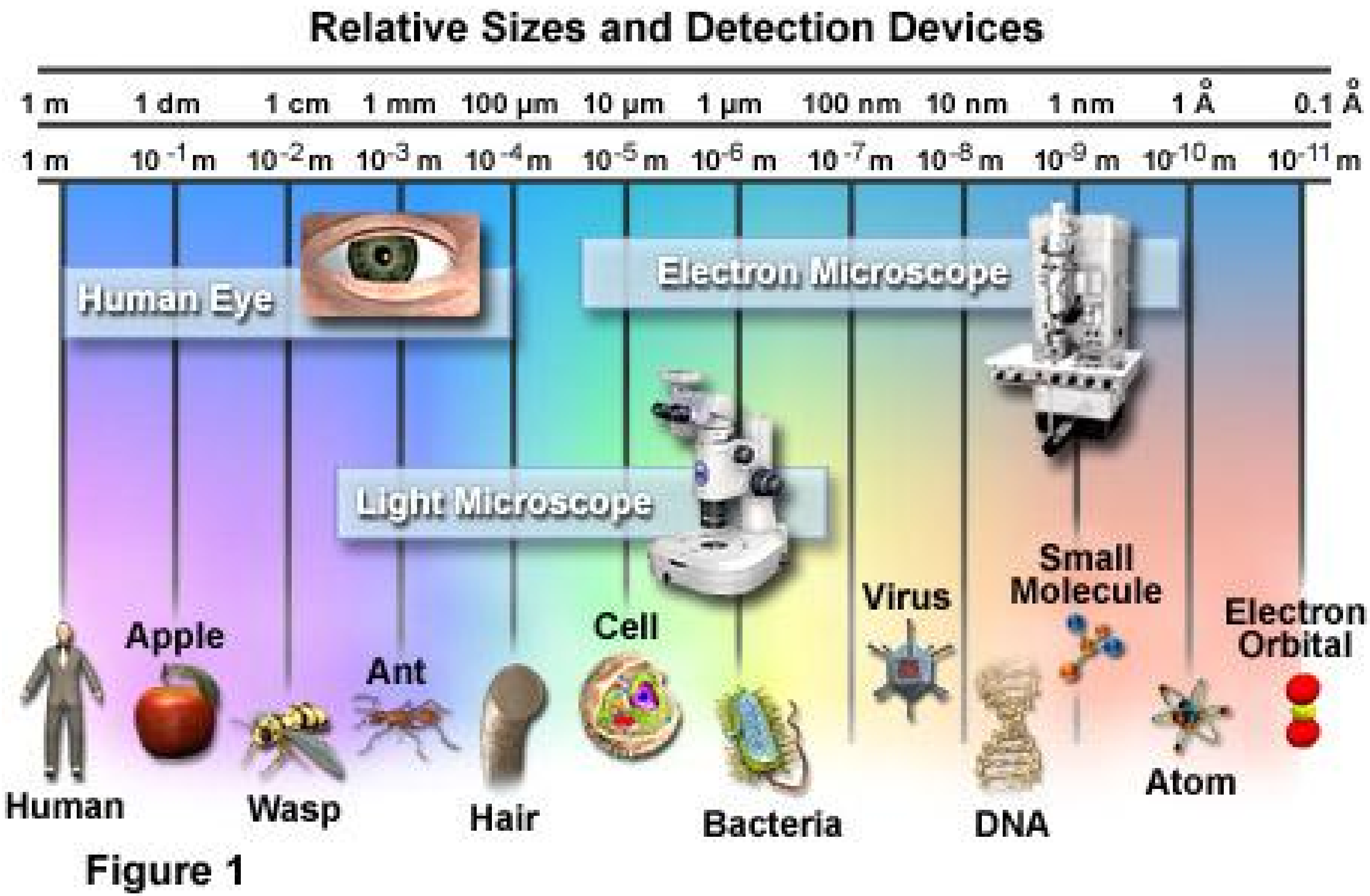

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Industries That Use SEMs

- Medicine
- Food Industry
- Materials Research
- Biology
- Geology
- Semiconductor Research
- Archaeology
- Aerospace Research
- Automotive Research
- Cosmetics
- Industrial
- Forensics
- Entomology
- Oceanography

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Optical versus Electron Microscopy

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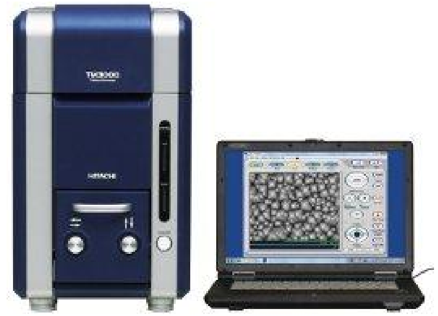

Feature	Optical	Desktop SEM	Full-Size SEM
Footprint	Small	Small	Large
Ease of Use	Easy	Easy	Trained Operator
Depth of Focus	Shallow	Deep	Deep
Magnification	Low: 1,000x	High: 30,000x	Very High: 300,000X
Resolution	Low	High: 20 nm	Very High: 2-3 nm
Chemistry	Not Possible	Good Spectroscopy	Better Spectroscopy
Maintenance	Simple	Simple	Stringent
Cost	$250 to $100,000	$75,000 to $125,000	$200,000 to $1M+

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Hitachi HTA STEM Outreach

Desktop models available for loan to schools, universities, community colleges, tech institutes, science camps, etc.

HTA trains teachers on how to handle the machine, input samples and adjust magnification, output results.

Hitachi TM-3000
A Portable Scanning Electron Microscope

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HTA STEM Outreach Flyer

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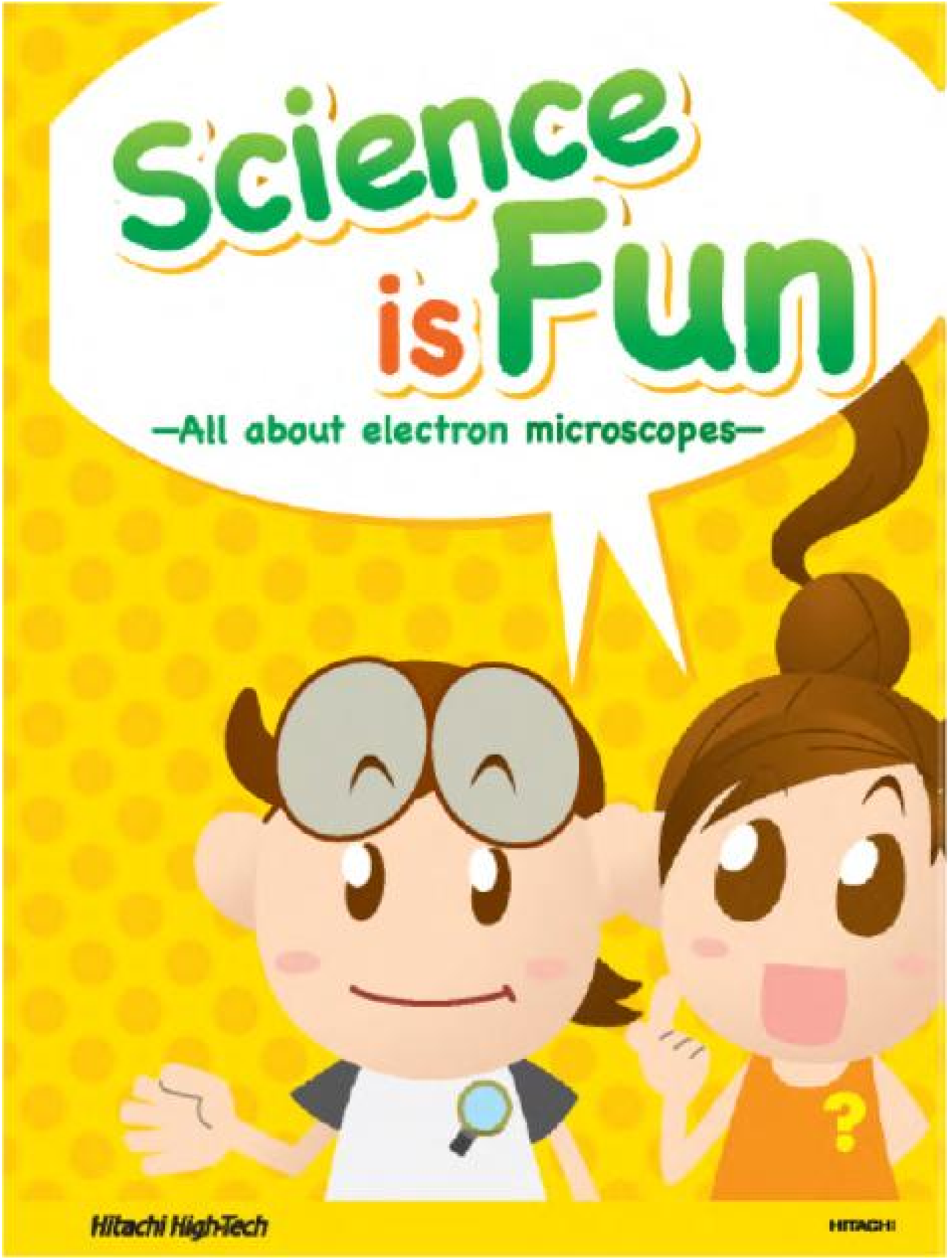
STEM Microscopy Handout



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Hitachi HTA STEM Outreach

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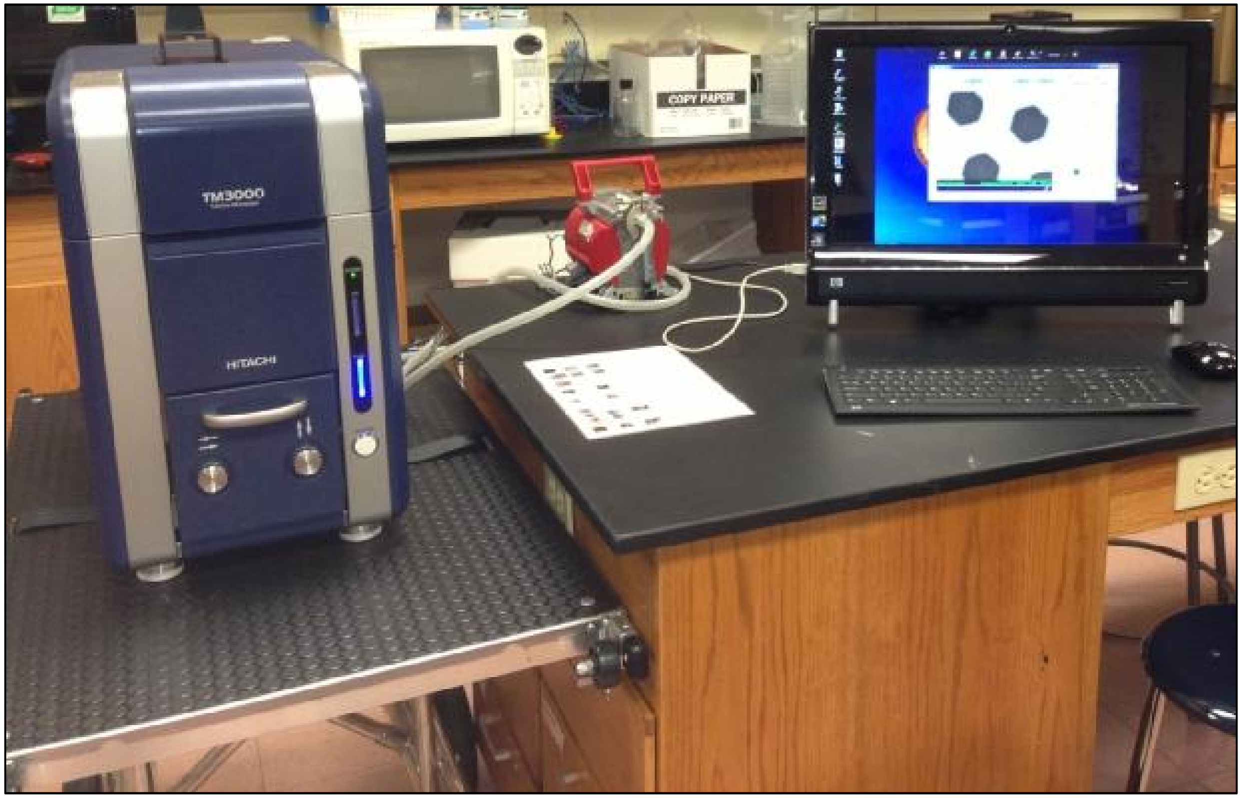
Hitachi HTA STEM Outreach



Mobility is Important:

- Take Technology to the students
- Support for remote educators in STEM fields
- Encourages “Hands On” learning

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TM3000 Loading Process

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TM3000 is Transportable

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NanoTruck for Brazilian Education Outreach

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TM3000 Training Inside NanoTruck

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Inside Senai Brazil Nano Truck

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7 Steps of Science Inquiry

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1) Choose a topic
general subject of inquiry

2) Develop a question
"If I make a change in X, what will happen to Y?"

3) Plan an investigation
think carefully about the sort of equipment and materials needed to investigate the research question

4) Predict an outcome
this is not a hypotheses

5) Experiment and observe
WRITE THINGS DOWN in lab notebook

6) Interpret results
tabulating, averaging, graphing

7) Communicate findings
poster, oral presentation

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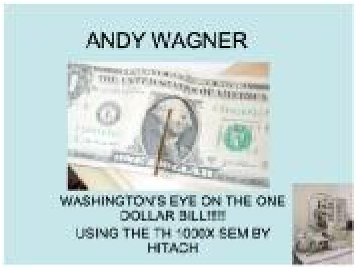
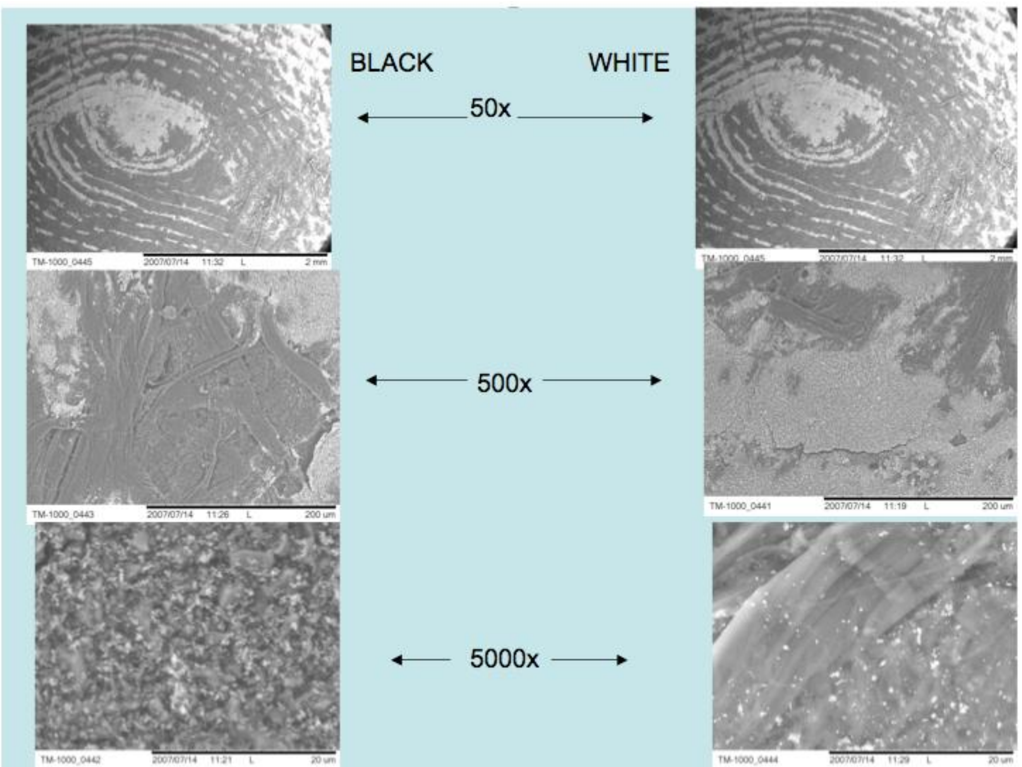
Eye of George Washington





Observations

- The bill is actually made from irregular fibers, which are probably organic in nature.
- The lines of ink used to draw the eagle's head on the back are between 100 and 150 µm wide.
- The ink seems to be made of small crystals only about 1 µm wide. The crystals stick to form stiff structures which can crack, in much the same way paint cracks.

Conclusions

- Because the panning was done mechanically and not by computer, the sample moved the same distance no matter what the magnification. This made it extremely sensitive at 5000x but very slow to search for things at 25x.
- The scale bar made it much easier to determine distances. In an optical microscope, it is usually hard to make accurate measurements.

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Student SEM Powerpoint

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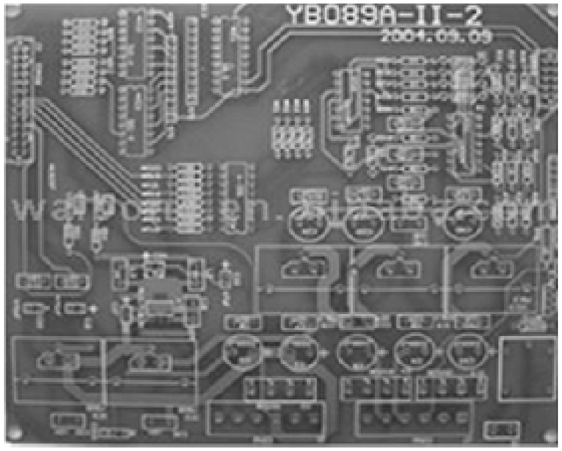
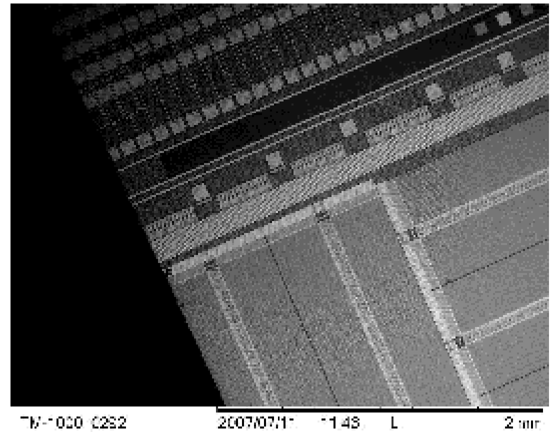
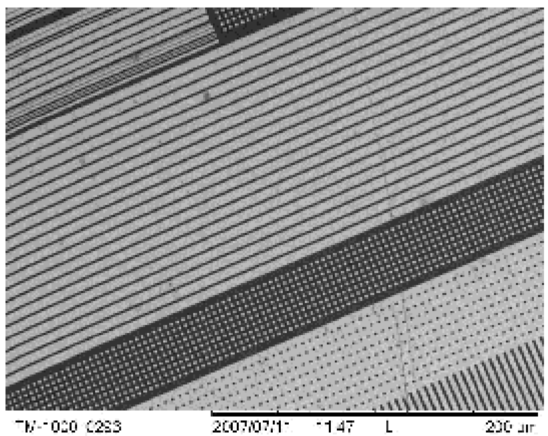


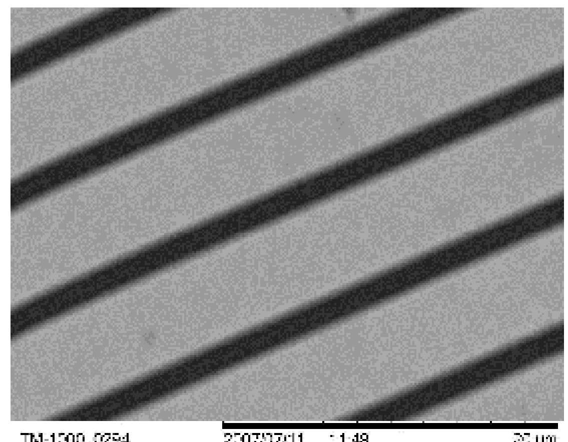
Actual Size



50x magnification



500x magnification



5000x magnification

My sample was a circuit. There were several interesting objects within the circuit. One interesting detail was the group of lines that at first appear as a solid block. As seen in the 50x image, the solid block of lines is about 300 microns thick. However, when you magnify it further, you can see that the block of lines is not solid. There are 6 micron wide lines with 1 micron spacing in between them. I learned a lot by operating the SEM. It was a great experience and I hope to use it again.

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Student SEM Powerpoint

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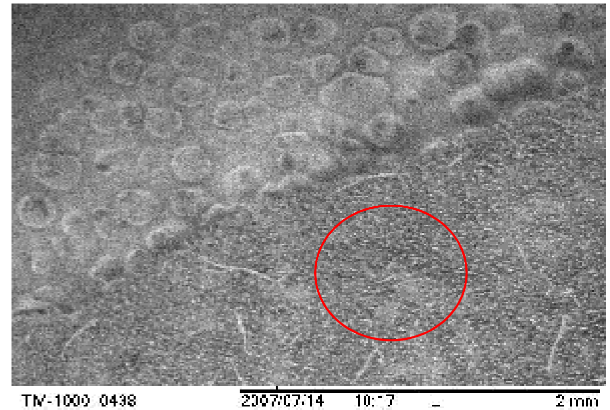
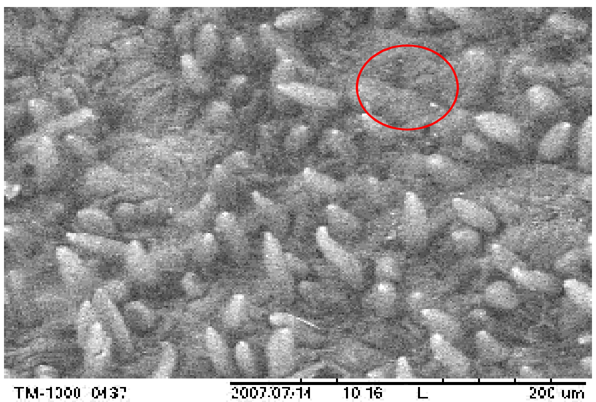
ß Peach

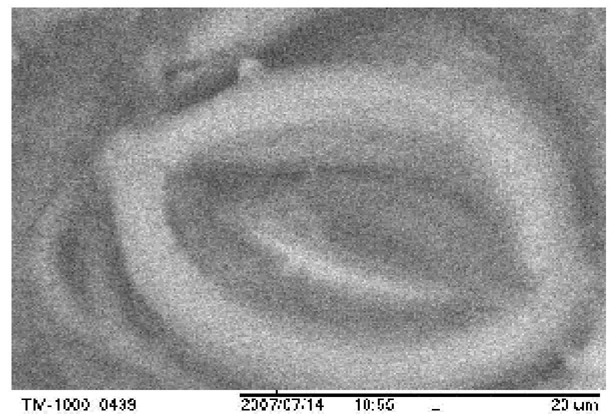
50x à





ß 500x

5000x à



I put a small sliver of peach skin under the microscope to see what the “fuzz” was and to look at the skin’s features.

Taking a closer look at a peach skin, we can see that the “fuzz” is really tiny hair-like strands that are about 40 µm tall and roughly 5-10 µm in diameter.

I learned that there is more on a surface then what we first think and only by using advanced technology can we even begin to explore this world.

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TM3000 Imaging

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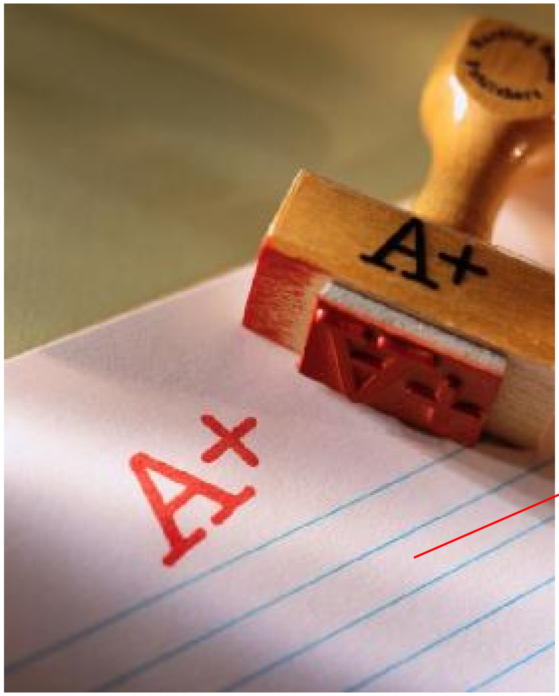
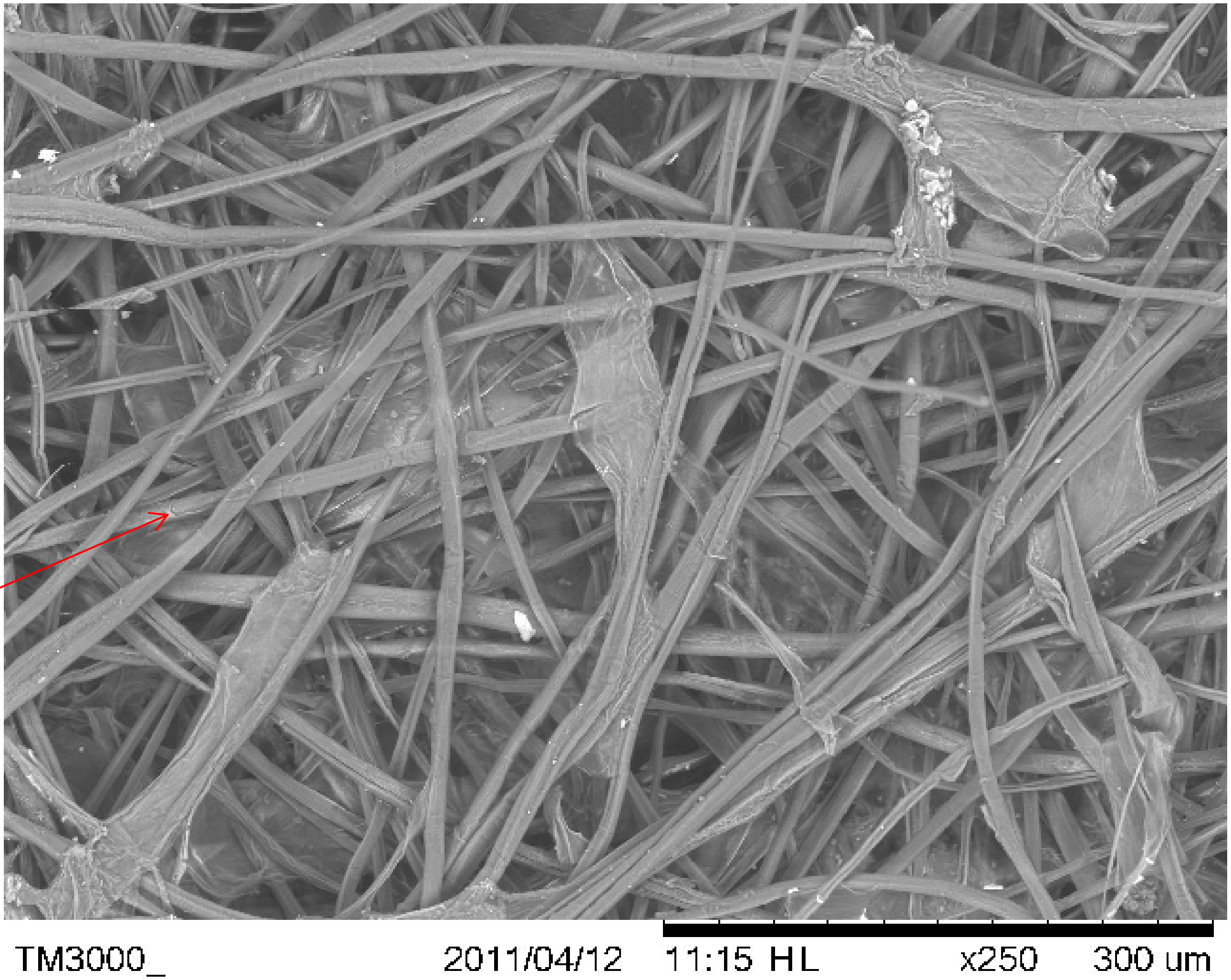
Paper





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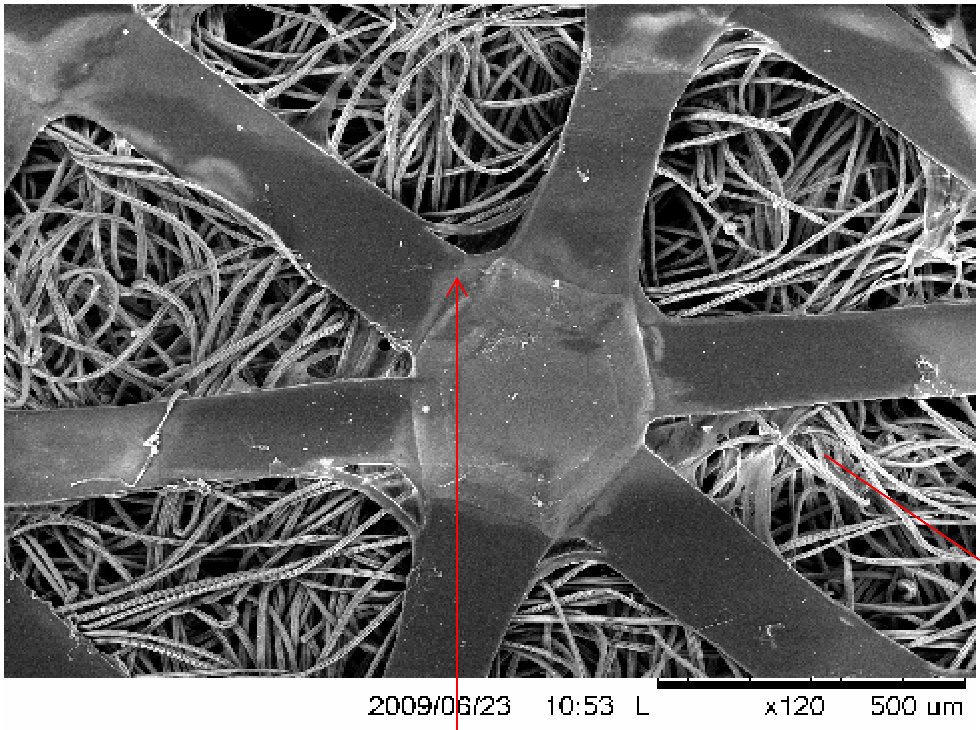
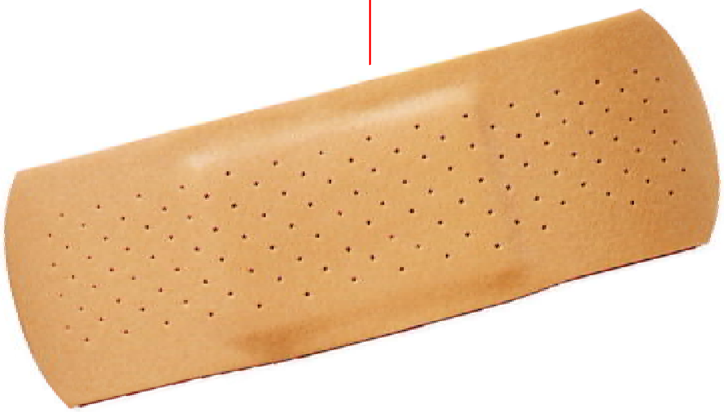
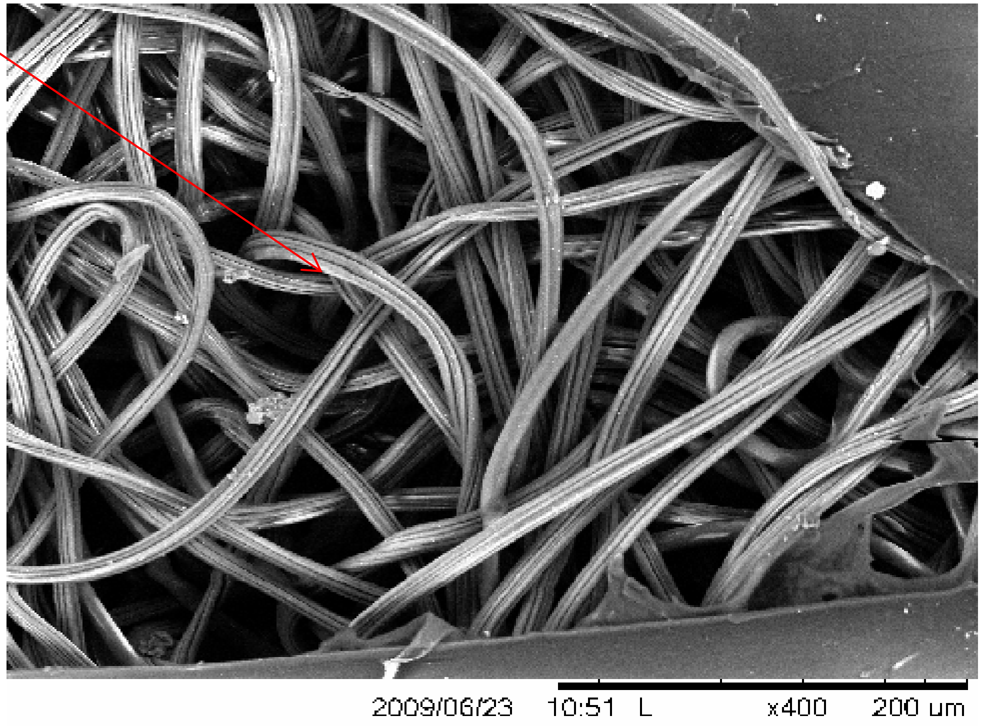




Band-Aid



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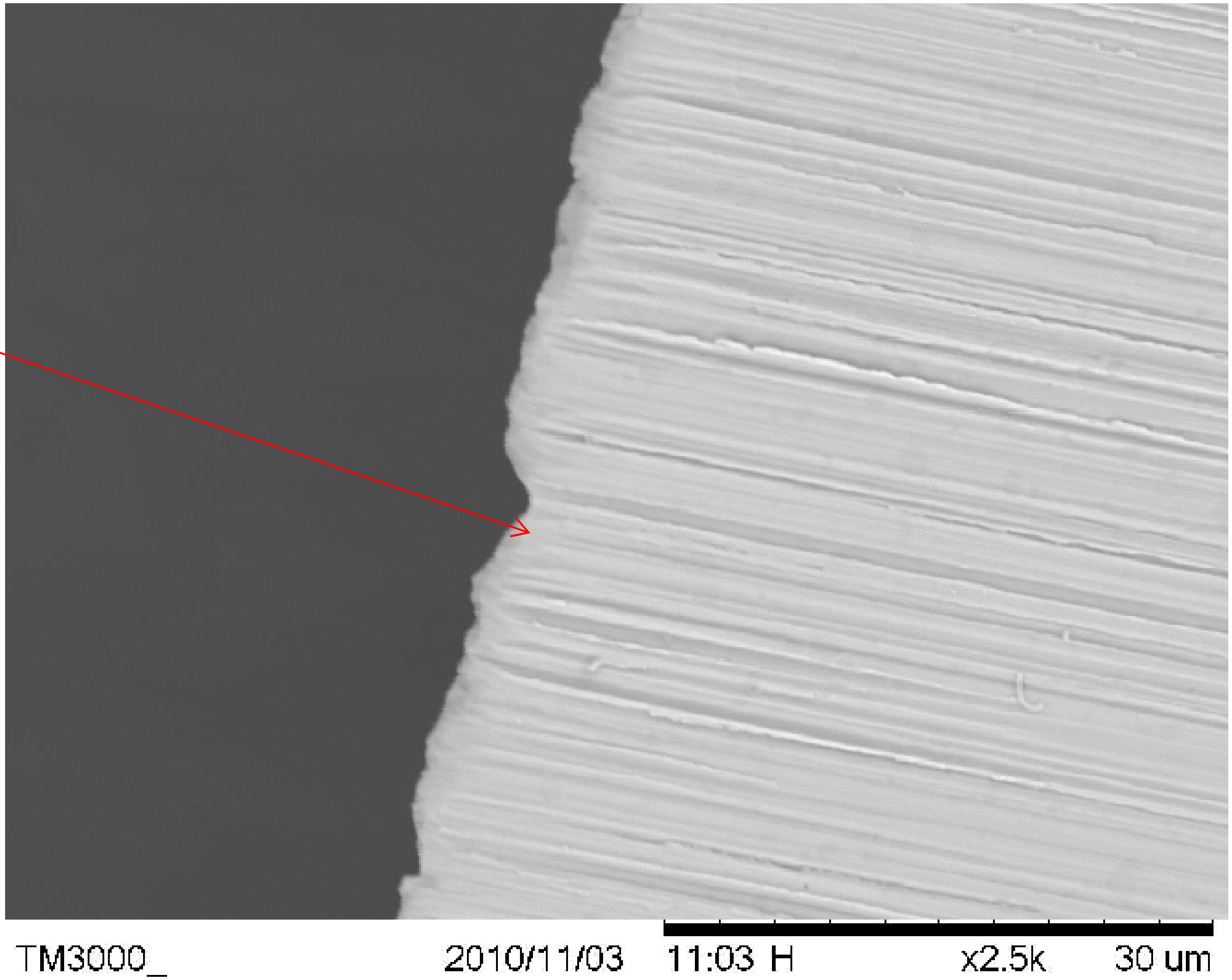
TM3000 Imaging

Razor Edge



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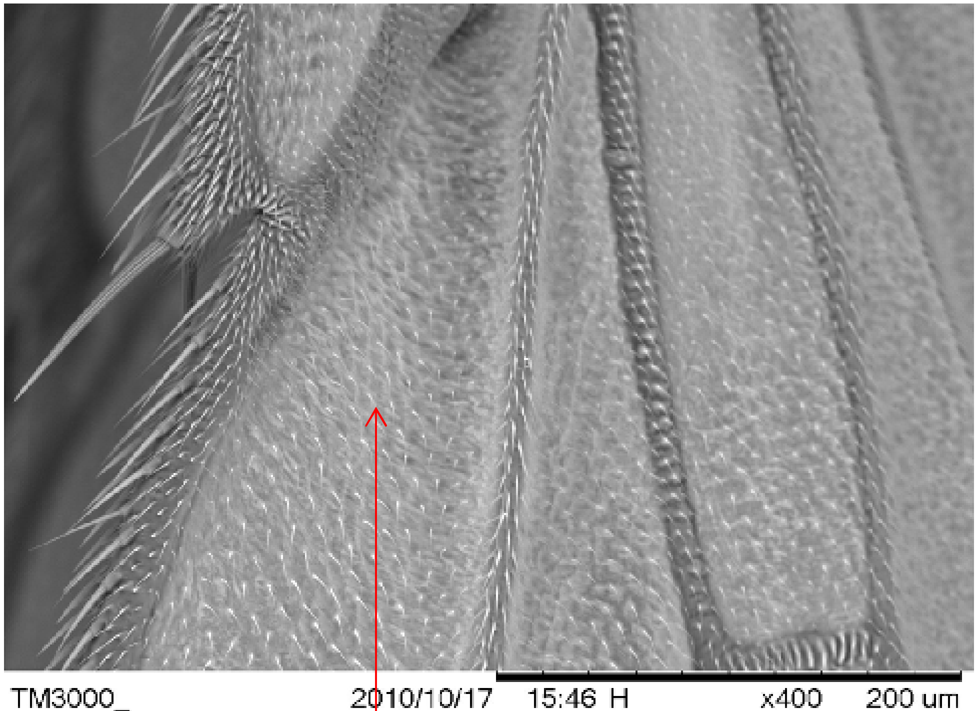
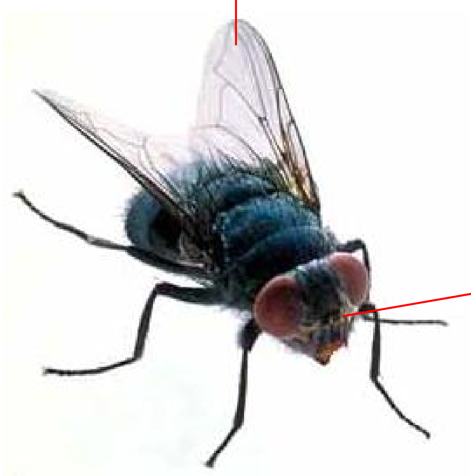
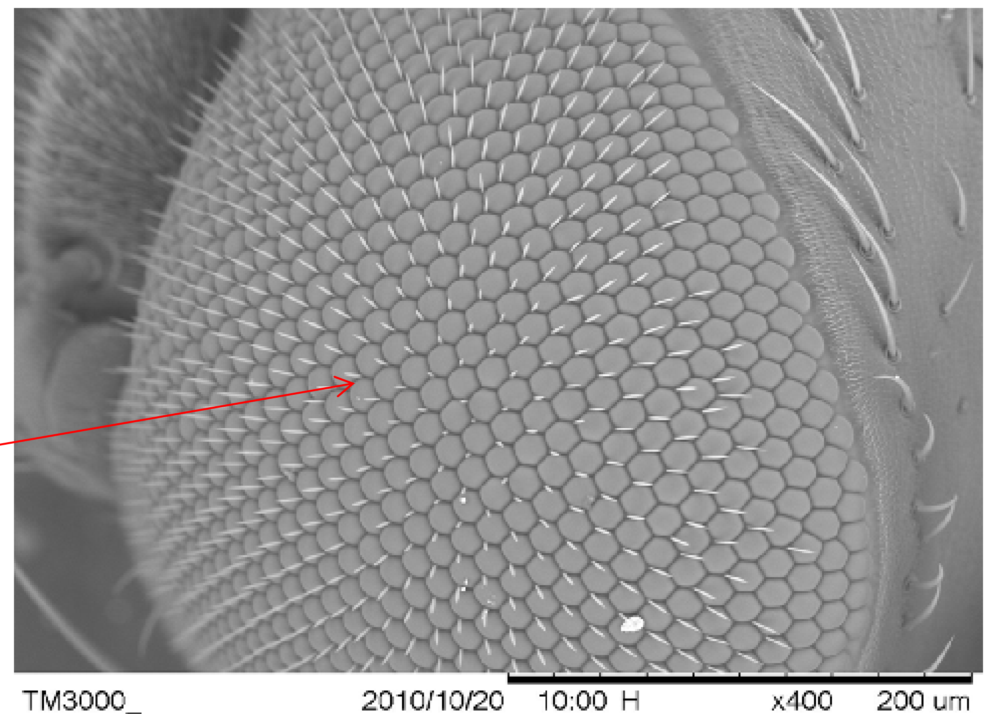
TM3000 Imaging

Fly Wing and Eye

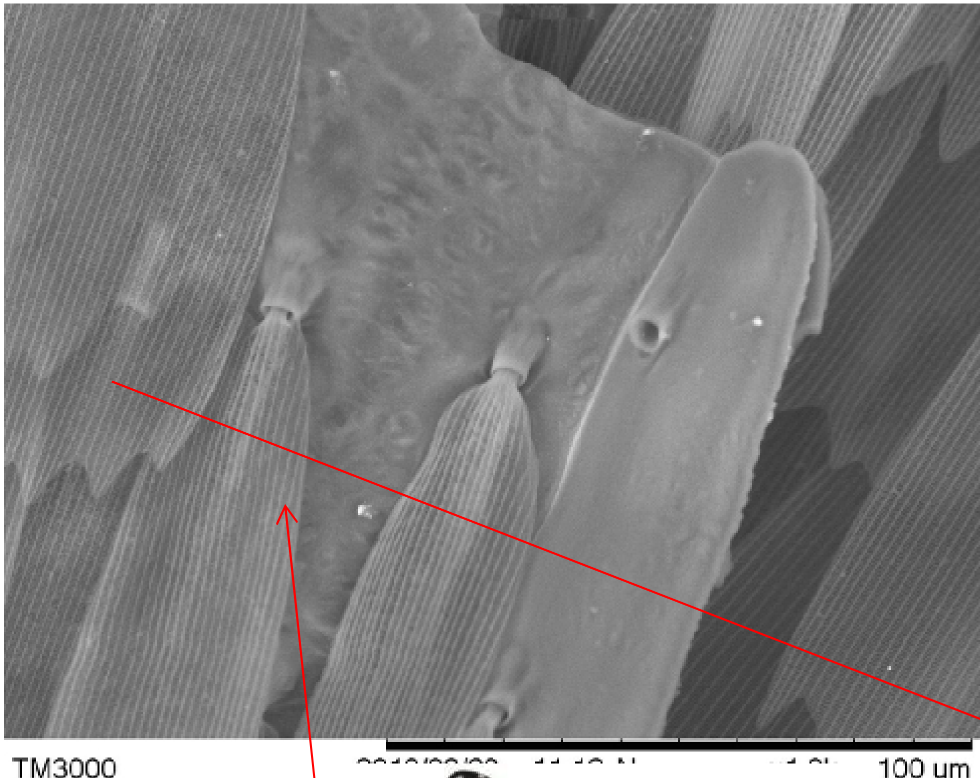


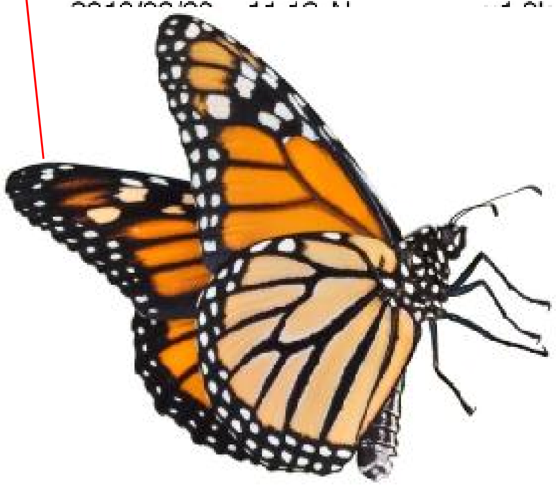


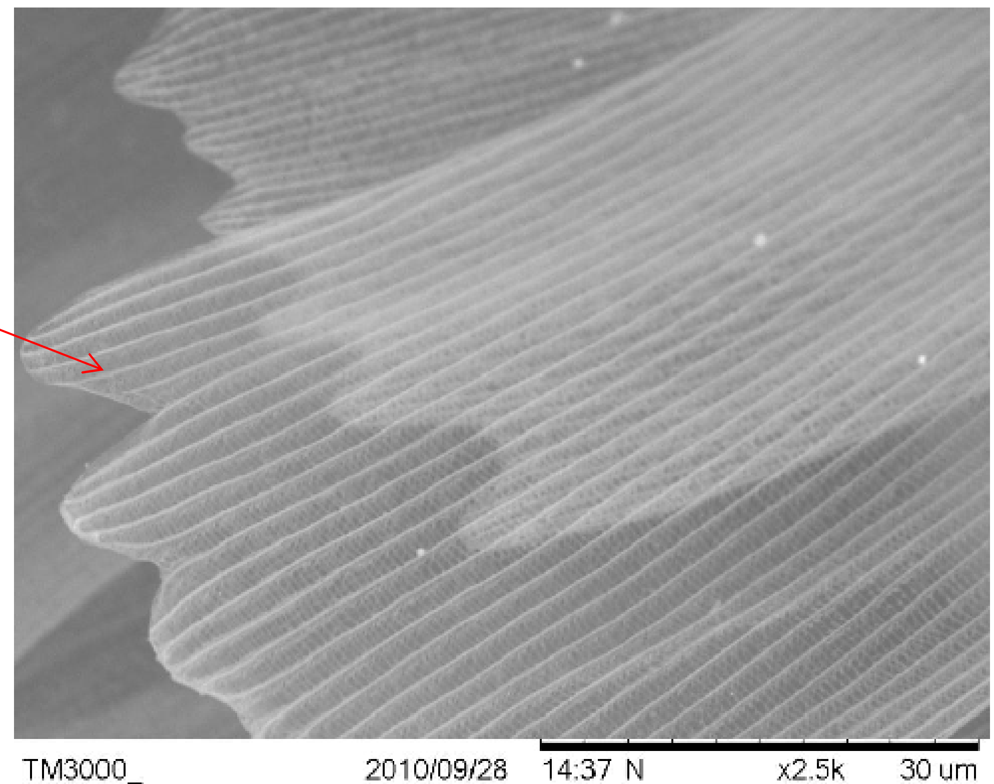


TM3000 Imaging

Butterfly Wing







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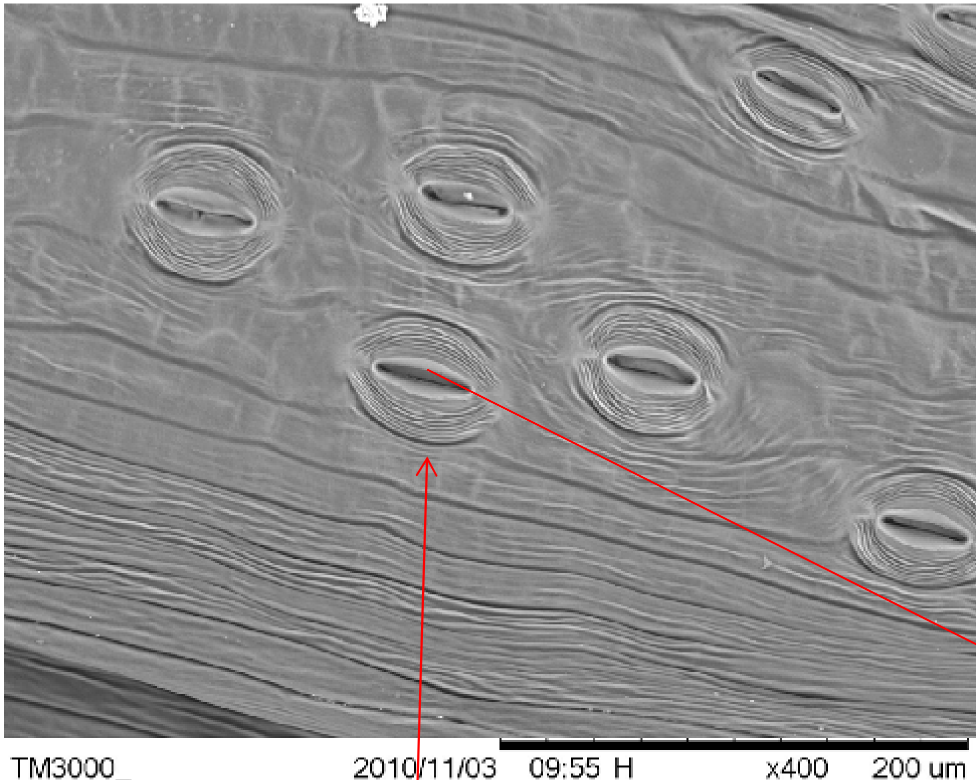
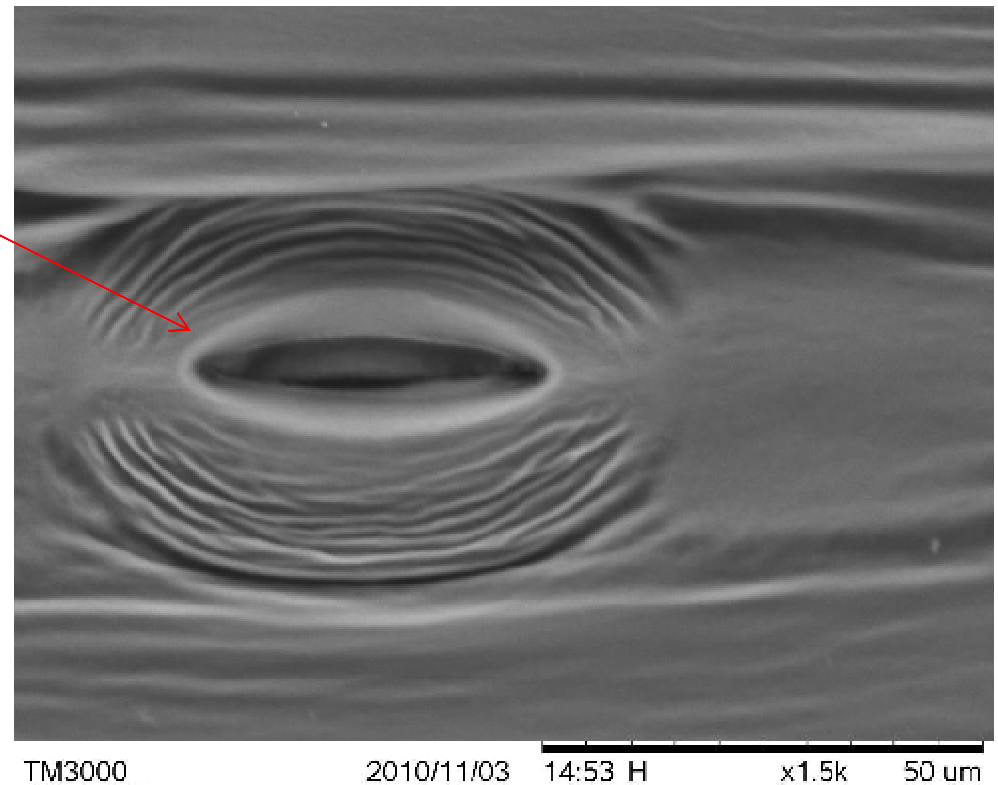


Stoma (Stomata)

These tiny structures allow plants to take in and release gases which achieves photosynthesis.



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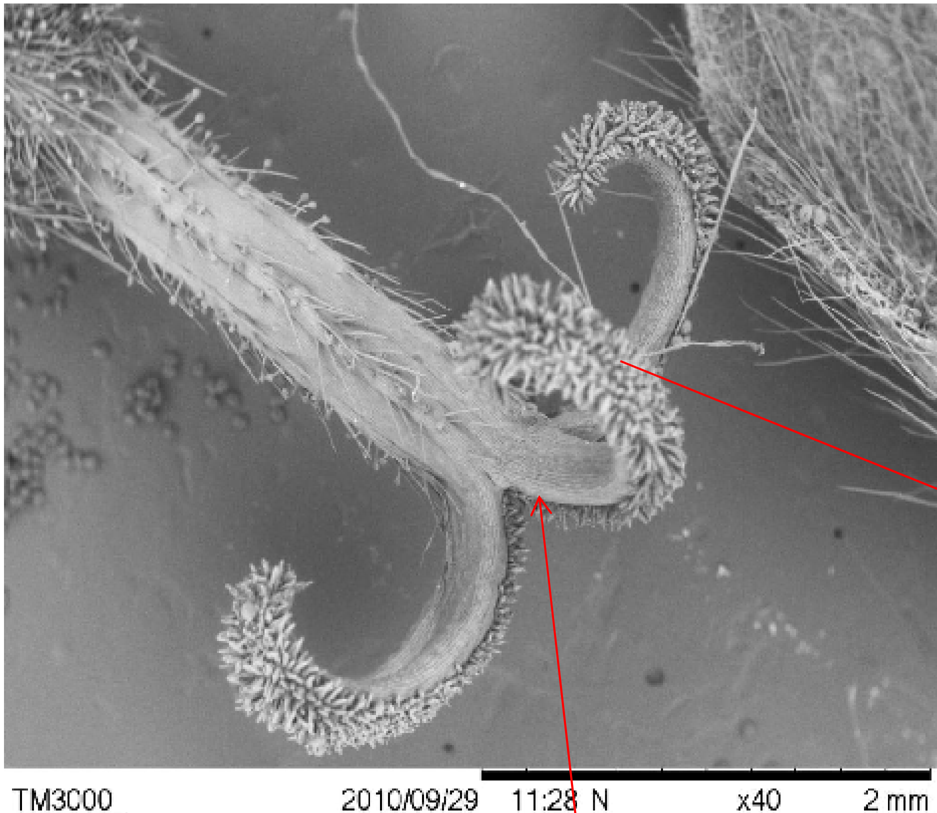
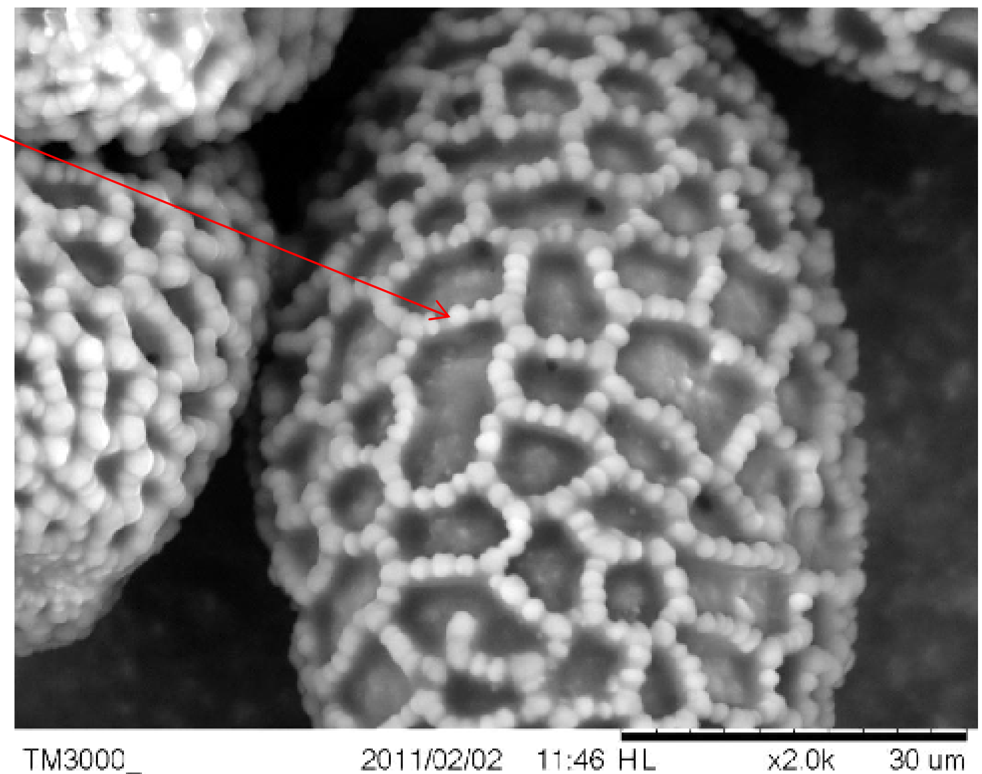


Flower Stamen and Pollen



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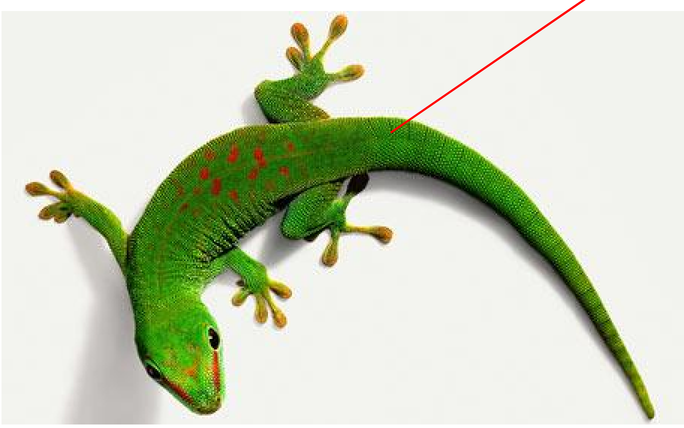
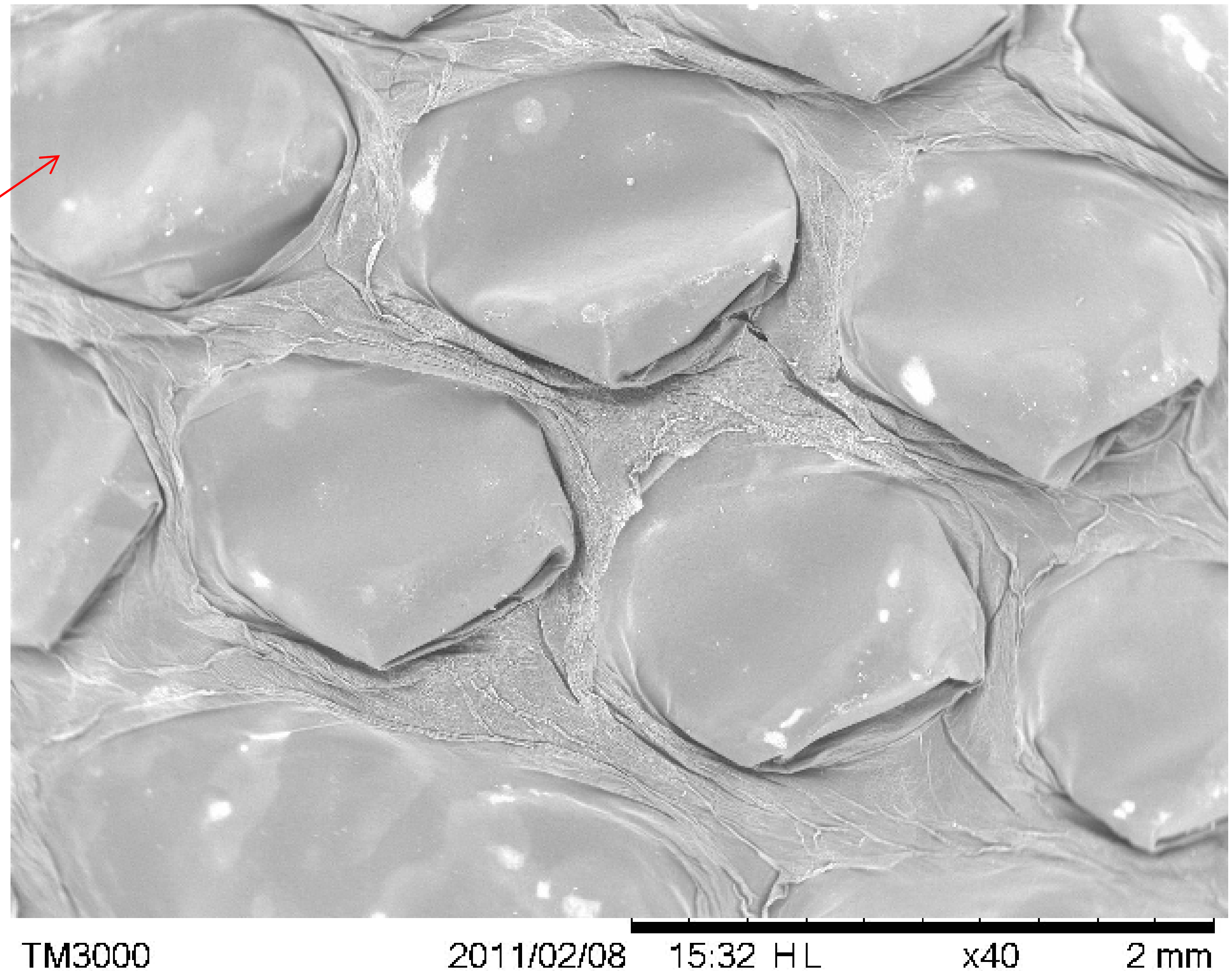
Gecko Skin





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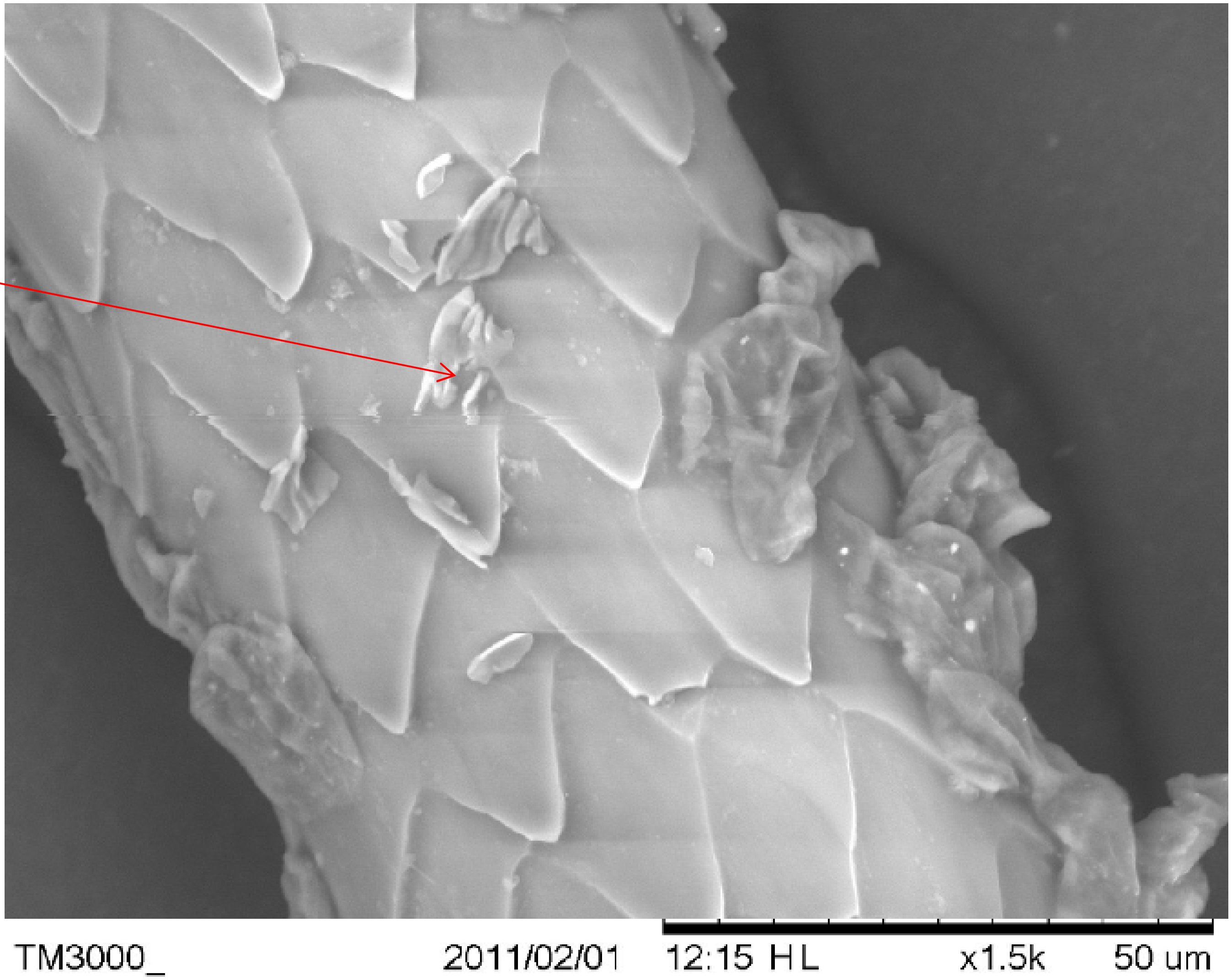
Cat Hair and Dander

Are you allergic to cats? This is the dander that makes you sneeze!



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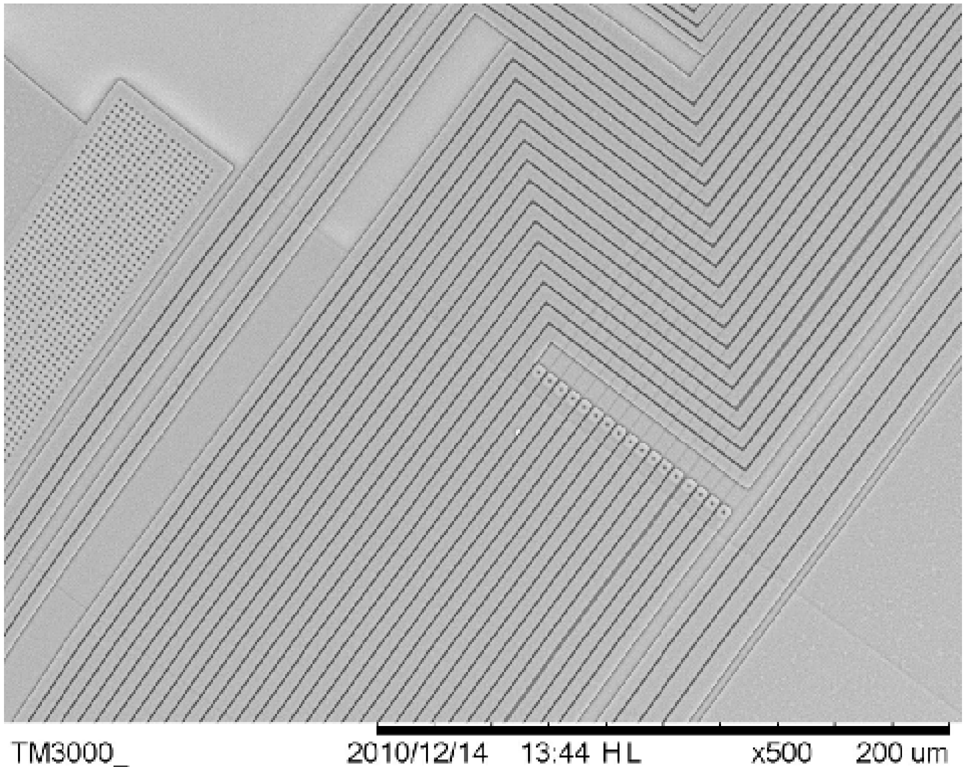
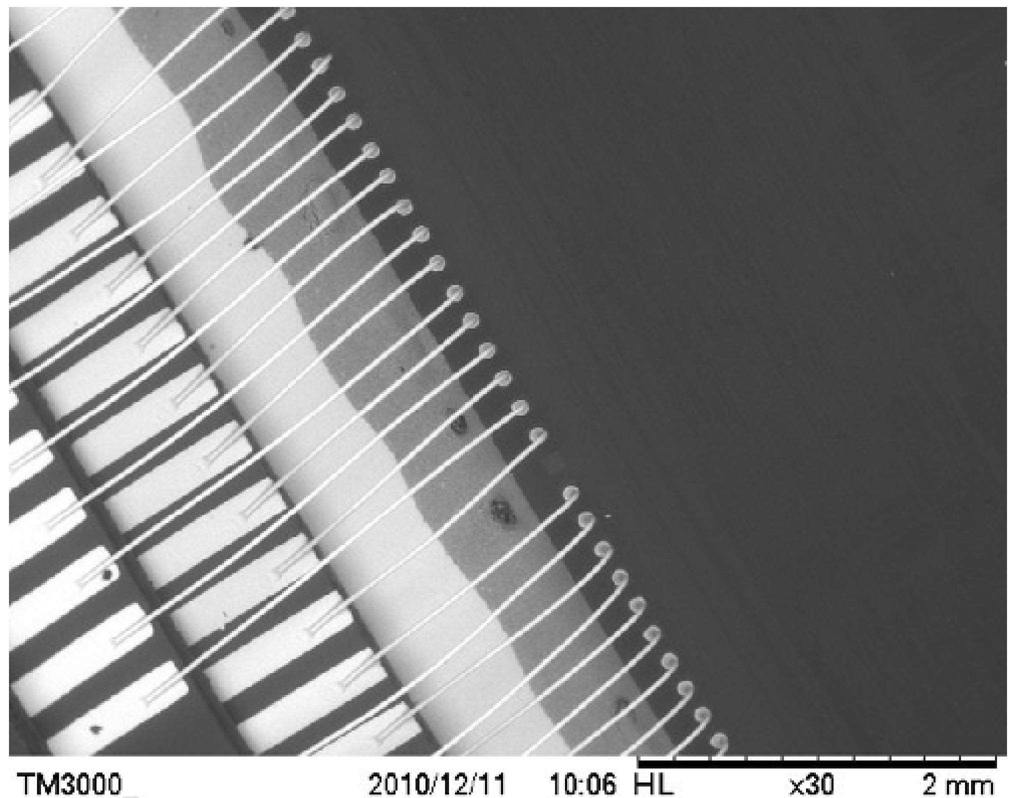


Inside of a Smart Phone



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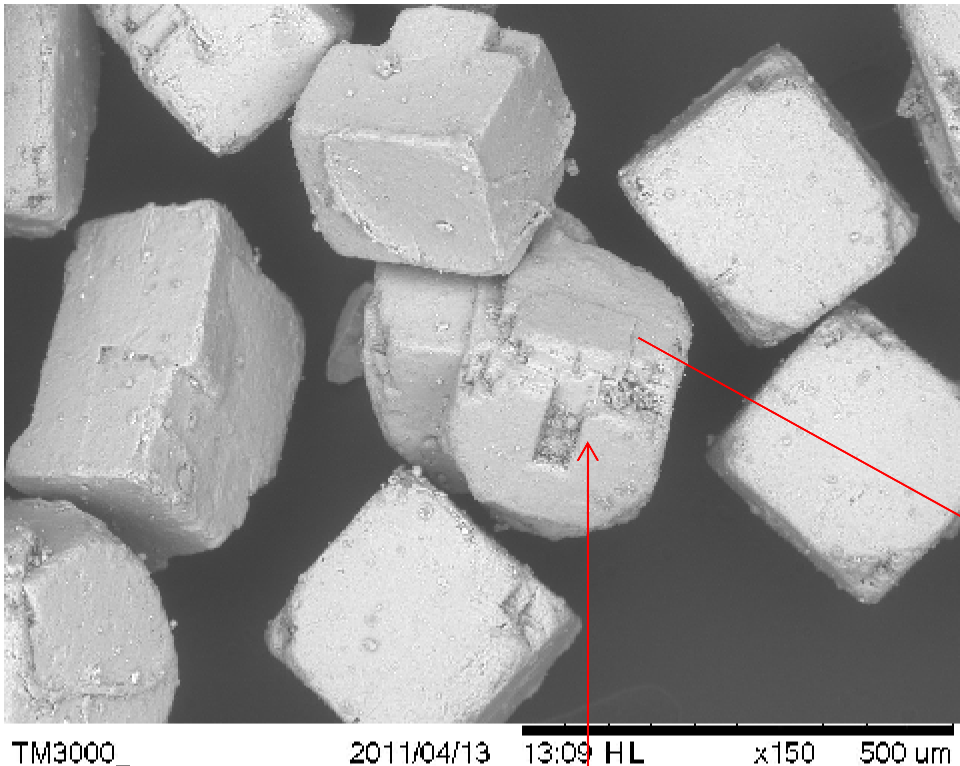
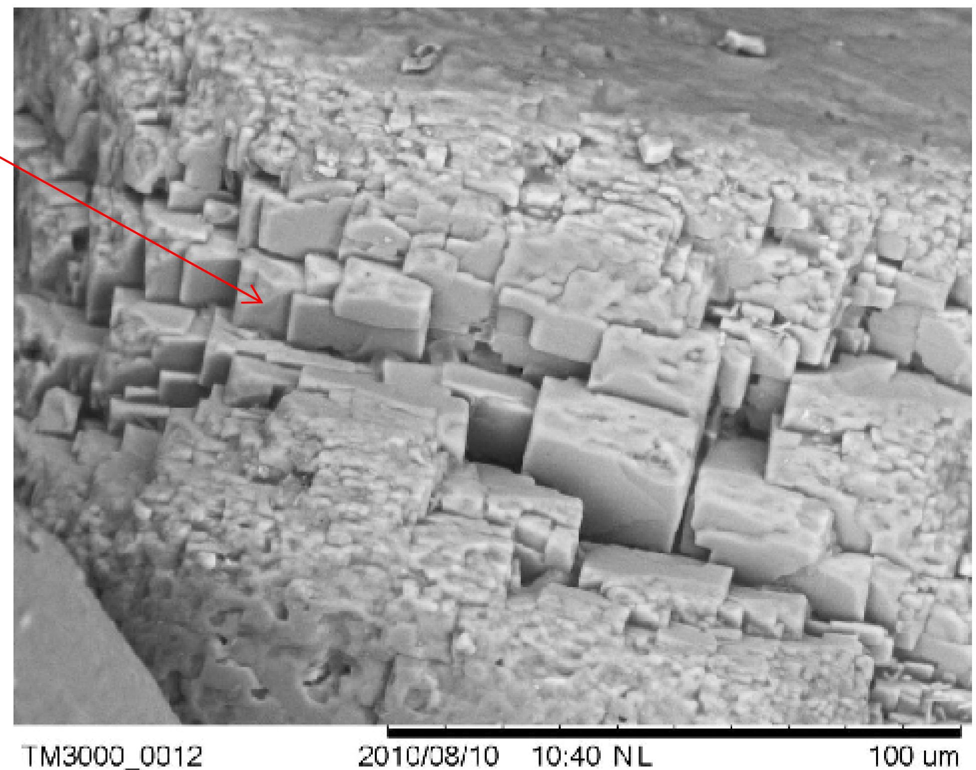
TM3000 Imaging



Salt (NaCl)



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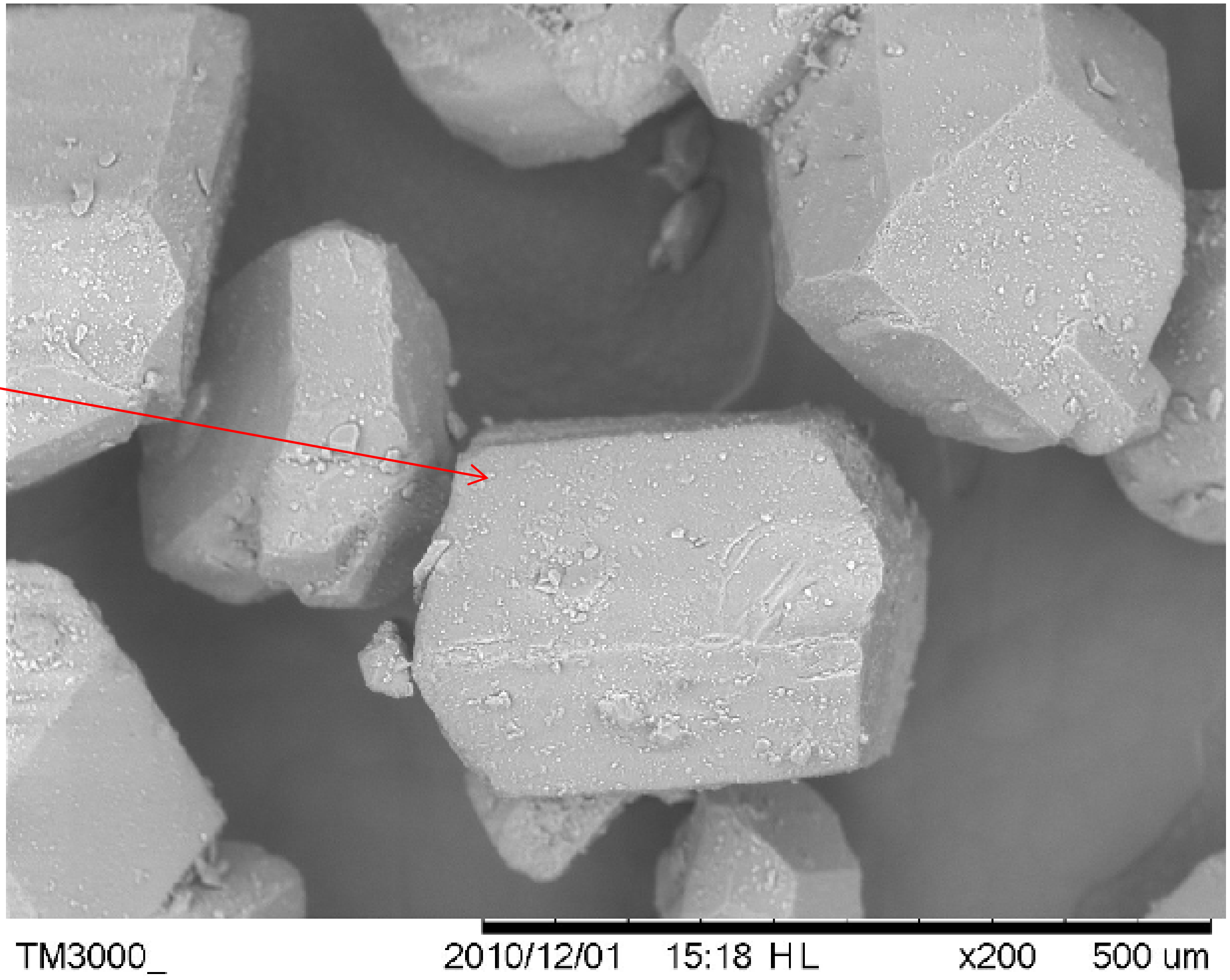
TM3000 Imaging

Sugar



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EDS Elemental Analysis

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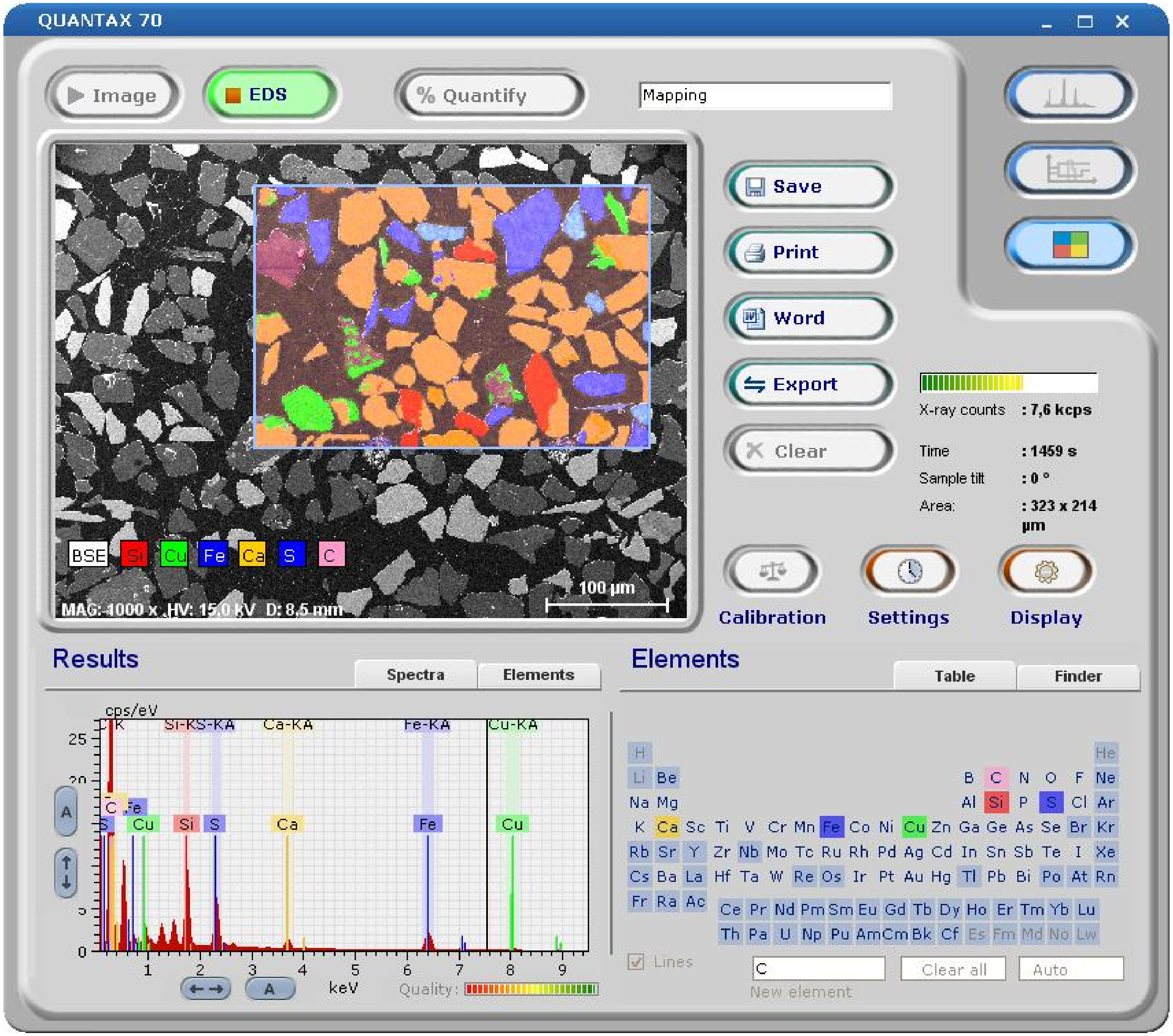

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EDS Elemental Analysis

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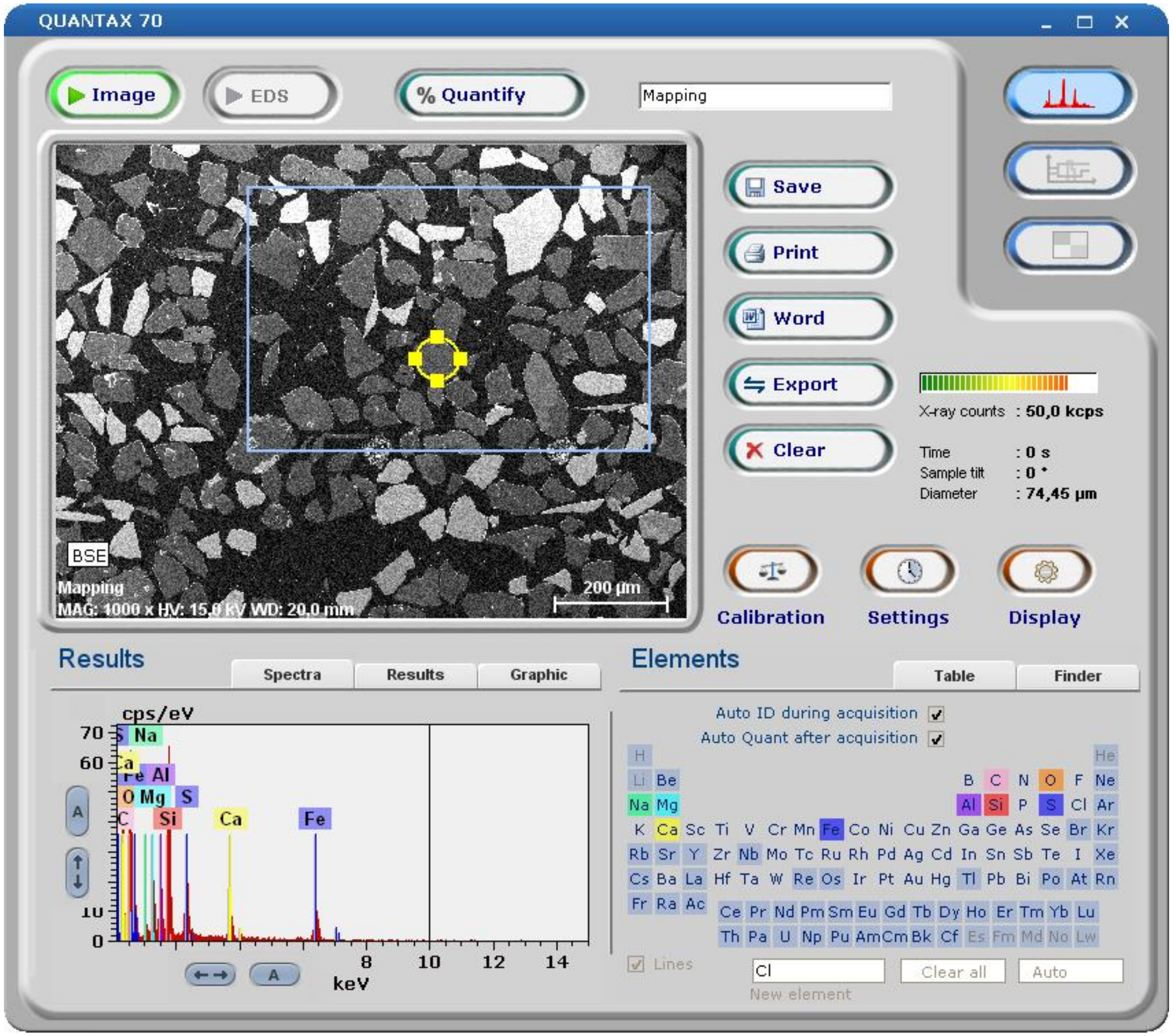
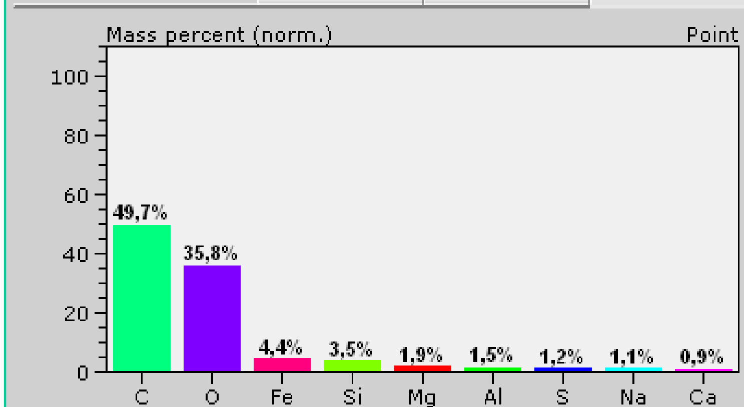


Results

	AN	Series	nor. C [wt.%]	Atom C [at.%]	Error [%]
Carbon	6	K series	49,66	60,63	16,96
Oxygen	8	K series	35,79	32,80	12,34
Iron	26	K series	4,36	1,14	0,44
Silicon	14	K series	3,53	1,84	0,50
Magnesium	12	K series	1,92	1,16	0,35
Aluminium	13	K series	1,52	0,83	0,25
Sulfur	16	K series	1,17	0,53	0,16
Sodium	11	K series	1,15	0,73	0,25
Calcium	20	K series	0,90	0,33	0,11
		Total	100,00	100,00	

Results



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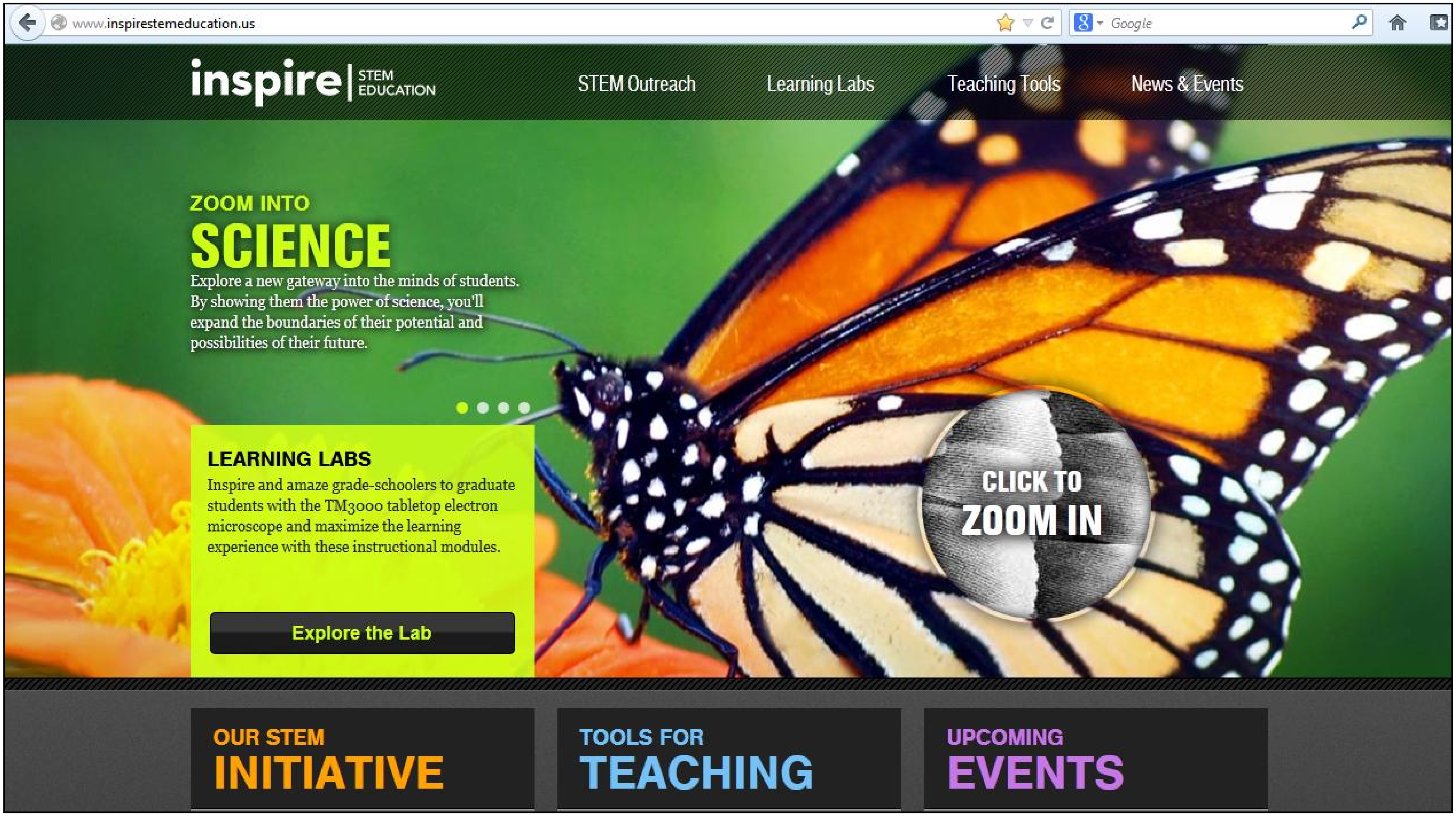
STEM Education Website



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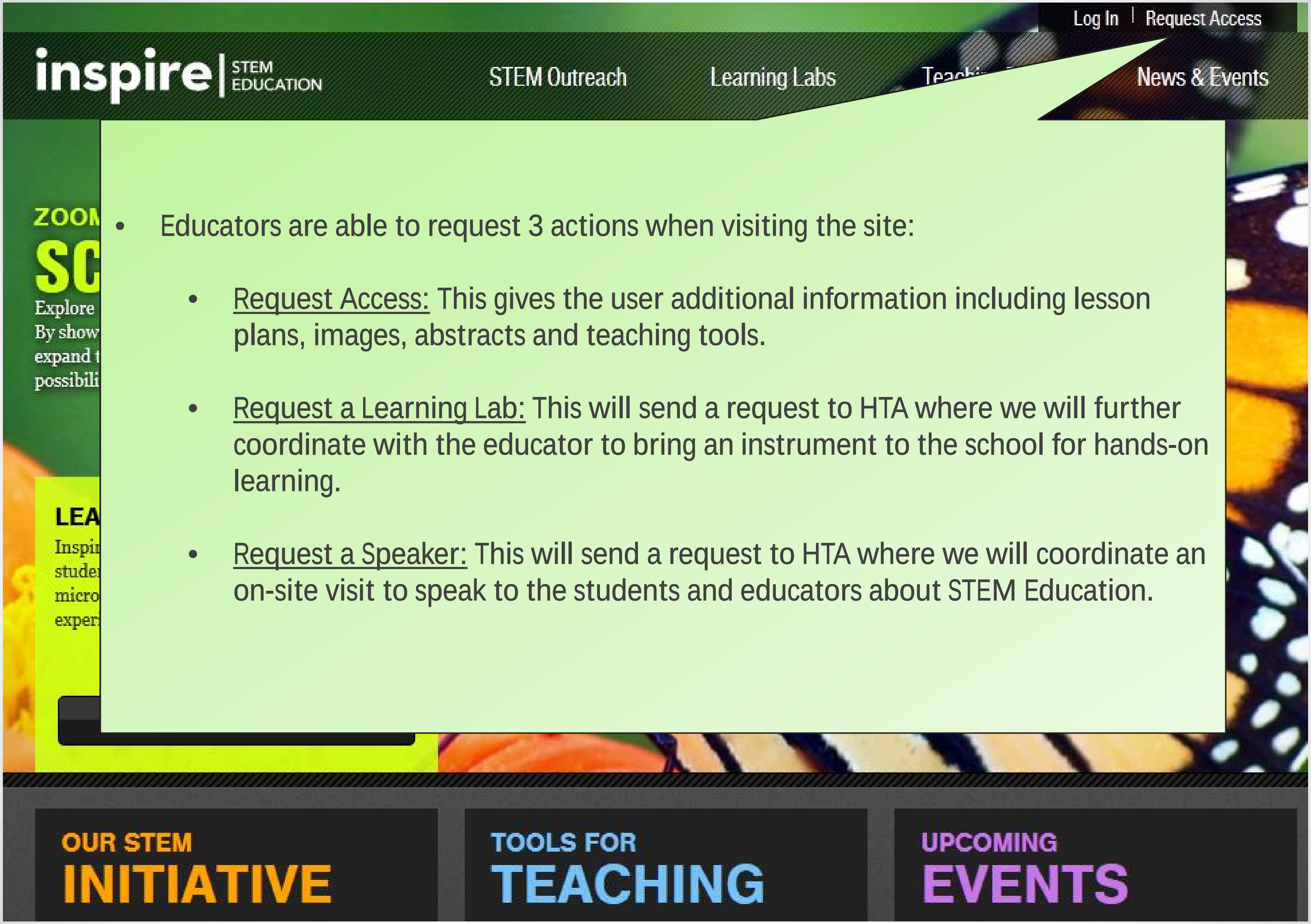
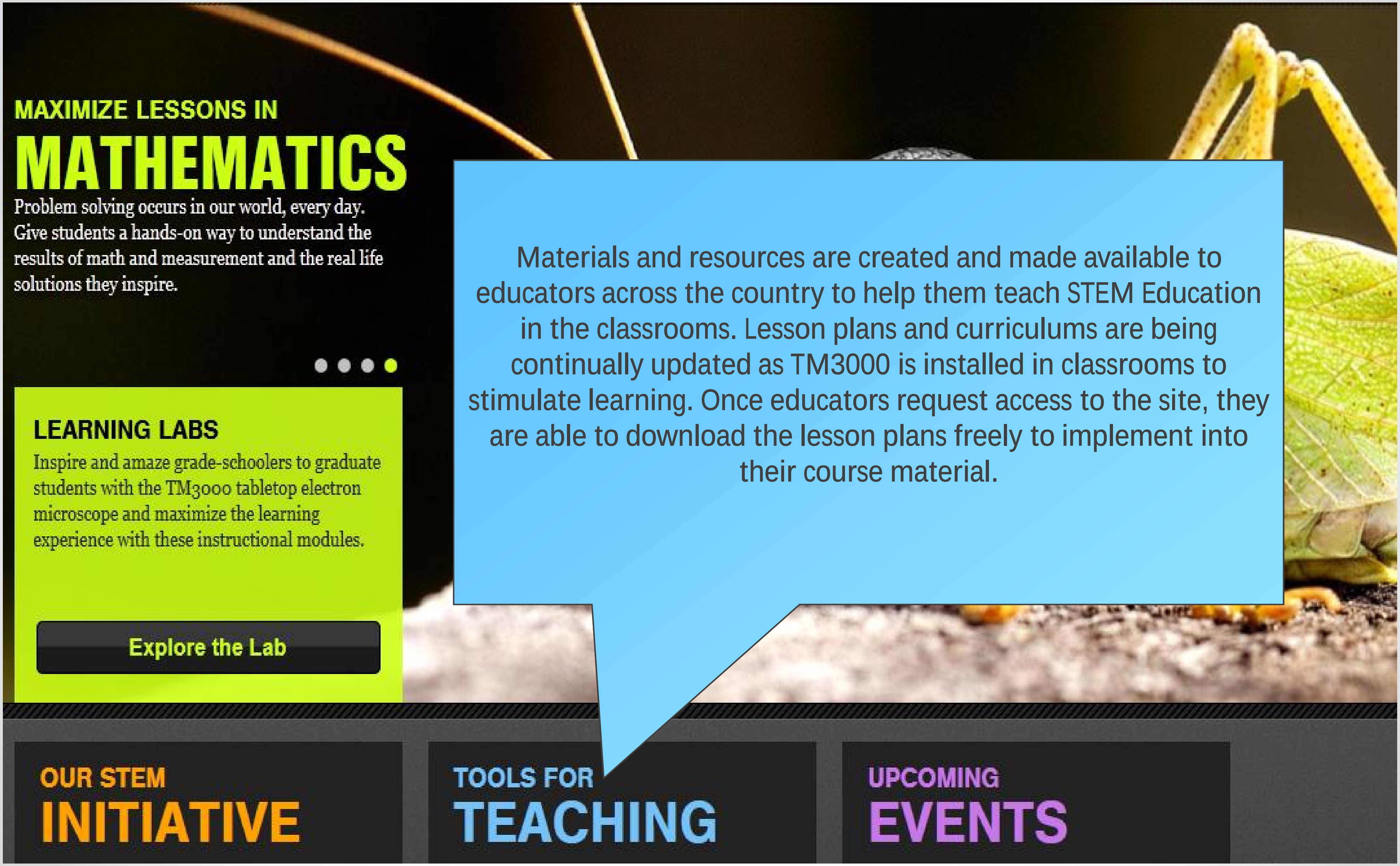


- Educators are able to request 3 actions when visiting the site:
  - Request Access: This gives the user additional information including lesson plans, images, abstracts and teaching tools.
  - Request a Learning Lab: This will send a request to HTA where we will further coordinate with the educator to bring an instrument to the school for hands-on learning.
  - Request a Speaker: This will send a request to HTA where we will coordinate an on-site visit to speak to the students and educators about STEM Education.

Our mission is to inspire the next generation of innovative pioneers through the advancement of Science, Technology, Engineering, and Mathematics. Together we work with Change The Equation and The National Nanotechnology Infrastructure Network to promote STEM education nationally.



Materials and resources are created and made available to educators across the country to help them teach STEM Education in the classrooms. Lesson plans and curriculums are being continually updated as TM3000 is installed in classrooms to stimulate learning. Once educators request access to the site, they are able to download the lesson plans freely to implement into their course material.

People interested in seeing the TM3000 in action can view upcoming events where TM3000 will be displayed.

inspire | STEM EDUCATION

Bonus
Quiz corner

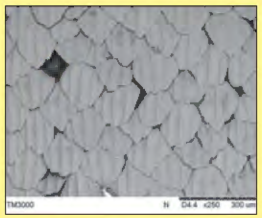
We looked at various samples with a Tabletop electron microscope. What are they?

Q1 We use this when we have cut or scratched ourselves.

Q2 We use this when we write something.

Q3 This red, summer fruit makes delicious pies and jams.

Q4 You know this big fish by its fin. It looks smooth, but this covering is tough armor.



Answers at the bottom of page 10.

Hitachi High-Technologies Corporation

Science is Fun

—All about electron microscopes—

Hitachi High-Tech

HITACHI

History of the electron microscope

How were microscopes invented?

Optical microscopes were invented first

Microscopes that use light, from the sun for example, are called optical microscopes. Light acts like waves. Waves have a wavelength (the distance between the waves). Sunlight contains a mixture of light with different wavelengths. The light that our eyes can see is called visible light. Optical microscopes use visible light to illuminate the object.

Optical microscopes were invented around 1590. Dutchman Hans Janssen and his son Zacharias Janssen discovered that you can make something look bigger if you combine two convex lenses. This discovery triggered the development of the first optical microscope. Then, in the 17th Century, Robert Hooke in England published drawings of cork cells and microorganisms as seen through a microscope. At that time microscopes could only magnify things up to 150 times in size.

Electron microscopes were invented later

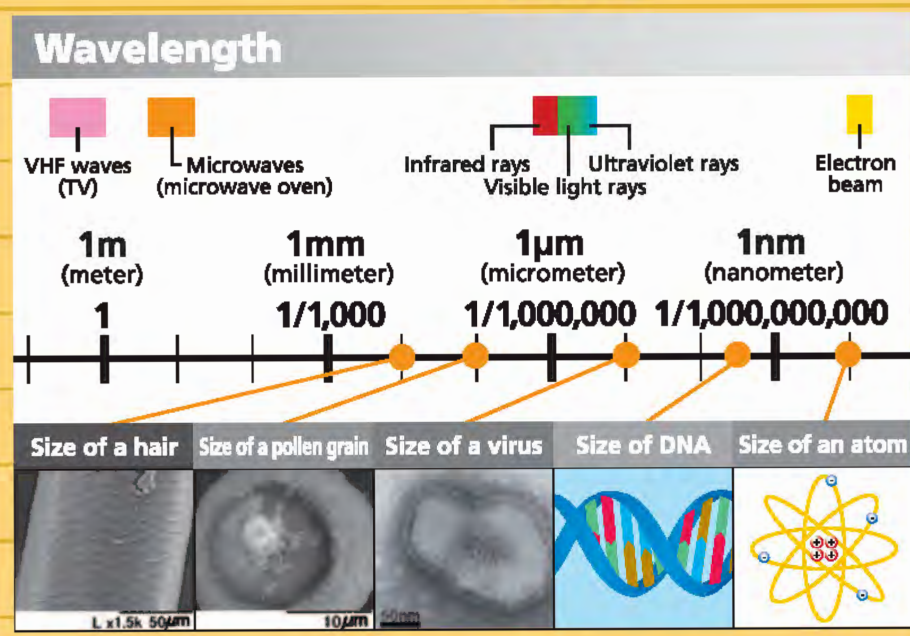
If you want to see objects that are smaller than the things you can see with an optical microscope, you need to have a microscope that uses something with a wavelength that is shorter than visible light. In 1924, scientists proved that electrons act like waves, just like light. Then in 1926, Hans Busch of Germany discovered that magnetic or electrical fields could act like a lens and bend electron beams, just like an optical lens bends light.

This discovery led the way to the invention of the electron microscope, using electrons instead of light because electrons have a shorter wavelength than visible light.

The first electron microscope was invented in 1931 by Max Knoll and Ernst Ruska at the Technical University of Berlin in Germany. Ruska then went on to invent an electron microscope with even better functionality. He was awarded the Nobel Prize in Physics in 1986 because of this research.

What is the "micro world?"

How big are things at the micro level?



We basically use meters (m) to describe the length of things. A micrometer means one millionth of a meter and a nanometer means one billionth of a meter. It is difficult to imagine how small these things are.

Lets look at an example. If we say 1m is the size of the earth (diameter: 12,000km = 1.2 billion cm), then 1nm would be the size of a marble (diameter: 1.2cm). That is how small a nanometer is.

Electron microscopes are helpful in lots of ways

Engineering

Diamond ring

This is the smallest diamond ring in the world (5 millionths of a meter) as seen through an electron microscope. Electron microscopes are useful to see manufactured products at this micro level or to make sure things are of good quality.

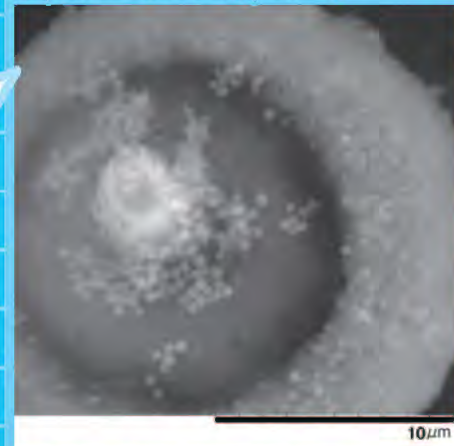
Biology

Electron microscopes have been very helpful in the development of medicines when new viruses are discovered, to watch cells growing, or when making new biological discoveries.

Wow! They have also been used in the discovery of new viruses!

Medicine

Japanese cedar pollen



Electron microscopes are used for research in ragweed or Japanese cedar pollen that cause hay fever, and research into the body's tissues.

Electron microscopes have helped us to see the bird flu virus and norovirus

Several years ago, many people were infected by the bird flu virus or norovirus and these viruses became a major threat. The viruses that cause these diseases are only 30–150nm in size (1nm = 1 billionth of a meter), so they can only be seen using an electron microscope. When the disease SARS spread, mainly in China, in 2003, electron microscopes helped scientists to confirm that a new type of coronavirus caused this highly dangerous disease. Now scientists are investigating new treatments and medicines. Electron microscopes are therefore important as they help scientists to develop new medicines.

Hong Kong flu (influenza A virus)

More infectious than a normal cold

Adenovirus

A type of virus that can cause conjunctivitis and pneumonia

Norovirus

A type of virus that can cause acute gastroenteritis

Photo: Dr. Etsuko Utagawa, Senior Researcher, Department of Virology II, National Institute of Infectious Diseases

The world seen through a Tabletop electron microscope

Living things

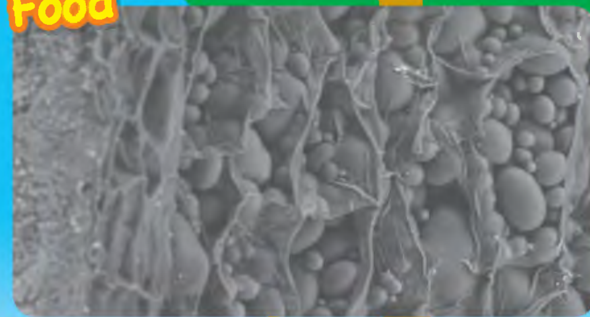
Sunflower pollen

There are lots of spines, just like a sea urchin! The pollen is designed to stick to things easily.

Potato starch

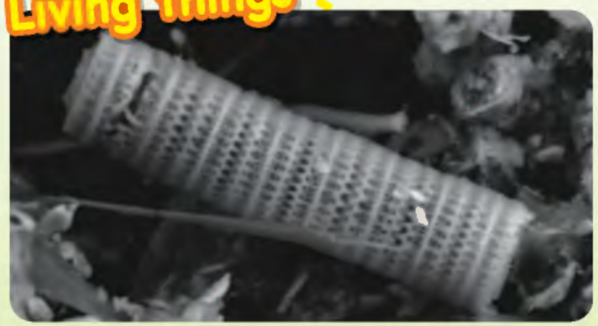
The little ovals may look like a bumper crop of potatoes but are actually starch. Potato starch is used to keep baked goods soft and is also used in papermaking as an adhesive and coating.

Food



We looked at everyday items with Hitachi High-Technologies' electron microscope.

Living things

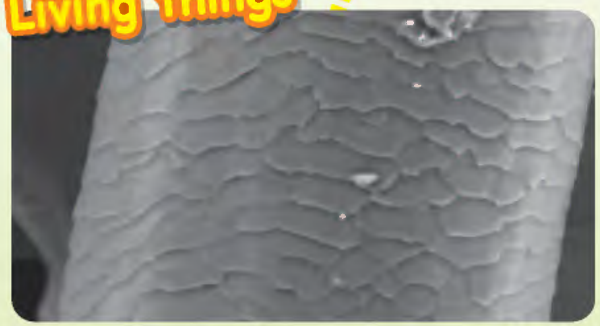


Diatom All diatoms photosynthesize and have one or several chloroplasts in their cells. You cannot tell from this black and white picture, but the diatom has a green body.

Living things

Ant The v-shaped bent antennae are really important. Ants live in the dark soil and use their antennae to identify different smells. Based on the smell, they know what is out there and where things are located.

Living things



Hair With the naked eye, a hair just looks like a single strand. When we look at a healthy strand of hair using an electron microscope, we can see the cuticle that looks like fish scales.

The beautiful world of nanoArt® as seen through electron microscopes

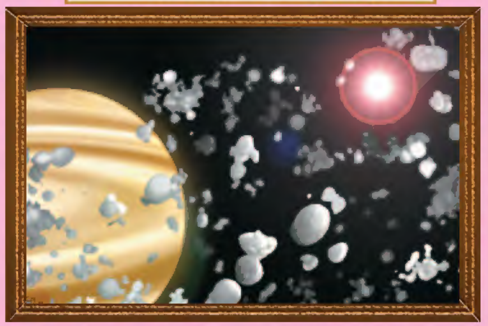
These are photographs of objects seen using an electron microscope. What do you see?

NanoArt® involves using electron signals to create black and white images that capture the beauty within metals, minerals, or living things and then turning these into gorgeous photographs by applying colors using computer graphics technology.

Fluttering Butterflies (2006)

This looks like a butterfly fluttering through a field of grass. The picture is actually calcium sulfate as seen through an electron microscope. Calcium sulfate is used in chalk and other substances.

Nano Universe (2009)



This looks like Jupiter in the front and the sun at the back, right? It is actually a combination of 200 pictures of bismuth oxide particles, which are used in glass. Amazingly, the tiny world as seen through the microscope looks like outer space!

Yukitsuri (snow ropes) (2004)

This looks like a tree in a snowy field supported by ropes. This photograph is actually of a fungus that grows when it rains a lot.

The smallest frog in the universe (2008)

This one looks like a small frog in water, but it is actually small bumps sticking out of the cell wall of plant plankton called a diatom. The frog's face and legs are made up of different types of bumps and the artist has combined images of these different bumps to make a cute frog.

Electron fireworks festival (2007)

This is a diffraction image of oxides as seen through an electron microscope. The electron beam passing through the crystals produces a brilliant picture just like a firework display.

Micro Bouquet (2009)

The pretty colors look like a bunch of flowers. This is actually a picture of a synthetic zeolite. There are lots of holes on the zeolite surface, which can be used to clean smells and water. The picture looks like flowers with many layers of petals, just like real roses.

Seawalking (2006)

This looks like the ocean floor in a beautiful tropical sea. When looking at things through an electron microscope, scientists sometimes freeze the object being studied. This picture shows the ice that has formed on the surface of a frozen sample. Isn't it interesting that the ice looks like a tropical sea?

The light of gas lamps on the arch bridge (2007)

This looks like a photograph of a bridge lined with gaslights. The gaslights are only 15μm tall (0.015mm)! They are made of silicon wafers that have been processed using a special machine. The artist made the picture look like the Bandai Bridge that crosses the Shinano River in Niigata, Japan.

* Silicon wafer: The metalloid silicon is used to make the integrated chips found in mobile phones and other devices. A silicon wafer is made of silicon cut into a very thin disk shape.

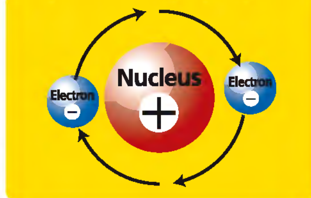
You can see more nanoArt® here:
http://www.hitachi-hitec.com/global/em/nanoart/index.html
* nanoArt® is a registered trademark of Hitachi High-Technologies

Q&A corner

Q What are electrons?

A Electrons are particles (the smallest units making up substances) that rotate around an atomic nucleus (the heart of the atom, which makes up matter) and also flow along electrical circuits. Electrons are so small we cannot see them and they have energy called an electric charge. Electrons have a negative charge.

The structure of an atom



Q What is an atom?

A Negatively charged electrons are attracted to things with a positive charge. The atomic nucleus has a positive charge, so electrons are drawn towards the atomic nucleus. This force makes the electron rotate around the atomic nucleus. This combination of an atomic nucleus and electrons makes up an atom. An atom is the smallest unit of matter.

- Visible to the naked eye: **0.2mm**
- Bacteria: **1–5μm** (μm: one millionth of a meter)
- E. coli: **2μm**
- Visible with an optical microscope: **200nm** (nm: one billionth of a meter)
- Yellow fever virus: **40–50nm**
- Norovirus: **25–35nm**

Q What is a virus?

A A virus is a disease-causing agent that lives and replicates by taking over the cells of other living things. Viruses are only between several dozen and several hundred nanometers in size (nanometer: one billionth of a meter).

Viruses are smaller than bacteria, which are 1–5μm in size (micrometer: one millionth of a meter). Almost all viruses are smaller than 300nm, so they can only be seen using an electron microscope.

Q&A corner

Q What does wavelength mean?

A Wavelength describes the distance between electromagnetic waves (radio waves, infrared rays, visible light rays, ultraviolet rays). For example, light acts like waves and the distance between each wave valley (or between each wave peak) is called the wavelength. Visible light in the electromagnetic spectrum refers to the light that we can see (the colors we can detect) and has a wavelength of between 0.4μm and 0.8μm. We cannot see light with a wavelength longer or shorter than this.

Q Why do electron microscopes take black and white pictures?

A Unlike the optical microscope that produces magnified images using visible light (that we can see), an electron microscope uses an electron beam to produce a magnified image of something. An electron beam has a shorter wavelength than visible light and we cannot see the color of an electron beam, so the pictures come out black and white.

Q What does resolution mean?

A Resolution describes the shortest distance between two neighboring points that allows us to see them as two separate points. Resolution gets better as this distance gets smaller. Therefore, we can see smaller things as resolution increases.

A: Q1. Bandage Q2. Tip of a ballpoint pen Q3. Strawberry Q4. Shark skin